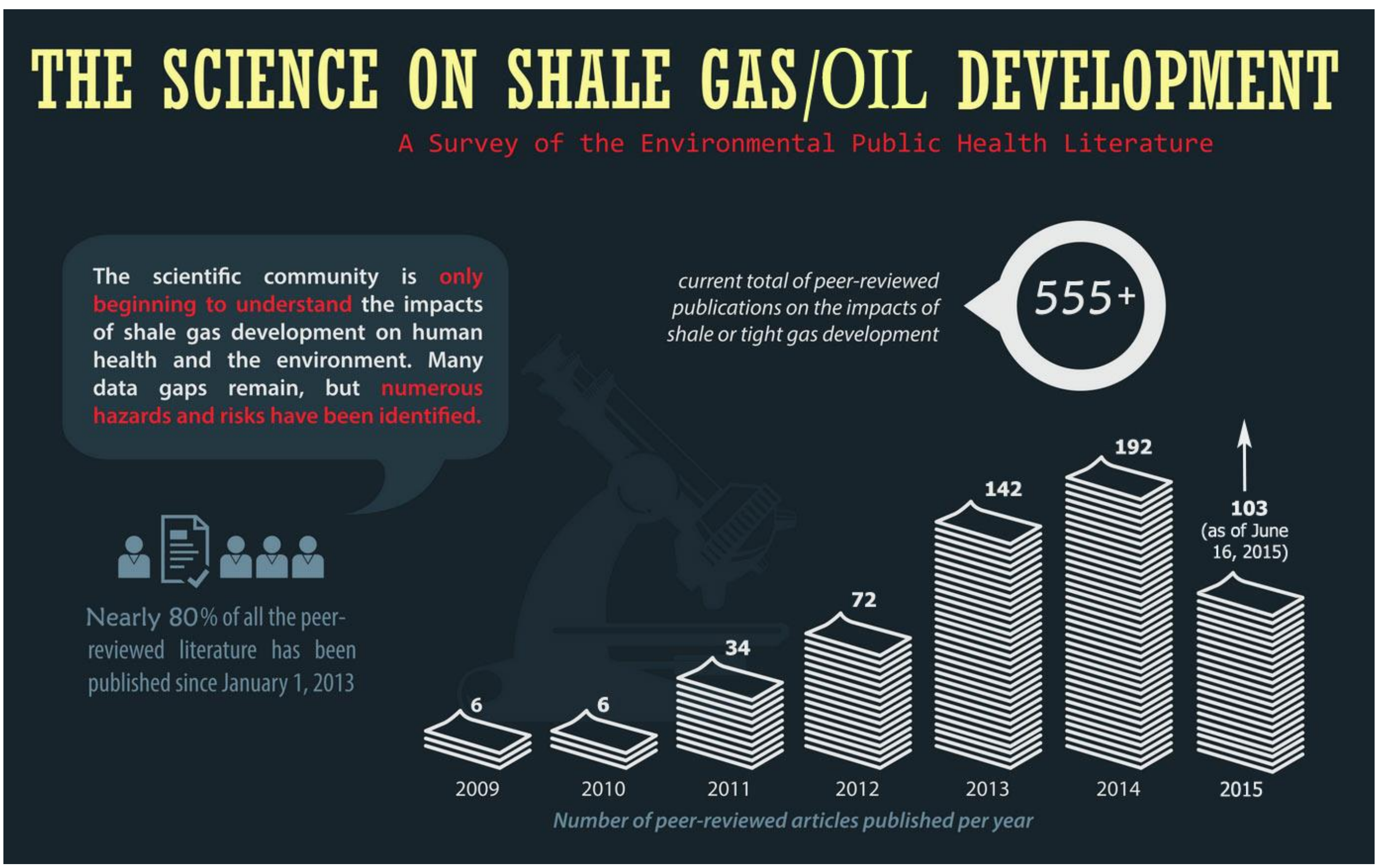
A CHRONOLOGICAL & SINGLE DOCUMENT REFERENCE TOOL:

FOR PSE's (Physicians, Scientists & Engineers's) HEALTY ENERGY CITATION DATABASE ON SHALE GAS & TIGHT OIL DEVELOPMENTS

By Will Koop,
B.C. Tap Water Alliance
(www.bctwa.org / www.bctwa.org/FrackingBC.html)

Version 2.0, June 23, 2015
(Citations accessed by PSE up to June 18, 2015)



(Original image from PSE's website, December 2014, modified by Will Koop, June 22, 2015.)

The creation of this document, *A Chronological & Single Document Reference Tool*, stemmed from a reading of PSE's (Physicians, Scientists & Engineers') December 2014 document, *Towards an understanding of the environmental and public health impacts of shale gas development: and analysis of the peer-reviewed scientific literature, 2009-2014* (recently revised, June 2015). The idea arose: What if all of PSE's Zotero-powered library of peer-reviewed literature citations was collected, re-formatted, and re-organized into a single, word-searchable document, wouldn't such a document become even more useful, more powerful?

Almost all of the citations in this new reference tool include abstracts. Where some citations in PSE's database lacked abstracts, quotes were extracted from citation texts available on the internet to fill in this overview or summary gap. Almost all of the dates for each publication, organized in chronological order (most recent to oldest) represent the epub (electronic or on-line publication) date, almost all of which were double-checked for verification on-line. All the 12 categories or themes ascribed to each publication in PSE's library – air quality, climate, community, ecology, economics, general, health, regulation, seismicity, waste/fluids, water quality, and water usage – were also included to accompany each citation date within rectangular parentheses (square brackets).

This document tool will be updated irregularly, with the revised date and version noted on this document's cover page. Everything else will be updated as well, including the (as yet) four-page list of journals, periodicals, etc., found at the beginning of this document, where the number of citations for each, tabulated from PSE's database, are included for statistical purposes.

We thank all of the PSE folk for their incredible work toward the maintenance of an indispensible website, particularly as it relates to the creation of this hammer tool for PSE's on-line toolkit.

I include the following lengthy quotes from *Towards an understanding of the environmental and public health impacts of shale gas development: an analysis of the peer-reviewed scientific literature, 2009-2015*, as the quotes define the scope and describe the purpose of PSE's database.

> *Conversations on the environmental and public health dimensions of shale gas development enabled by high-volume hydraulic fracturing continue to play out in the media, in policy discussions, and among the general public. But what does the science actually say? While research continues to lag behind the rapid scaling of unconventional forms of oil and gas development, there has been a surge of peer-reviewed scientific papers published in recent years. In fact, of all the available literature on the impacts of shale gas development nearly 80% has been published since January 1, 2013 and over 50% in just the past year and a half (since January 1, 2014). What this tells us is that the scientific community is only now beginning to better understand the environmental and public health implications of unconventional gas development. Numerous hazards and risks have been identified in studies to date, but many data gaps remain. For instance, while there is now a far more substantive body science than there was several years ago, there is still a notable dearth of quantitative epidemiology that assesses associations between risk factors and human health outcomes among populations.*

This analysis was conducted using the PSE Study Citation Database (available at: http://psehealthyenergy.org/site/view/1180). This near exhaustive collection of peer-reviewed literature on shale gas development is divided into 12 topics that attempt to organize the papers in a useful and coherent manner. These topics include air quality, climate, community, ecology, economics, general (comment/review), health, regulation, seismicity, waste/fluids, water quality, and water usage. This study database has been assembled over several years using a number of different search strategies, including the following:

- *Systematic searches in scientific databases across multiple disciplines: PubMed (http://www.ncbi.nlm.nih.gov/pubmed/), Web of Science (http://www.webofknowledge.com), and ScienceDirect (http://www.sciencedirect.com)*
- *Searches in existing collections of scientific literature on shale gas development, such as the Marcellus Shale Initiative Publications Database at Bucknell University (http://www.bucknell.edu/script/environmentalcenter/marcellus), complemented by Google (http://www.google.com) and Google Scholar (http://scholar.google.com)*
- *Manual searches (hand-searches) of references included in peer-reviewed studies and government reports that pertain directly to shale gas development.*

For scientific literature search engines we used a combination of Medical Subject Headings (MeSH)-based and keyword strategies, which included the following terms as well as relevant combinations thereof:

> *shale gas, shale, hydraulic fracturing, fracking, drilling, natural gas, air pollution, methane, water pollution, public health, water contamination, fugitive emissions, air quality, climate, seismicity, waste, fluids, economics, ecology, water usage, regulation, community, epidemiology, Marcellus, Barnett, Denver-Julesberg Basin, unconventional gas development, and environmental pathways.*

This database and subsequent analysis excluded technical papers on shale gas development not applicable to determining potential environmental and public health impacts. Examples of literature that we exclude are papers on optimal drilling strategies, reservoir evaluations, estimation algorithms of absorption capacity, patent analysis, and fracture models designed to inform stimulation techniques. Because our analysis is limited to papers subjected to external peer-review, <u>it does not include government reports, environmental impact statements, policy briefs, white papers, law review articles, or other grey literature. Our analysis also excludes studies on coalbed methane, coal seam gas, tar sands or other forms of fossil fuel extraction.</u> [Underline emphasis.]

We have tried to include all literature that meets our criteria in our collection of the peer-reviewed science; however, it is very possible that some papers may be missing from our analysis. Thus, we refer to the collection as <u>near</u> exhaustive. We are sure, however, that the most seminal studies on the public health dimensions of shale gas development in leading scientific journals are accounted for.

The PSE Healthy Energy database has been used and reviewed by academics, experts, and government officials throughout the U.S. and internationally and has been subjected to public and professional scrutiny before and after this analysis. It represents the most comprehensive public collection of peer-reviewed scientific literature on shale and tight gas development in the world and has been accessed by thousands of people. Again, many of the publications in this database are discussed in greater detail in published review articles (Shonkoff et al. 2014; Adgate et al. 2014; Werner et al. 2015) and government reports.

The temporal focus of this analysis is, first and foremost, on the primary research on shale gas development published between 1 January 2009 and 16 June 2015. The reason for starting this analysis in 2009 is that research on shale gas development did not appear until this time. We include papers that evaluate environmental and public health hazards, risks, and impacts of shale gas development. As such, most publications in the PSE Study Citation Database were not used in this analysis. We exclude the following topics: climate, community, ecology, economics, regulation, seismicity, waste/fluids, and water usage.

We also exclude some papers that fall under the three topics used in this analysis (health, water quality, and air quality). With the exception of public health papers, for which there has been very little primary research, we exclude commentaries and review articles. We exclude papers that only provide baseline data or address research methods but fail to assess hazards, risks, and impacts. Finally, we exclude letters to the editors of scientific journals that critique a particular study or the subsequent response of the author(s).

As previously mentioned, we restrict the studies included in this analysis to those published from 1 January 2009 through 16 June 2015. There are studies on conventional forms of oil and natural gas development that are relevant to shale gas, but to maintain greater consistency we have decided to exclude those prior to 2009 from the analysis….

Again, it is important to note that scientists are only beginning to understand the environmental and public health dimensions of these rapidly expanding industrial practices. Our analysis represents a survey of the existing science to date in an attempt to determine the direction in which scientific consensus may be headed and to achieve a better understanding of the environmental and public health impacts of this form of energy development.

We have included in this topic papers that consider the question of public health in the context of shale gas development. Of course, research findings in other categories such as air quality and water quality are relevant to public health, but here we only include those studies that <u>directly</u> consider the health of human populations and individuals as well as studies that have examined animal disease events as sentinel information for human health risks. We only consider research to be original if it measures potential or actual health outcomes or complaints (i.e., not health research that only attempts to determine public opinion or consider methods for future research agendas).

Will Koop,
Vancouver, British Columbia,
June 23, 2015.

PSE Library Collection: Journals Cited (to June 19, 2015)

(with total number of peer-reviewed citations for each)

AAPG Bulletin - 2
Abstracts of Papers American Chemical Society - 1
Accident Analysis & Prevention - 1
Acs Sustainable Chemistry & Engineering - 1
Aiche Journal - 1
American Journal of Industrial Medicine - 1
American Journal of Nursing - 1
American Journal of Public Health - 4
Analytical and Bioanalytical Chemistry - 1
Analytical Chemistry - 1
Annals of the New York Academy of Sciences - 1
Annual Review of Chemical and Biomolecular Engineering - 1
Annual Review of Environment and Resources - 1
Applied and Environmental Microbiology - 2
Applied Energy - 3
Applied Geochemistry - 7
Applied Geography - 1
Applied Radiation and Isotopes - 1
Aquatic Microbiology - 1
Archives of Environmental & Occupational Health - 3
Atmospheric Chemistry and Physics - 4
Atmospheric Environment - 1
Avian Conservation and Ecology - 1
Biodegration - 1
Biological Conservation - 1
BMJ - 1
Bulletin of the Seismological Society of America - 1
Canadian Journal of Earth Sciences - 1
Chemical Geology - 1
Chemosphere - 3
Clean Technologies and Environmental Policy - 1
Climatic Change - 4
Clinical Pulmonary Medicine - 2
Computers & Geosciences - 2
Culture, Agriculture, Food and Environment - 1
Daedalus - 1
Desalination - 1
Earth and Planetary Science Letters - 2
Earth's Future - 1
Eastern Economic Journal - 1
Ecological Economics - 2

Ecology and Evolution - 1
Elementa: Science of the Anthropocene - 2
Elements - 1
Endocrinology - 1
Energy - 4
Energy Economics - 2
Energy Law Journal - 1
Energy Policy - 25
Energy Research & Social Science - 1
Energy Sources, Part A: Recovery, Utilization, and Environmental Effects - 2
Energy Strategy Reviews - 3
Energy Technology - 1
Environmental Chemistry - 2
Environmental Development - 1
Environmental Earth Sciences - 7
Environmental Engineering Science - 1
Environmental Geosciences - 1
Environmental Health - 1
Environmental Health Insights - 1
Environmental Health Perspectives - 12
Environmental Impact Assessment Review - 1
Environmental Management - 5
Environmental Pollution - 2
Environmental Practice - 4
Environmental Research Letters - 7
Environmental Reviews - 1
Environmental Science and Pollution Research International - 1
Environmental Science & Policy - 1
Environmental Science & Technology - 101
Environmental Science: Processes & Impacts - 6
Environmental Toxicology and Chemistry / SETAC - 2
EOS, Transactions America Geophysical Union - 2
Ethics in Biology, Engineering and Medicine - 1
FEMS Microbiology Ecology - 1
Fisheries - 1
Frontiers in Ecology and the Environment - 2
Frontiers in Microbiology - 1
Fuel - 1
Gaceta sanitaria / S.E.S.P.A.S - 1
Geochemistry, Geophysics, Geosystems - 1
Geology - 1
Geophysical Journal International - 2
Geophysical Research Letters - 5
Gesundheitswesen - 1
Groundwater - 12

Health Physics - 1
Human and Ecological Risk Assessment: An International Journal - 3
Hydrogeology Journal - 1
International Journal of Coal Geology - 9
International Journal of Environmental Research and Public Health - 1
International Journal of Occupational and Environmental Health - 1
International Journal of Remote Sensing - 1
ISRN Public Health - 1
Journal of American Water Works Association - 3
Journal of Applied Polymer Science - 1
Journal of Burn Care & Research - 1
Journal of Cleaner Production - 1
Journal of Community Health - 1
Journal of Contemporary Water Research & Education - 1
Journal of Energy Chemistry - 1
Journal of Environmental and Public Health - 1
Journal of Environmental Engineering - 1
Journal of Environmental Management - 3
Journal of Environmental Quality - 1
Journal of Environmental Psychology - 1
Journal of Environmental Radioactivity - 1
Journal of Environmental Science and Health - 8
Journal of Environmental Studies and Sciences - 1
Journal of Geophysical Research - 3
Journal of Geophysical Research: Atmospheres - 5
Journal of Geophysical Research: Solid Earth - 3
Journal of Hazardous Materials - 3
Journal of Hazardous Waste Materials - 1
Journal of Hydrology - 2
Journal of Hydrology: Regional Studies - 1
Journal of Industrial Ecology - 1
Journal of International Biodeterioration & Biodegradation - 1
Journal of Natural Gas Science and Engineering - 6
Journal of Occupational and Environmental Hygiene - 4
Journal of Occupational and Environmental Medicine / American College of Occupational and Environmental Medicine - 2
Journal of Pediatric Nursing - 1
Journal of Petroleum Science and Engineering - 4
Journal of Rural Social Sciences - 6
Journal of Seismology - 1
Journal of the Air & Waste Management Association - 10
Journal of Toxicology and Environmental Health – Part A – Current Issues - 1
Journal of Unconventional Oil and Gas Resources - 6
KSCE Journal of Civil Engineering - 1
Landscape and Urban Planning - 1

Marine and Petroleum Geology - 6
Medical Journal of Australia - 1
Medycyna Pracy - 1
Microbial Biology - 1
MRS Energy & Sustainability - 1
Natural Hazards - 1
Nature - 6
Nature Communications - 1
Nature Geoscience - 1
New England Journal of Medicine - 1
New Solutions: A Journal of Environmental and Occupational Health Policy: NS - 14
Notre Dame Journal of Law, Ethics & Public Policy - 1
Organization and Environment - 1
Petroleum Exploration and Development - 1
Physical Review. E, Statistical, Nonlinear, and Soft Matter Physics - 1
PLOS ONE - 6
Procedia Earth and Planetary Science - 2
Procedia – Social and Behavioral Sciences - 1
Proceedings of the Institution of Civil Engineers-Energy - 1
Proceedings of the National Academy of Sciences (PNAS) - 21
Public Health - 2
Public Health Nursing (Boston, Mass.) - 1
Public Relations Review - 1
Public Understanding of Science - 1
Public Understanding of Science (Bristol, England) - 1
Pure and Applied Geophysics - 1
Quarterly Journal of Engineering Geology and Hydrogeology - 1
Regional Science and Urban Economics - 1
Renewable and Sustainable Energy Reviews - 6
Research Journal of Environmental and Earth Sciences - 1
Resource and Energy Economics - 1
Resources, Conservation and Recycling - 1
Resources Policy - 1
Review of Policy Research - 1
Review of Scientific Instruments - 1
Reviews on Environmental Health - 4
Risk Analysis (an Official Publication of the Society for Risk Analysis) - 1
Rural Sociology - 1
Science - 6
Science and Engineering Ethics - 1
Science of the Total Environment - 13
Seismological Research Letters - 3
Seminars in Respiratory and Critical Care Medicine - 1
Society & Natural Resources - 1
South African Medical Journal - 1

Southeastern Naturalist - 1
Stochastic Environmental Research and Risk Assessment - 1
The Electricity Journal - 4
The Extractive Industries and Society - 2
The Journal of Contemporary Health Law and Policy - 1
The Lancet - 2
The Pennsylvania Nurse - 2
The Scientific World Journal - 1
Toxicological Sciences: An Official Journal of the Society of Toxicology - 1
Trends in Environmental Analytical Chemistry - 1
United States Environmental Protection Agency - 2
Water - 1
Water, Air, & Soil Pollution - 1
Water Research - 1
Water Resources Research - 4
Western Economics Forum - 1
Workplace Health Safety - 1
World Pumps - 1

June 16, 2015. [*Category:* Water Quality]

A Comprehensive Analysis of Groundwater Quality in the Barnett Shale Region.

- Zacariah Louis Hildenbrand; Doug D Carlton; Brian Fontenot; Jesse M. Meik; Jayme Walton; Josh Taylor; Jonathan Thacker; Stephanie Korlie; C. Phillip Shelor; Drew Henderson; Akinde Florence Kadjo; Corey Roelke; Paul F. Hudak; Taylour Burton; Hanadi S. Rifai; Kevin A. Schug.
- In: *Environmental Science & Technology* (ahead of print).
- http://pubs.acs.org/doi/abs/10.1021/acs.est.5b01526

Abstract: The exploration of unconventional shale energy reserves and the extensive use of hydraulic fracturing during well stimulation have raised concerns about the potential effects of unconventional oil and gas extraction (UOG) on the environment. Most accounts of groundwater contamination have focused primarily on the compositional analysis of dissolved gases to address whether UOG activities have had deleterious effects on overlying aquifers. Here, we present an analysis of 550 groundwater samples collected from private and public supply water wells drawing from aquifers overlying the Barnett shale formation of Texas. We detected multiple volatile organic carbon compounds throughout the region, including various alcohols, the BTEX family of compounds, and several chlorinated compounds. These data do not necessarily identify UOG activities as the source of contamination; however, they do provide a strong impetus for further monitoring and analysis of groundwater quality in this region as many of the compounds we detected are known to be associated with UOG techniques.

June 12, 2015. [*Categories:* Community; General (Comment/Review)]

Eliciting public concerns about an emerging energy technology: The case of unconventional shale gas development in the United States.

- Israel, Andrei L.; Wong-Parodi, Gabrielle; Webler, Thomas; Stern, Paul C.
- In: *Energy Research & Social Science*, Vol. 8, pages 139-150, July 2015.
- http://www.sciencedirect.com/science/article/pii/S2214629615000638

Abstract: Development of shale gas resources using hydraulic fracturing has dramatically increased U.S. gas production, but also created new needs for risk analysis and governance. Risk analysis for an emerging technology has traditionally relied on experts with knowledge of the technology and its anticipated impacts. But today it is accepted that input from non-expert interested and affected parties (IAPs) is also essential. We present a novel method to elicit concerns from IAPs about the development of shale gas resources. We used an Internet-based snowball sample to identify IAPs and an open-ended prompt to gather their concerns. Reported concerns included potential consequences for environmental, social, and health systems, as well as hazards, hazardous events, precursors to hazards, risk amplifiers, and issues concerning the effective and fair governance of the risks. Some concerns raised have not been addressed in expert-led analyses of shale gas risks. Long-term consequences such as disruptions to economic activities, and governance issues such as regulatory capacity, were more prominent in the responses than in expert analyses. These findings show how engagement with interested and affected parties can elucidate key issues for risk governance in shale gas development. The method can also be applied to other emerging energy development issues.

June 12, 2015. [*Category:* General (Comment/Review)]

Policy recommendations to promote shale gas development in China based on a technical and economic evaluation.

- Yuan, Jiehui; Luo, Dongkun; Xia, Liangyu; Feng, Lianyong.
- In: *Energy Policy*, Vol. 85, pages 194-206, October 2015.
- http://www.sciencedirect.com/science/article/pii/S0301421515002244

Abstract: Because of its resource potential and clean burning advantages, the development of shale gas can significantly increase the supply of cleaner energy while offering the associated benefits. To foster shale gas development, many policy incentives have been introduced in China. However, the current incentives have not been sufficiently aggressive, and the shale gas industry has been slow to develop. Existing policies thus need to be further improved. To provide effective support for decision makers in China, a technical and economic evaluation is performed in this study to explore the profitability of shale gas production in pilot zones. The results show that shale gas production is subeconomic under the current technical and economic conditions. Based on this evaluation, a policy analysis is conducted to investigate the profitability improvement offered by the major policies available in China to elucidate a path toward improving incentive policies. The results indicate that policy instruments related to gas prices, financial subsidies, corporate income taxes or combinations thereof could be used as priority options to improve policy incentives. Based on these results, recommendations are presented to improve the current incentive polices aimed at accelerating shale gas development.

June 10, 2015. [*Categories:* Air Quality; Health]

The Barnett Shale: From problem formulation to risk management.

- Ethridge, Shannon; Bredfeldt, Tiffany; Sheedy, Keith; Shirley, Stephanie; Lopez, Glendora; Honeycutt, Michael.
- In: *Journal of Unconventional Oil and Gas Resources* (ahead of print).
- http://www.sciencedirect.com/science/article/pii/S2213397615000270

Abstract: There is a nationwide trend to develop shale formations due to advances in horizontal drilling and hydraulic fracturing technology. The Barnett Shale in north Texas is one of the largest onshore natural gas fields in the US, and has experienced exponential growth since the 1990's. This immense amount of well development and gas production has occurred near heavily populated, urban areas, leading to increased public concern regarding the impacts of these activities on human health and welfare. The Texas Commission on Environmental Quality (TCEQ) is charged with regulating sources of air emissions from natural gas operations (NGOs) and is in a unique position to evaluate any associated risks. The goal of this manuscript is to describe the problem formulation process used by the TCEQ to characterize risks associated with air emissions from NGOs, and the subsequent risk management strategies implemented. Details on how potential sources of risk to human health were identified and quantified are provided. Initial assessments identified volatile organic compounds (VOCs) as chemicals of concern. Over 4.7 million data points for VOCs were used in this assessment on both a short-term and long-term basis. Only one short-term sample measured VOCs levels above short-term health concern. Several short-term samples measured VOCs above odor-based values. None of the VOCs were measured above levels of long-term health concern. We describe efforts to engage stakeholders early in the risk assessment process and outreach programs used. Finally, details on new rules and regulations that are being used to more efficiently manage risks are provided. Given the resources and experience TCEQ possesses to evaluate environmental impacts that may be caused by shale gas development and production, it is our hope that this manuscript may serve as a resource to others to identify and manage risks associated with oil and gas activities in their area.

June 5, 2015. [*Category:* Waste / Fluids]

Analysis of hydraulic fracturing additives by LC/Q-TOF-MS.

- Ferrer, Imma; Thurman, E. Michael.
- In: *Analytical and Bioanalytical Chemistry*, June 2015, pages 1-12.
- http://link.springer.com/article/10.1007/s00216-015-8780-5

Abstract: The chemical additives used in fracturing fluids can be used as tracers of water contamination caused by hydraulic fracturing operations. For this purpose, a complete chemical characterization is necessary using advanced analytical techniques. Liquid chromatography coupled with quadrupole time-of-flight mass spectrometry (LC/Q-TOF-MS) was used to identify chemical additives present in flowback and produced waters. Accurate mass measurements of main ions and fragments were used to characterize the major components of fracking fluids. Sodium adducts turned out to be the main molecular adduct ions detected for some additives due to oxygen-rich structures. Among the classes of chemical components analyzed by mass spectrometry include gels (guar gum), biocides (glutaraldehyde and alkyl dimethyl benzyl ammonium chloride), and surfactants (cocamidopropyl dimethylamines, cocamidopropyl hydroxysultaines, and cocamidopropyl derivatives). The capabilities of accurate mass and MS-MS fragmentation are explored for the unequivocal identification of these compounds. A special emphasis is given to the mass spectrometry elucidation approaches used to identify a major class of hydraulic fracturing compounds, surfactants.

June 3, 2015. [*Category:* Health]

Perinatal Outcomes and Unconventional Natural Gas Operations in Southwest Pennsylvania.

- Stacy, Shaina L.; Brink, LuAnn L.; Larkin, Jacob C.; Sadovsky, Yoel; Goldstein, Bernard D.; Pitt, Bruce R.; Talbott, Evelyn O.
- In: *PLOS One*, Vol. 10, Issue 6.
- http://journals.plos.org/plosone/article?id=10.1371/journal.pone.0126425

Abstract: Unconventional gas drilling (UGD) has enabled extraordinarily rapid growth in the extraction of natural gas. Despite frequently expressed public concern, human health studies have not kept pace. We investigated the association of proximity to UGD in the Marcellus Shale formation and perinatal outcomes in a retrospective cohort study of 15,451 live births in Southwest Pennsylvania from 2007–2010. Mothers were categorized into exposure quartiles based on inverse distance weighted (IDW) well count; least exposed mothers (first quartile) had an IDW well count less than 0.87 wells per mile, while the most exposed (fourth quartile) had 6.00 wells or greater per mile. Multivariate linear (birth weight) or logistical (small for gestational age (SGA) and prematurity) regression analyses, accounting for differences in maternal and child risk factors, were performed. There was no significant association of proximity and density of UGD with prematurity. Comparison of the most to least exposed, however, revealed lower birth weight (3323 ± 558 vs 3344 ± 544 g) and a higher incidence of SGA (6.5 vs 4.8%, respectively; odds ratio: 1.34; 95% confidence interval: 1.10–1.63). While the clinical significance of the differences in birth weight among the exposure groups is unclear, the present findings further emphasize the need for larger studies, in regio-specific fashion, with more precise characterization of exposure over an extended period of time to evaluate the potential public health significance of UGD.

June 3, 2015. [*Category:* Waste / Fluids]

Aerobic biodegradation of organic compounds in hydraulic fracturing fluids.

- Kekacs, Daniel; Drollette, Brian D.; Brooker, Michael; Plata, Desiree L.; Mouser, Paula J.
- In: *Biodegration*, June 2015.
- http://link.springer.com/article/10.1007/s10532-015-9733-6

Abstract: Little is known of the attenuation of chemical mixtures created for hydraulic fracturing within the natural environment. A synthetic hydraulic fracturing fluid was developed from disclosed industry formulas and produced for laboratory experiments using commercial additives in use by Marcellus shale field crews. The experiments employed an internationally accepted standard method (OECD 301A) to evaluate aerobic biodegradation potential of the fluid mixture by monitoring the removal of dissolved organic carbon (DOC) from an aqueous solution by activated sludge and lake water microbial consortia for two substrate concentrations and four salinities. Microbial degradation removed from 57 % to more than 90 % of added DOC within 6.5 days, with higher removal efficiency at more dilute concentrations and little difference in overall removal extent between sludge and lake microbe treatments. The alcohols isopropanol and octanol were degraded to levels below detection limits while the solvent acetone accumulated in biological treatments through time. Salinity concentrations of 40 g/L or more completely inhibited degradation during the first 6.5 days of incubation with the synthetic hydraulic fracturing fluid even though communities were pre-acclimated to salt. Initially diverse microbial communities became dominated by 16S rRNA sequences affiliated with *Pseudomonas* and other *Pseudomonadaceae* after incubation with the synthetic fracturing fluid, taxa which may be involved in acetone production. These data expand our understanding of constraints on the biodegradation potential of organic compounds in hydraulic fracturing fluids under aerobic conditions in the event that they are accidentally released to surface waters and shallow soils.

May 30, 2015. [*Category:* Water Quality]

Stream primary producers relate positively to watershed natural gas measures in north-central Arkansas streams.

- Austin, Bradley J.; Hardgrave, Natalia; Inlander, Ethan; Gallipeau, Cory; Entrekin, Sally; Evans-White, Michelle A.
- In: *Science of The Total Environment*, Vol. 529, pages 54-64, October 1, 2015.
- http://www.sciencedirect.com/science/article/pii/S0048969715300887

Abstract: Construction of unconventional natural gas (UNG) infrastructure (e.g., well pads, pipelines) is an increasingly common anthropogenic stressor that increases potential sediment erosion. Increased sediment inputs into nearby streams may decrease autotrophic processes through burial and scour, or sediment bound nutrients could have a positive effect through alleviating potential nutrient limitations. Ten streams with varying catchment UNG well densities (0–3.6 wells/km^2) were sampled during winter and spring of 2010 and 2011 to examine relationships between landscape scale disturbances associated with UNG activity and stream periphyton [chlorophyll *a* (Chl *a*)] and gross primary production (GPP). Local scale variables including light availability and water column physicochemical variables were measured for each study site. Correlation analyses examined the relationships of autotrophic processes and local scale variables with the landscape scale variables percent pasture land use and UNG metrics (well density and well pad inverse flow path length). Both GPP and Chl *a* were primarily positively associated with the UNG activity metrics during most sample periods; however, neither landscape variables nor response variables correlated well with local scale factors. These positive correlations do not confirm causation, but they do suggest that it is possible that UNG development can alleviate one or more limiting factors on autotrophic production within these streams. A secondary manipulative study was used to examine the link between nutrient limitation and algal growth across a gradient of streams impacted by natural gas activity. Nitrogen limitation was common among minimally impacted stream reaches and was alleviated in streams with high UNG activity. These data provide evidence that UNG may stimulate the primary production of Fayetteville shale streams via alleviation of N-limitation. Restricting UNG activities from the riparian zone along with better enforcement of best management practices should help reduce these possible impacts of UNG activities on stream autotrophic processes.

May 29, 2015. [*Categories:* Air Quality; Health]

Air Contaminants Associated with Potential Respiratory Effects from Unconventional Resource Development Activities.

- McCawley, Michael
- In: *Seminars in Respiratory and Critical Care Medicine*, Vol. 36, Issue 3, pages 379-387.
- https://www.thieme-connect.de/DOI/DOI?10.1055/s-0035-1549453

Abstract: Unconventional natural gas development uses horizontal drilling in conjunction with hydraulic fracturing to gain access to natural gas deposits which may be tightly held in shale deposits and unavailable to conventional vertical drilling operations. The intensive work required to extract this source of energy results in higher than usual numbers of vehicles involved, potential release of emissions from those vehicles in congested zones surrounding the drill site, and release of other contaminants from materials drawn back out of the borehole after fracturing of the shale. Typical contaminants would be diesel exhaust particulate and gases, volatile organic compounds and other hydrocarbons both from diesels and the drilling process, crystalline silica, used as part of the hydraulic fracturing process in kiloton quantities, and methane escaping from the borehole and piping. A rise in respiratory disease with proximity to the process has been reported in nearby communities and both silica and diesel exposures at the worksite are recognized respiratory hazards. Because of the relatively short time this process has been used to the extent it is currently being used, it is not possible to draw detailed conclusions about the respiratory hazards that may be posed. However, based on the traffic volume associated with each drill site and the number of drill sites in any locale, it is possible at least to compare the effects to that of large traffic volume highways which are known to produce some respiratory effects in surrounding areas.

May 29, 2015. [*Category:* General (Comment/Review)]

The current situation of shale gas in Sichuan, China.

- Xin-gang, Zhao; Ya-hui, Yang.
- In: *Renewable and Sustainable Energy Reviews*, Vol. 50, pages 653-664, October 2015.
- http://www.sciencedirect.com/science/article/pii/S1364032115004827

Abstract: The oil crisis and the successful commercial exploitation of shale gas in America have made shale gas become the focus of global energy industry. Shale gas industry will be developed mainly in the future. Sichuan has natural geographical advantages and becomes the main battlefield of shale gas in China. So it is necessary and urgent to analyze the current situation of Sichuan shale gas. This paper introduces the status quo of shale gas in Sichuan, and systematically analyzes the industrial environment for developing Sichuan shale gas from four aspects of policy, economy, society, technology. Then the issues facing Sichuan are discussed. Finally, the paper puts forward some corresponding recommendations to provide certain references to the development of shale gas industry in Sichuan.

May 27, 2015. [*Categories:* Ecology; Water Quality]

Stream macroinvertebrate communities across a gradient of natural gas development in the Fayetteville Shale.

- Johnson, Erica; Austin, Bradley J.; Inlander, Ethan; Gallipeau, Cory; Evans-White, Michelle A.; Entrekin, Sally.

- In: *The Science of the Total Environment*, October 15, 2015, pages 323-332.
- http://www.sciencedirect.com/science/article/pii/S0048969715300851

Abstract: Oil and gas extraction in shale plays expanded rapidly in the U.S. and is projected to expand globally in the coming decades. Arkansas has doubled the number of gas wells in the state since 2005 mostly by extracting gas from the Fayetteville Shale with activity concentrated in mixed pasture-deciduous forests. Concentrated well pads in close proximity to streams could have adverse effects on stream water quality and biota if sedimentation associated with developing infrastructure or contamination from fracturing fluid and waste occurs. Cumulative effects of gas activity and local habitat conditions on macroinvertebrate communities were investigated across a gradient of gas well activity (0.2–3.6 wells per km^2) in ten stream catchments in spring 2010 and 2011. In 2010, macroinvertebrate density was positively related to well pad inverse flowpath distance from streams ($r = 0.84$, $p < 0.001$). Relatively tolerant mayflies *Baetis* and *Caenis* ($r = 0.64$, $p = 0.04$), filtering hydropsychid caddisflies ($r = 0.73$, $p = 0.01$), and chironomid midge densities ($r = 0.79$, $p = 0.008$) also increased in streams where more well pads were closer to stream channels. Macroinvertebrate trophic structure reflected environmental conditions with greater sediment and primary production in streams with more gas activity close to streams. However, stream water turbidity ($r = 0.69$, $p = 0.02$) and chlorophyll a ($r = 0.89$, $p < 0.001$) were the only in-stream variables correlated with gas well activities. In 2011, a year with record spring flooding, a different pattern emerged where mayfly density ($p = 0.74$, $p = 0.01$) and mayfly, stonefly, and caddisfly richness ($r = 0.78$, $p = 0.008$) increased in streams with greater well density and less silt cover. Hydrology and well pad placement in a catchment may interact to result in different relationships between biota and catchment activity between the two sample years. Our data show evidence of different macroinvertebrate communities expressed in catchments with different levels of gas activity that reinforce the need for more quantitative analyses of cumulative freshwater-effects from oil and gas development.

May 26, 2015. [*Category:* Climate]

Near-Field Characterization of Methane Emission Variability from a Compressor Station Using a Model Aircraft.

- Nathan, Brian J.; Golston, Levi M.; O'Brien, Anthony S; Ross, Kevin; Harrison, William A.; Tao, Lei;
- Lary, David J.; Johnson, Derek R.; Covington, April N.; Clark, Nigel N.; Zondlo, Mark A.

- In: *Environmental Science & Technology*.
- http://pubs.acs.org/doi/abs/10.1021/acs.est.5b00705

Abstract: A model aircraft equipped with a custom laser-based, open-path methane sensor was deployed around a natural gas compressor station to quantify the methane leak rate and its variability at a compressor station in the Barnett Shale. The open-path, laser-based sensor provides fast (10 Hz) and precise (0.1 ppmv) measurements of methane in a compact package while the remote control aircraft provides nimble and safe operation around a local source. Emission rates were measured from 22 flights over a one-week period. Mean emission rates of 14 ± 8 g CH_4 s^{-1} (7.4 ± 4.2 g CH_4 s^{-1} median) from the station were observed or approximately 0.02% of the station throughput. Significant variability in emission rates (0.3–73 g CH_4 s^{-1} range) was observed on time scales of hours to days, and plumes showed high spatial variability in the horizontal and vertical dimensions. Given the high spatiotemporal variability of emissions, individual measurements taken over short durations and from ground-based platforms should be used with caution when examining compressor station emissions. More generally, our results demonstrate the unique advantages and challenges of platforms like small unmanned aerial vehicles for quantifying local emission sources to the atmosphere.

May 22, 2015. [*Category:* Waste / Fluids]

Current perspective on produced water management challenges during hydraulic fracturing for oil and gas recovery.

- Gregory, Kelvin; Mohan, Arvind Murali.
- In: *Environmental Chemistry*, Vol. 12, Issue 3, pages 261-266.
- http://www.publish.csiro.au/paper/EN15001.htm

Abstract: The need for cheap and readily available energy and chemical feedstock, and the desire for energy independence have spurred worldwide interest in the development of unconventional oil and gas resources; in particular, the production of oil and gas from shale formations. Although these resources have been known for a long time, the technical expertise and market forces that enable economical development has coincided over the last 15 years. The amalgamation of horizontal drilling and hydraulic fracturing have enabled favourable economics for development of fossil energy from these unconventional reservoirs, but their potential widespread application has raised concerns over deleterious environmental impacts on fragile water resources. The environmental management challenges faced by the oil and gas industry arise from local water availability and infrastructure for treating and disposing of the high-strength wastewater that is produced. Although there are significant challenges, these create opportunities for innovation in the industry.

May 21, 2015.

Comment on the German Draft Legislation on Hydraulic Fracturing: The Need for an Accurate State of Knowledge and for Independent Scientific Research.

- Elsner, Martin; Schreglmann, Kathrin; Calmano, Wolfgang; Bergmann, Axel; Vieth-Hillebrand, Andrea; Wilke, Franziska D. H.; Wollin, Klaus-Michael; Georgi, Anett; Schmidt, Winfried; Hofmann, Thilo; Micić, Vesna; Vengosh, Avner; Mayer, Bernhard.
- In: *Environmental Science & Technology*, Vol. 49, Issue 11, pages 6367-6369.
- http://pubs.acs.org/doi/abs/10.1021/acs.est.5b01921

Introduction: Exploitation of unconventional gas resources is challenged by societal concerns about environmental risks associated with high volume multistage hydraulic fracturing (HF) in horizontal wells. To regulate HF in Germany, on April first 2015, the German Chancellor's cabinet signed off on a draft law which is currently under discussion in the parliament and states the following (Figure 1):

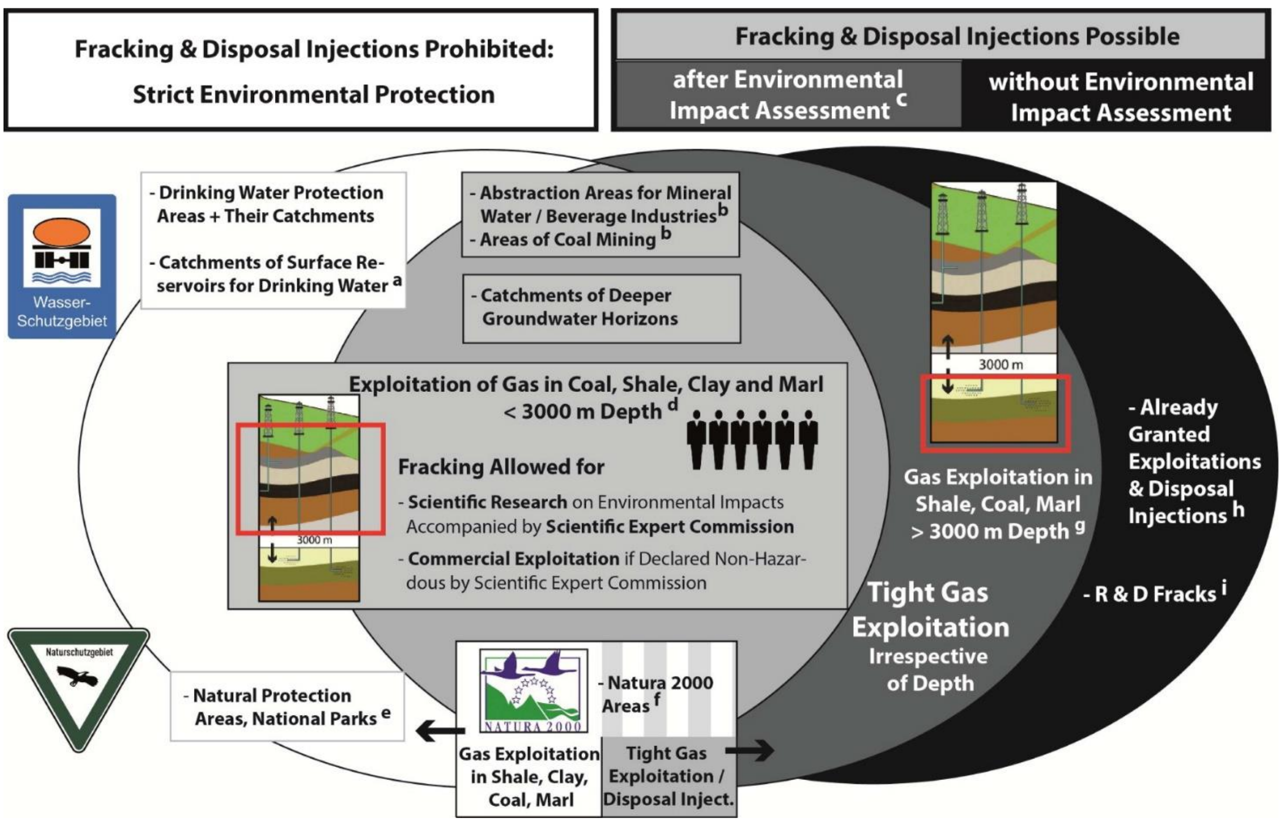


Figure 1. Schematic representation of the current German draft legislation on HF. (a) Water Management Act (WHG) §13a, Para.1 No. 2. (b) left to state legislation. (c) WHG §9, Para.2, Environmental Risk Assessment of Mining Authorities (WUVP-V Bergbau) §1 No. 2. (d) WHG §13a Para.2, 6, 7. (e) Federal Nature Conservation Act (BNatSchG) §23 Para.3, §24 Para.3, §33 Para.1a. (f) BNatSchG §7 Para.1 No. 8. (g) WHG § 13a Para.1. (h) Over a period of five years, UVP-V Bergbau §4 Para.5; UVP-V Bergbau §1 No. 2.

(1) HF is prohibited in water protection areas, their catchments and natural habitats by the Water Management Act and the Federal Nature Conservation Act (WHG §13a, Para.1 No. 2, BNatSchG §23 Para. 3, §24 Para. 3, §33 Para.1a). Not regulated are catchments of deeper groundwater horizons or abstraction areas for beverage industries (WHG §9, Para. 2).
(2) Elsewhere, HF and disposal injections of formation water are possible, but subject to Environmental Risk Assessment by Mining Authorities (WHG §9, Para. 2) involving declaration of all chemical additives (WHG § 13b Para. 1).
(3) In shale, coal, clay and marl formations less than 3000 m deep, HF activities are forbidden except for (i) scientific investigations to explore environmental impacts of HF, or (ii) if an accompanying scientific expert panel concludes that HF for commercial purposes is non-problematic in a given formation (WHG §13a Para. 2, 6, 7).

As expert group on HF chemicals within the Water Chemistry Society, German Chemical Society (GDCh) we appreciate the intention to put the topic in Germany on a well-founded regulated basis. Together with scientists from North America we nonetheless comment on the draft–guided by current scientific knowledge, research gaps, and the necessity of independent research.

May 16, 2015. [*Category:* Climate]

Life-cycle comparison of greenhouse gas emissions and water consumption for coal and shale gas fired power generation in China.

- Chang, Yuan; Huang, Runze; Ries, Robert J.; Masanet, Eric.
- In: *Energy*, Vol. 86, pages 335-342, June 15, 2015.
- http://www.sciencedirect.com/science/article/pii/S0360544215004880

Abstract: China has the world's largest shale gas reserves, which might enable it to pursue a new pathway for electricity generation. This study employed hybrid LCI (life cycle inventory) models to quantify the ETW (extraction-to-wire) GHG (greenhouse gas) emissions and water consumption per kWh of coal- and shale gas-fired electricity in China. Results suggest that a coal-to-shale gas shift and upgrading coal-fired power generation technologies could provide pathways to less GHG and water intensive power in China. Compared to different coal-fired generation technologies, the ETW GHG emissions intensity of gas-fired CC (combined cycle) technology is 530 g CO_2e/kWh, which is 38–45% less than China's present coal-fired electricity. Gas-fired CT (combustion turbine) technology has the lowest ETW water consumption intensity at 960 g/kWh, which is 34–60% lower than China's present coal-fired electricity. The GHG-water tradeoff of the two gas-fired power generation technologies suggests that gas-fired power generation technologies should be selected based on regional-specific water resource availabilities and electricity demand fluctuations in China. However, the low price of coal-fired electricity, high cost of shale gas production, insufficient pipeline infrastructures, and multiple consumers of shale gas resources may serve as barriers to a coal-to-shale gas shift in China's power sector in the near term.

May 15, 2015.

Spatial analysis of environment and population at risk of natural gas fracking in the state of Pennsylvania, USA.

- Meng, Qingmin.
- In: *Science of the Total Environment*, Vol. 515-516, pages 198-206.
- http://www.sciencedirect.com/science/article/pii/S0048969715001667

Abstract: Hydraulic fracturing, also known as fracking, has been increasing exponentially across the United States, which holds the largest known shale gas reserves in the world. Studies have found that the high-volume horizontal hydraulic fracturing process (HVHFP) threatens water resources, harms air quality, changes landscapes, and damages ecosystems. However, there is minimal research focusing on the spatial study of environmental and human risks of HVHFP, which is necessary for state and federal governments to administer, regulate, and assess fracking. Integrating GIS and spatial kernel functions, we study the presently operating fracking wells across the state of Pennsylvania (PA), which is the main part of the current hottest Marcellus Shale in US. We geographically process the location data of hydraulic fracturing wells, 2010 census block data, urbanized region data, railway data, local road data, open water data, river data, and wetland data for the state of PA. From this we develop a distance based risk assessment in order to understand the environmental and urban risks. We generate the surface data of fracking well intensity and population intensity by integrating spatial dependence, semivariogram modeling, and a quadratic kernel function. The surface data of population risk generated by the division of fracking well intensity and population intensity provide a novel insight into the local and regional regulation of hydraulic fracturing activities in terms of environmental and health related risks due to the proximity of fracking wells.

May 14, 2015. [*Category:* General (Comment/Review)]

Scenarios for shale gas development and their related land use impacts in the Baltic Basin, Northern Poland.

- Baranzelli, Claudia; Vandecasteele, Ine; Ribeiro Barranco, Ricardo; Mari i Rivero, Ines; Pelletier, Nathan; Batelaan, Okke; Lavalle, Carlo.
- In: *Energy Policy*, Vol. 84, pages 80-95, September, 2015.
- http://www.sciencedirect.com/science/article/pii/S0301421515001822

Abstract: Scenarios for potential shale gas development were modelled for the Baltic Basin in Northern Poland for the period 2015–2030 using the land allocation model EUCS100. The main aims were to assess the associated land use requirements, conflicts with existing land use, and the influence of legislation on the environmental impact. The factors involved in estimating the suitability for placement of shale gas well pads were analysed, as well as the potential land and water requirements to define 2 technology-based scenarios, representing the highest and lowest potential environmental impact. 2 different legislative frameworks (current and restrictive) were also assessed, to give 4 combined scenarios altogether. Land consumption and allocation patterns of well pads varied substantially according to the modelled scenario. Potential landscape fragmentation and conflicts with other land users depended mainly on development rate, well pad density, existing land-use patterns, and geology. Highly complex landscapes presented numerous barriers to drilling activities, restricting the potential development patterns. The land used for shale gas development could represent a significant percentage of overall land take within the shale play. The adoption of appropriate legislation, especially the protection of natural areas and water resources, is therefore essential to minimise the related environmental impact.

May 12, 2015. [*Category:* General (Comment/Review)]

Effect of Providing Information on Students' Knowledge and Concerns about Hydraulic Fracking.

- Burger, Joanna; Nakata, Kimi; Liang, Laura; Pittfield, Taryn; Jeitner, Christian.
- In: *Journal of Toxicology and Environmental Health-Part a-Current Issues*
- http://www.tandfonline.com/doi/abs/10.1080/15287394.2015.1017683?url_ver=Z39.88-2003&rfr_id=ori:rid:crossref.org&rfr_dat=cr_pub%3dpubmed

Abstract: Governmental agencies, regulators, health professionals, and the public are faced with understanding and responding to new development practices and conditions in their local and regional environment. While hydraulic fracking (fracking) for shale gas has been practiced for over 50 years in some states, it is a relatively recent event in the northeastern United States. Providing environmental health information to the public about fracking requires understanding both the knowledge base and the perceptions of the public. The knowledge, perceptions, and concerns of college students about fracking were examined. Students were interviewed at Rutgers University in New Jersey, a state without any fracking, although fracking occurs in nearby Pennsylvania. Objectives were to determine (1) knowledge about fracking, (2) rating of concerns, (3) trusted information sources, (4) importance of fracking relative to other energy sources, and (5) the effect of a 15-min lecture and discussion on these aspects. On the second survey, students improved on their knowledge (except the components used for fracking), and their ratings changed for some concerns, perceived benefits, and trusted information sources. There was no change in support for further development of natural gas, but support for solar, wind, and wave energy decreased. Data suggest that students' knowledge and perceptions change with exposure to information, but many of these changes were due to students using the Internet to look up information immediately after the initial survey and lecture. Class discussions indicated a general lack of trust for several information sources available on the Web.

May 10, 2015. [*Category:* Climate]

Carbon Disulfide (CS2) Mechanisms in Formation of Atmospheric Carbon Dioxide (CO2) Formation from Unconventional Shale Gas Extraction and Processing Operations and Global Climate Change.

- Rich, Alisa L.; Patel, Jay T.
- In: *Environmental Health Insights*, Vol. 9 (Suppl 1), pages 35-39.
- http://www.ncbi.nlm.nih.gov/pmc/articles/PMC4428389/

Abstract: Carbon disulfide (CS2) has been historically associated with the production of rayon, cellophane, and carbon tetrachloride. This study identifies multiple mechanisms by which CS2 contributes to the formation of CO2 in the atmosphere. CS2 and other associated sulfide compounds were found by this study to be present in emissions from unconventional shale gas extraction and processing (E&P) operations. The breakdown products of CS2; carbonyl sulfide (COS), carbon monoxide (CO), and sulfur dioxide (SO2) are indirect greenhouse gases (GHGs) that contribute to CO2 levels in the atmosphere. The heat-trapping nature of CO2 has been found to increase the surface temperature, resulting in regional and global climate change. The purpose of this study is to identify five mechanisms by which CS2 and the breakdown products of CS2 contribute to atmospheric concentrations of CO2. The five mechanisms of CO2 formation are as follows:

1. Chemical Interaction of CS2 and hydrogen sulfide (H2S) present in natural gas at high temperatures, resulting in CO2 formation;
2. Combustion of CS2 in the presence of oxygen producing SO2 and CO2;
3. Photolysis of CS2 leading to the formation of COS, CO, and SO2, which are indirect contributors to CO2 formation;
4. One-step hydrolysis of CS2, producing reactive intermediates and ultimately forming H2S and CO2;
5. Two-step hydrolysis of CS2 forming the reactive COS intermediate that reacts with an additional water molecule, ultimately forming H2S and CO2. CS2 and COS additionally are implicated in the formation of SO2 in the stratosphere and/or troposphere. SO2 is an indirect contributor to CO2 formation and is implicated in global climate change.

May 5, 2015. [*Category:* Waste / Fluids]

Evolution of water chemistry during Marcellus Shale gas development: A case study in West Virginia.

- Ziemkiewicz, Paul F.; Thomas He, Y.
- In: *Chemosphere*, Vol. 134, September 2015, pages 224-231.
- http://www.sciencedirect.com/science/article/pii/S0045653515003793

Abstract: Hydraulic fracturing (HF) has been used with horizontal drilling to extract gas and natural gas liquids from source rock such as the Marcellus Shale in the Appalachian Basin. Horizontal drilling and HF generates large volumes of waste water known as flowback. While inorganic ion chemistry has been well characterized, and the general increase in concentration through the flowback is widely recognized, the literature contains little information relative to organic compounds and radionuclides.

This study examined the chemical evolution of liquid process and waste streams (including makeup water, HF fluids, and flowback) in four Marcellus Shale gas well sites in north central West Virginia. Concentrations of organic and inorganic constituents and radioactive isotopes were measured to determine changes in waste water chemistry during shale gas development.

We found that additives used in fracturing fluid may contribute to some of the constituents (e.g., Fe) found in flowback, but they appear to play a minor role. Time sequence samples collected during flowback indicated increasing concentrations of organic, inorganic and radioactive constituents. Nearly all constituents were found in much higher concentrations in flowback water than in injected HF fluids suggesting that the bulk of constituents originate in the Marcellus Shale formation rather than in the formulation of the injected HF fluids. Liquid wastes such as flowback and produced water, are largely recycled for subsequent fracturing operations. These practices limit environmental exposure to flowback.

May 4, 2015. [*Category:* Water Quality]

Evaluating a groundwater supply contamination incident attributed to Marcellus Shale gas development.

- Llewellyn, Garth T.; Dorman, Frank; Westland, J. L.; Yoxtheimer, D.; Grieve, Paul; Sowers, Todd; Humston-Fulmer, E.; Brantley, Susan L.
- In: *Proceedings of the National Academy of Sciences*, Vol. 112, Issue 20, pages 6325-6330.
- http://www.pnas.org/content/112/20/6325.abstract

Abstract: High-volume hydraulic fracturing (HVHF) has revolutionized the oil and gas industry worldwide but has been accompanied by highly controversial incidents of reported water contamination. For example, groundwater contamination by stray natural gas and spillage of brine and other gas drilling-related fluids is known to occur. However, contamination of shallow potable aquifers by HVHF at depth has never been fully documented. We investigated a case where Marcellus Shale gas wells in Pennsylvania caused inundation of natural gas and foam in initially potable groundwater used by several households. With comprehensive 2D gas chromatography coupled to time-of-flight mass spectrometry (GCxGC-TOFMS), an unresolved complex mixture of organic compounds was identified in the aquifer. Similar signatures were also observed in flowback from Marcellus Shale gas wells. A compound identified in flowback, 2-n-Butoxyethanol, was also positively identified in one of the foaming drinking water wells at nanogram-per-liter concentrations. The most likely explanation of the incident is that stray natural gas and drilling or HF compounds were driven ∼1–3 km along shallow to intermediate depth fractures to the aquifer used as a potable water source. Part of the problem may have been wastewaters from a pit leak reported at the nearest gas well pad—the only nearby pad where wells were hydraulically fractured before the contamination incident. If samples of drilling, pit, and HVHF fluids had been available, GCxGC-TOFMS might have fingerprinted the contamination source. Such evaluations would contribute significantly to better management practices as the shale gas industry expands worldwide.

May 4, 2015. [*Category:* Seismicity]

Regional detection and monitoring of injection-induced seismicity: Application to the 2010-12 Youngstown, Ohio seismic sequence.

- Holtkamp, S.G.; Brudzinski, M.R.; Currie, B.S.
- In: *AAPG Bulletin* (ahead of print).
- http://archives.datapages.com/data/bulletns/aop/2015-05-04/aapgbltn13194.html

Abstract: Increased rates of seismicity in tectonically quiescent regions like the midcontinent region of the United States have been hypothesized to be related to human activities such as oil and gas production and wastewater injection. It can be difficult to establish how human activities relate to earthquakes, particularly when local seismic networks are not available to provide a high quality characterization of the seismic sequence in question. Here, we employ a multi-station waveform cross-correlation approach to evaluate the relationships between earthquakes associated with the 2011-12 Youngstown, Ohio seismic sequence and the injection history of a local wastewater disposal well. Utilizing data recorded by four regional seismic stations 50-200 km away from Youngstown, we demonstrate that high-resolution results can be achieved without utilizing costly and scientifically focused local seismic deployments. Compared to the number of events recorded using standard detection methodologies, we realize a 25-fold increase in detected seismicity (282 detected events) during the sequence, and allow us with confidence to interpret a direct link between seismicity and well injection volumes. Using a combination of absolute and relative location techniques, we demonstrate that seismicity migrated from below the injection well towards the west, along a line consistent with a nodal plane of the largest earthquake in the sequence. We are able to separate the seismic sequence into three distinct phases, consistent with changes in injection rates and maximum injection pressures. In addition, using daily injection volume records, we can identify two families of similar earthquakes. The first family, occurring early in the sequence and close to the injection well, and followed a recurrence pattern that lagged injection activity by 1 day. The second family, occurred later in the sequence and further from the well and displayed a 4 day lag. We interpret these relationships to be to be related to pore pressure diffusion rates within the fault network responsible for the seismicity. Collectively our technique shows the high quality of results possible when only a few regional seismic stations are available for monitoring.

April 24, 2015.

Ecosystem services lost to oil and gas in North America.

- Allred, Brady W.; Smith, W. Kolby; Twidwell, Dirac; Haggerty, Julia H.; Running, Steven W.; Naugle, David E.; Fuhlendorf, Samuel D.
- In: *Science*, Vol. 348, Issue 6233, pages 401-402.
- http://www.sciencemag.org/content/348/6233/401

Abstract: Advanced technologies in oil and gas extraction coupled with energy demand have encouraged an average of 50,000 new wells per year throughout central North America since 2000. Although similar to past trends (see the graph, this page), the space and infrastructure required for horizontal drilling and high-volume hydraulic fracturing are transforming millions of hectares of the Great Plains into industrialized landscapes, with drilling projected to continue. Although this development brings economic benefits and expectations of energy security, policy and regulation give little attention to trade-offs in the form of lost or degraded ecosystem services. It is the scale of this transformation that is important, as accumulating land degradation can result in continental impacts that are undetectable when focusing on any single region. With the impact of this transformation on natural systems and ecosystem services yet to be quantified at broad extents, decisions are being made with few data at hand.

April 23, 2015. [*Category:* Seismicity]

Hydraulic fracturing and the Crooked Lake Sequences: Insights gleaned from regional seismic networks.

- Schultz, Ryan; Stern, Virginia; Novakovic, Mark; Atkinson, Gail; Gu, Yu Jeffrey.
- In: *Geophysical Research Letters*, Vol. 42, Issue 8, pages 2750-2758.
- http://onlinelibrary.wiley.com/doi/10.1002/2015GL063455/abstract

Abstract: Within central Alberta, Canada, a new sequence of earthquakes has been recognized as of 1 December 2013 in a region of previous seismic quiescence near Crooked Lake, ~30 km west of the town of Fox Creek. We utilize a cross-correlation detection algorithm to detect more than 160 events to the end of 2014, which is temporally distinguished into five subsequences. This observation is corroborated by the uniqueness of waveforms clustered by subsequence. The Crooked Lake Sequences have come under scrutiny due to its strong temporal correlation (>99.99%) to the timing of hydraulic fracturing operations in the Duvernay Formation. We assert that individual subsequences are related to fracturing stimulation and, despite adverse initial station geometry, double-difference techniques allow us to spatially relate each cluster back to a unique horizontal well. Overall, we find that seismicity in the Crooked Lake Sequences is consistent with first-order observations of hydraulic fracturing induced seismicity.

April 21, 2015. [*Category:* Air Quality]

***Atmospheric Emission Characterization of Marcellus Shale Natural Gas Development Sites*.**

- Goetz, J. Douglass; Floerchinger, Cody; Fortner, Edward Charles; Wormhoudt, Joda; Massoli, Paola; Knighton, W. Berk; Herndon, Scott C.; Kolb, Charles E.; Knipping, Eladio; Shaw, Stephanie; DeCarlo, Peter.
- In: *Environmental Science & Technology*, Vol. 49, Issue 11, pages 7012-7020.
- http://pubs.acs.org/doi/abs/10.1021/acs.est.5b00452

Abstract: Limited direct measurements of criteria pollutants emissions and precursors, as well as natural gas constituents, from Marcellus shale gas development activities contribute to uncertainty about their atmospheric impact. Real-time measurements were made with the Aerodyne Research Inc. Mobile Laboratory to characterize emission rates of atmospheric pollutants. Sites investigated include production well pads, a well pad with a drill rig, a well completion, and compressor stations. Tracer release ratio methods were used to estimate emission rates. A first-order correction factor was developed to account for errors introduced by fenceline tracer release. In contrast to observations from other shale plays, elevated volatile organic compounds, other than CH_4 and C_2H_6, were generally not observed at the investigated sites. Elevated submicrometer particle mass concentrations were also generally not observed. Emission rates from compressor stations ranged from 0.006 to 0.162 tons per day (tpd) for NO_x, 0.029 to 0.426 tpd for CO, and 67.9 to 371 tpd for CO_2. CH_4 and C_2H_6 emission rates from compressor stations ranged from 0.411 to 4.936 tpd and 0.023 to 0.062 tpd, respectively. Although limited in sample size, this study provides emission rate estimates for some processes in a newly developed natural gas resource and contributes valuable comparisons to other shale gas studies.

April 21, 2015. [*Category:* Seismicity]

Causal factors for seismicity near Azle, Texas.

- Hornbach, Matthew J.; DeShon, Heather R.; Ellsworth, William L.; Stump, Brian W.; Hayward, Chris; Frohlich, Cliff; Oldham, Harrison R.; Olson, Jon E.; Magnani, M. Beatrice; Brokaw, Casey; Luetgert, James H.
- In: *Nature Communications*, Vol. 6, Article # 6728.
- http://www.nature.com/ncomms/2015/150421/ncomms7728/full/ncomms7728.html

Abstract: In November 2013, a series of earthquakes began along a mapped ancient fault system near Azle, Texas. Here we assess whether it is plausible that human activity caused these earthquakes. Analysis of both lake and groundwater variations near Azle shows that no significant stress changes were associated with the shallow water table before or during the earthquake sequence. In contrast, pore-pressure models demonstrate that a combination of brine production and wastewater injection near the fault generated subsurface pressures sufficient to induce earthquakes on near-critically stressed faults. On the basis of modelling results and the absence of historical earthquakes near Azle, brine production combined with wastewater disposal represent the most likely cause of recent seismicity near Azle. For assessing the earthquake cause, our research underscores the necessity of monitoring subsurface wastewater formation pressures and monitoring earthquakes having magnitudes of ~M2 and greater. Currently, monitoring at these levels is not standard across Texas or the United States.

April 20, 2015.

Assessment of the Acute and Chronic Health Hazards of Hydraulic Fracturing Fluids.

- Wattenberg, Elizabeth V.; Bielicki, Jeffrey M.; Suchomel, Ashley E.; Sweet, Jessica T.; Vold, Elizabeth M.; Ramachandran, Gurumurthy.
- In: *Journal of Occupational and Environmental Hygiene* (ahead of print).
- http://www.tandfonline.com/doi/abs/10.1080/15459624.2015.1029612

Abstract: There is growing concern about how hydraulic fracturing affects public health because this activity involves handling large volumes of fluids that contain toxic and carcinogenic constituents, which are injected under high pressure through wells into the subsurface to release oil and gas from tight shale formations. The constituents of hydraulic fracturing fluids (HFFs) present occupational health risks because workers may be directly exposed to them, and general public health risks because of potential air and water contamination. Hazard identification, which focuses on the types of toxicity that substances may cause, is an important step in the complex health risk assessment of hydraulic fracturing. This paper presents a practical and adaptable tool for the hazard identification of HFF constituents, and its use in the analysis of HFF constituents reported to be used in 2,850 wells in North Dakota between December 2009 and November 2013. Of the 569 reported constituents, 347 could be identified by a Chemical Abstract Service Registration Number (CASRN) and matching constituent name. The remainder could not be identified either because of trade secret labeling (210) or because of an invalid CASRN (12). Eleven public databases were searched for health hazard information on thirteen health hazard endpoints for 168 identifiable constituents that had at least 25 reports of use. Health hazard counts were generated for chronic and acute endpoints, including those associated with oral, inhalation, ocular, and dermal exposure. Eleven of the constituents listed in the top 30 by total health hazard count were also listed in the top 30 by reports of use. This includes naphthalene, which along with benzyl chloride, has the highest health hazard count. The top 25 constituents reportedly used in North Dakota largely overlap with those reported for Texas and Pennsylvania, despite different geologic formations, target resources (oil vs. gas), and disclosure requirements. Altogether, this database provides a public health tool to help inform stakeholders about potential health hazards, and to aid in the reformulation of less hazardous HFFs.

April 20, 2015. [*Category:* Water Usage]

Investment optimization model for freshwater acquisition and wastewater handling in shale gas production.

- Yang, Linlin; Grossmann, Ignacio E.; Mauter, Meagan S.; Dilmore, Robert M.
- In: *Aiche Journal*, Vol. 61, Issue 6, pages 1770-1782.
- http://onlinelibrary.wiley.com/doi/10.1002/aic.14804/abstract

Abstract: Major challenges of water use in the drilling and fracturing process in shale gas production are large volumes required in a short-period of time and the nonsteady nature of wastewater treatment. A new mixed-integer linear programming (MILP) model for optimizing capital investment decisions for water use for shale gas production through a discrete-time representation of the State-Task Network is presented. The objective is to minimize the capital cost of impoundment, piping, and treatment facility, and operating cost including freshwater, pumping, and treatment. The goal is to determine the location and capacity of impoundment, the type of piping, treatment facility locations and removal capability, freshwater sources, as well as the frac schedule. In addition, the impact of several factors such as limiting truck hauling and increasing flowback volume on the solution is examined. A case study is optimized to illustrate the application of the proposed formulation.

April 20, 2015.

Assessment of the Acute and Chronic Health Hazards of Hydraulic Fracturing Fluids.

- Wattenberg, Elizabeth V.; Bielicki, Jeffrey M.; Suchomel, Ashley E.; Sweet, Jessica T.; Vold, Elizabeth M.; Ramachandran, Gurumurthy.
- In: *Journal of Occupational and Environmental Hygiene* (published ahead of print).
- http://www.ncbi.nlm.nih.gov/pubmed/25894916

Abstract: There is growing concern about how hydraulic fracturing affects public health because this activity involves handling large volumes of fluids that contain toxic and carcinogenic constituents, which are injected under high pressure through wells into the subsurface to release oil and gas from tight shale formations. The constituents of hydraulic fracturing fluids (HFFs) present occupational health risks because workers may be directly exposed to them, and general public health risks because of potential air and water contamination. Hazard identification, which focuses on the types of toxicity that substances may cause, is an important step in the complex health risk assessment of hydraulic fracturing. This paper presents a practical and adaptable tool for the hazard identification of HFF constituents, and its use in the analysis of HFF constituents reported to be used in 2,850 wells in North Dakota between December 2009 and November 2013. Of the 569 reported constituents, 347 could be identified by a Chemical Abstract Service Registration Number (CASRN) and matching constituent name. The remainder could not be identified either because of trade secret labeling (210) or because of an invalid CASRN (12). Eleven public databases were searched for health hazard information on thirteen health hazard endpoints for 168 identifiable constituents that had at least 25 reports of use. Health hazard counts were generated for chronic and acute endpoints, including those associated with oral, inhalation, ocular, and dermal exposure. Eleven of the constituents listed in the top 30 by total health hazard count were also listed in the top 30 by reports of use. This includes naphthalene, which along with benzyl chloride, has the highest health hazard count. The top 25 constituents reportedly used in North Dakota largely overlap with those reported for Texas and Pennsylvania, despite different geologic formations, target resources (oil vs. gas), and disclosure requirements. Altogether, this database provides a public health tool to help inform stakeholders about potential health hazards, and to aid in the reformulation of less hazardous HFFs.

April 20, 2015. [*Category:* Waste / Fluids]

Organic and inorganic composition and microbiology of produced waters from Pennsylvania shale gas wells.

- Akob, Denise M.; Cozzarelli, Isabelle M.; Dunlap, Darren S.; Rowan, Elisabeth L.; Lorah, Michelle M.
- In: *Applied Geochemistry* (ahead of print).
- http://www.sciencedirect.com/science/article/pii/S0883292715000955

Abstract: Hydraulically fractured shales are becoming an increasingly important source of natural gas production in the United States. This process has been known to create up to 420 gallons of produced water (PW) per day, but the volume varies depending on the formation, and the characteristics of individual hydraulic fracture. PW from hydraulic fracturing of shales are comprised of injected fracturing fluids and natural formation waters in proportions that change over time. Across the state of Pennsylvania, shale gas production is booming; therefore, it is important to assess the variability in PW chemistry and microbiology across this geographical span. We quantified the inorganic and organic chemical composition and microbial communities in PW samples from 13 shale gas wells in north central Pennsylvania. Microbial abundance was generally low (66–9400 cells/mL). Non-volatile dissolved organic carbon (NVDOC) was high (7–31 mg/L) relative to typical shallow groundwater, and the presence of organic acid anions (e.g., acetate, formate, and pyruvate) indicated microbial activity. Volatile organic compounds (VOCs) were detected in four samples (~1 to 11.7 μg/L): benzene and toluene in the Burket sample, toluene in two Marcellus samples, and tetrachloroethylene (PCE) in one Marcellus sample. VOCs can be either naturally occurring or from industrial activity, making the source of VOCs unclear. Despite the addition of biocides during hydraulic fracturing, H_2S-producing, fermenting, and methanogenic bacteria were cultured from PW samples. The presence of culturable bacteria was not associated with salinity or location; although organic compound concentrations and time in production were correlated with microbial activity. Interestingly, we found that unlike the inorganic chemistry, PW organic chemistry and microbial viability were highly variable across the 13 wells sampled, which can have important implications for the reuse and handling of these fluids.

April 18, 2015. [*Category:* Water Quality]

Numerical simulation of the environmental impact of hydraulic fracturing of tight/shale gas reservoirs on near-surface groundwater: Background, base cases, shallow reservoirs, short-term gas, and water transport.

- Reagan, Matthew T.; Moridis, George J.; Keen, Noel D.; Johnson, Jeffrey N.
- In: *Water Resources Research*, Vol. 51, Issue 4, pages 2543-2573.
- http://onlinelibrary.wiley.com/doi/10.1002/2014WR016086/abstract

Abstract: Hydrocarbon production from unconventional resources and the use of reservoir stimulation techniques, such as hydraulic fracturing, has grown explosively over the last decade. However, concerns have arisen that reservoir stimulation creates significant environmental threats through the creation of permeable pathways connecting the stimulated reservoir with shallower freshwater aquifers, thus resulting in the contamination of potable groundwater by escaping hydrocarbons or other reservoir fluids. This study investigates, by numerical simulation, gas and water transport between a shallow tight-gas reservoir and a shallower overlying freshwater aquifer following hydraulic fracturing operations, if such a connecting pathway has been created. We focus on two general failure scenarios: (1) communication between the reservoir and aquifer via a connecting fracture or fault and (2) communication via a deteriorated, preexisting nearby well. We conclude that the key factors driving short-term transport of gas include high permeability for the connecting pathway and the overall volume of the connecting feature. Production from the reservoir is likely to mitigate release through reduction of available free gas and lowering of reservoir pressure, and not producing may increase the potential for release. We also find that hydrostatic tight-gas reservoirs are unlikely to act as a continuing source of migrating gas, as gas contained within the newly formed hydraulic fracture is the primary source for potential contamination. Such incidents of gas escape are likely to be limited in duration and scope for hydrostatic reservoirs. Reliable field and laboratory data must be acquired to constrain the factors and determine the likelihood of these outcomes.

April 17, 2015. [*Categories:* Community; Health]

Spatial distribution of unconventional gas wells and human populations in the Marcellus Shale in the United States: Vulnerability analysis.

- Ogneva-Himmelberger, Yelena; Huang, Liyao.
- In: *Applied Geography*, Vol. 60, pages 165-174, June 2015.
- http://www.sciencedirect.com/science/article/pii/S0143622815000776

Abstract: Modern forms of drilling and extraction have recently led to a boom in oil and gas production in the U.S. and stimulated a controversy around its economic benefits and environmental and human health impacts. Using an environmental justice paradigm this study applies Geographic Information Systems (GIS) and spatial analysis to determine whether certain vulnerable human populations are unequally exposed to pollution from unconventional gas wells in Pennsylvania, West Virginia, and Ohio. Several GIS-based approaches were used to identify exposed areas, and a t-test was used to find statistically significant differences between rural populations living close to wells and rural populations living farther away. Sociodemographic indicators include age (children and the elderly), poverty level, education level, and race at the census tract level. Local Indicators of Spatial Autocorrelation (LISA) technique was applied to find spatial clusters where both high well density and high proportions of vulnerable populations occur. The results demonstrate that the environmental injustice occurs in areas with unconventional wells in Pennsylvania with respect to the poor population. There are also localized clusters of vulnerable populations in exposed areas in all three states: Pennsylvania (for poverty and elderly population), West Virginia (for poverty, elderly population, and education level) and Ohio (for children).

April 16, 2015. [*Category:* Water Usage]

Impact of Shale Gas Development on Water Resources: a Case Study in Northern Poland.

- Vandecasteele, Ine; Marí Rivero, Inés; Sala, Serenella; Baranzelli, Claudia; Barranco, Ricardo; Batelaan, Okke; Lavalle, Carlo.
- In: *Environmental Management*, Vol. 55, Issue 6, pages 1285-1299.
- http://link.springer.com/article/10.1007%2Fs00267-015-0454-8

Abstract: Shale gas is currently being explored in Europe as an alternative energy source to conventional oil and gas. There is, however, increasing concern about the potential environmental impacts of shale gas extraction by hydraulic fracturing (fracking). In this study, we focussed on the potential impacts on regional water resources within the Baltic Basin in Poland, both in terms of quantity and quality. The future development of the shale play was modeled for the time period 2015–2030 using the LUISA modeling framework. We formulated two scenarios which took into account the large range in technology and resource requirements, as well as two additional scenarios based on the current legislation and the potential restrictions which could be put in place. According to these scenarios, between 0.03 and 0.86 % of the total water withdrawals for all sectors could be attributed to shale gas exploitation within the study area. A screening-level assessment of the potential impact of the chemicals commonly used in fracking was carried out and showed that due to their wide range of physicochemical properties, these chemicals may pose additional pressure on freshwater ecosystems. The legislation put in place also influenced the resulting environmental impacts of shale gas extraction. Especially important are the protection of vulnerable ground and surface water resources and the promotion of more water-efficient technologies.

April 14, 2015. [*Category:* Water Quality]

A review of water and greenhouse gas impacts of unconventional natural gas development in the United States.

- Arent, Douglas; Logan, Jeffrey; Macknick, Jordan; Boyd, William; Medlock, Kenneth III; O'Sullivan, Francis; Edmonds, Jae; Clarke, Leon; Huntington, Hillard; Heath, Garvin; Statwick, Patricia; Bazilian, Morgan.
- In: *MRS Energy & Sustainability* - A Review Journal, 21 pages.
- http://journals.cambridge.org/download.php?file=%2FMRE%2FMRE2%2FS2329222915000057a.pdf&code=d9728d1afb106f97417e3dfa463249ff

Abstract: This paper reviews recent developments in the production and use of unconventional natural gas in the United States with a focus on water and greenhouse gas emission implications. If unconventional natural gas in the U.S. is produced responsibly, transported and distributed with little leakage, and incorporated into integrated energy systems that are designed for future resiliency, it could play a significant role in realizing a more sustainable energy future; however, the increased use of natural gas as a substitute for more carbon intensive fuels will alone not substantially alter world carbon dioxide concentration projections. This paper reviews recent developments in the production and use of unconventional natural gas in the United States with a focus on environmental impacts. Specifically, we focus on water management and greenhouse gas emission implications. If unconventional natural gas in the United States is produced responsibly, transported and distributed with little leakage, and incorporated into integrated energy systems that are designed for future resiliency, it could play a significant role in realizing a more sustainable energy future. The cutting-edge of industry water management practices gives a picture of how this transition is unfolding, although much opportunity remains to minimize water use and related environmental impacts. The role of natural gas to mitigate climate forcing is less clear. While natural gas has low CO2 emissions upon direct use, methane leakage and long term climate effects lead to the conclusion that increased use of natural gas as a substitute for more carbon intensive fuels will not substantially alter world carbon dioxide concentration projections, and that other zero or low carbon energy sources will be needed to limit GHG concentrations. We conclude with some possible avenues for further work.

April 13, 2015. [*Category:* Waste / Fluids]

Microbial Mats as a Biological Treatment Approach for Saline Wastewaters: The Case of Produced Water from Hydraulic Fracturing.

- Akyon, Benay; Stachler, Elyse; Wei, Na; Bibby, Kyle.
- In: *Environmental Science & Technology*, Vol. 49, Issue 10, pages 6172-6180.
- http://pubs.acs.org/doi/abs/10.1021/es505142t

Abstract: Treatment of produced water, i.e. wastewater from hydraulic fracturing, for reuse or final disposal is challenged by both high salinity and the presence of organic compounds. Organic compounds in produced water may foul physical-chemical treatment processes or support microbial corrosion, fouling, and sulfide release. Biological approaches have potential applications in produced water treatment, including reducing fouling of physical-chemical treatment processes and decreasing biological activity during produced water holding; however, conventional activated sludge treatments are intolerant of high salinity. In this study, a biofilm treatment approach using constructed microbial mats was evaluated for biodegradation performance, microbial community structure, and metabolic potential in both simulated and real produced water. Results demonstrated that engineered microbial mats are active at total dissolved solids (TDS) concentrations up to at least 100,000 mg/L, and experiments in real produced water showed a biodegradation capacity of 1.45 mg COD/gram$_{wet}$-day at a TDS concentration of 91,351 mg/L. Additionally, microbial community and metagenomic analyses revealed an adaptive microbial community that shifted based upon the sample being treated and has the metabolic potential to degrade a wide array of contaminants, suggesting the potential of this approach to treat produced waters with varying composition.

April 11, 2015. [*Categories:* Waste / Fluids; Water Quality]

Application of ICP-OES for evaluating energy extraction and production wastewater discharge impacts on surface waters in Western Pennsylvania.

- Pancras, Joseph Patrick; Norris, Gary A.; Landis, Matthew S.; Kovalcik, Kasey D.; McGee, John K.; Kamal, Ali S.
- In: *Science of the Total Environment*, Vol. 529, October 1, 2015, pages 21-29.
- http://www.sciencedirect.com/science/article/pii/S0048969715004477

Abstract: Oil and gas extraction and coal-fired electrical power generating stations produce wastewaters that are treated and discharged to rivers in Western Pennsylvania with public drinking water system (PDWS) intakes. Inductively coupled plasma optical emission spectroscopy (ICP-OES) was used to quantify inorganic species in wastewater and river samples using a method based on EPA Method 200.7 rev4.4. A total of 53 emission lines from 30 elements (Al, As, B, Ba, Ca, Cd, Ce, Co, Cr, Cu, Fe, K, Li, Mg, Mn, Mo, Na, Ni, P, Pb, S, Sb, Se, Si, Sn, Sr, Ti, Tl, V, and Zn) were investigated. Samples were prepared by microwave-assisted acid digestion using a mixture of 2% HNO_3 and 0.5% HCl. Lower interferences and better detection characteristics resulted in selection of alternative wavelengths for Al, As, Sb, Mg, Mo, and Na. Radial view measurements offered accurate determinations of Al, Ba, K, Li, Na, and Sr in high-brine samples. Spike recovery studies and analyses of reference materials showed 80–105% recoveries for most analytes. This method was used to quantify species in samples with high to low brine concentrations with method detection limits a factor of 2 below the maximum contaminant limit concentrations of national drinking water standards. Elements B, Ca, K, Li, Mg, Na, and Sr were identified as potential tracers for the sources impacting PDWS intakes. Usability of the ICP-OES derived data for factor analytic model applications was also demonstrated.

April 9, 2015. [*Categories:* Air Quality; Health]

Impact of natural gas extraction on PAH levels in ambient air.

- Paulik, L. Blair; Donald, Carey E.; Smith, Brian W.; Tidwell, Lane Gray; Hobbie, Kevin Andrew; Kincl, Laurel; Haynes, Erin N.; Anderson, Kim A.
- In: *Environmental Science & Technology*, Vol. 49, Issue 8, pages 5203-5210.
- http://pubs.acs.org/doi/abs/10.1021/es506095e?journalCode=esthag

Abstract: Natural gas extraction, often referred to as "fracking," has increased rapidly in the U.S. in recent years. To address potential health impacts, passive air samplers were deployed in a rural community heavily affected by the natural gas boom. Samplers were analyzed for 62 polycyclic aromatic hydrocarbons (PAHs). Results were grouped based on distance from each sampler to the nearest active well. PAH levels were highest when samplers were closest to active wells. Additionally, PAH levels closest to natural gas activity were an order of magnitude higher than levels previously reported in rural areas. Sourcing ratios indicate that PAHs were predominantly petrogenic, suggesting that elevated PAH levels were influenced by direct releases from the earth. Quantitative human health risk assessment estimated the excess lifetime cancer risks associated with exposure to the measured PAHs. Closest to active wells, the risk estimated for maximum residential exposure was 2.9 in 10 000, which is above the U.S. EPA's acceptable risk level. Overall, risk estimates decreased 30% when comparing results from samplers closest to active wells to those farthest. This work suggests that natural gas extraction may be contributing significantly to PAHs in air, at levels that are relevant to human health.

April 9, 2015. [*Category:* Health]

Predictors of Indoor Radon Concentrations in Pennsylvania, 1989–2013.

- Casey, Joan A.; Ogburn, Elizabeth L.; Rasmussen, Sara G.; Irving, Jennifer K.; Pollak, Jonathan; Locke, Paul A.; Schwartz, Brian S.
- In: *Environmental Health Perspectives* (ahead of print).
- http://ehp.niehs.nih.gov/1409014/#tab2

Abstract:

Background: Radon is the second-leading cause of lung cancer worldwide. Most indoor exposure occurs by diffusion of soil gas. Radon is also found in well water, natural gas and ambient air. Pennsylvania has high indoor radon concentrations; buildings are often tested during real estate transactions with results reported to the Department of Environmental Protection (PADEP).

Objectives: To evaluate predictors of indoor radon concentrations.

Methods: Using first floor and basement indoor radon results reported to the PADEP between 1987-2013, we evaluated associations of radon concentrations (*ln*-transformed) with geology, water source, building characteristics, season, weather, community socioeconomic status, community type and unconventional natural gas development measures based on drilled and producing wells.

Results: Primary analysis included 866,735 first measurements by building, the large majority from homes. The geologic rock layer on which the building sat was strongly associated with radon concentration (e.g., Axemann Formation, median = 365 Bq/m^3, IQR = 167-679 vs. Stockton Formation, median = 93 Bq/m^3, IQR = 52-178). In adjusted analysis, buildings using well water had 21% higher concentrations ($\beta = 0.191$, 95% CI: 0.184, 0.198). Buildings in cities (vs. townships) had lower concentrations ($\beta = -0.323$, 95% CI: -0.333, -0.314). When we included multiple tests per building, concentrations declined with repeated measurements over time. Between 2005-2013, 7469 unconventional wells were drilled in Pennsylvania. Basement radon concentrations fluctuated between 1987-2003, but began an upward trend from 2004-2012 in all county categories ($p < 0.001$), higher levels in counties with ≥100 drilled wells vs. counties with none, and with highest levels in the Reading Prong.

Conclusions: Geologic unit, well water, community, weather and unconventional natural gas development were associated with indoor radon concentrations. Future studies should include direct environmental measurement of radon, and building features unavailable for this analysis.

April 2, 2015. [*Category:* Waste / Fluids]

Understanding the Radioactive Ingrowth and Decay of Naturally Occurring Radioactive Materials in the Environment: An Analysis of Produced Fluids from the Marcellus Shale.

- Nelson, Andrew W.; Eitrheim, Eric S.; Knight, Andrew W.; May, Dustin; Mehrhoff, Marinea A.; Shannon, Robert; Litman, Robert; Burnett, William C.; Forbes, Tori Z.; Schultz, Michael K.
- In: *Environmental Health Perspectives* (ahead of print).
- http://ehp.niehs.nih.gov/1408855/#tab2

Abstract:

Background: The economic value of unconventional natural gas resources has stimulated rapid globalization of horizontal drilling and hydraulic fracturing. However, natural radioactivity found in the large volumes of “produced fluids” generated by these technologies is emerging as an international environmental health concern. Current assessments of the radioactivity concentration in liquid wastes focus on a single element – radium. However, the use of radium alone to predict radioactivity concentrations can greatly underestimate total levels.

Objective: We investigated the contribution to radioactivity concentrations from naturally occurring radioactive materials (NORM), including uranium, thorium, actinium, radium, lead, bismuth, and polonium isotopes to the total radioactivity of hydraulic fracturing wastes.

Methods: For this study we used established methods and developed new methods designed to quantitate NORM of public health concern that may be enriched in complex brines from hydraulic fracturing wastes. Specifically, we demonstrate the use of high purity germanium gamma spectrometry and isotope dilution alpha spectrometry to quantitate NORM.

Results: We observed that radium decay products are initially absent from produced fluids due to differences in solubility. However, in systems closed to the release of gaseous radon, our model predicts that decay products will begin to ingrow immediately and (under these closed-system conditions) can contribute to an increase in the total radioactivity for over 100 years.

Conclusions: Accurate predictions of radioactivity concentrations are critical for estimating doses to potentially exposed individuals and the surrounding environment. These predictions must include an understanding of the geochemistry, decay properties, and ingrowth kinetics of radium and its decay product radionuclides.

April 1, 2015. [*Category:* Seismicity]

Ground Motions from Three Recent Earthquakes in Western Alberta and Northeastern British Columbia and Their Implications for Induced-Seismicity Hazard in Eastern Regions.

- Atkinson, Gail; Assatourians, Karen; Cheadle, Burns; Greig, Wes.
- In: *Seismological Research Letters*, Vol. 86, Issue 3, pages 1022-1031.
- http://srl.geoscienceworld.org/content/early/2015/03/30/0220140195.abstract

Abstract: A key issue in the assessment of hazard due to induced seismicity from fluid injection activity is to determine the potential ground motions. Although wastewater disposal typically receives the most attention, hydraulic fracturing is increasingly recognized as a significant source of seismic hazard. We present an analysis of the ground motions from the three largest events of 2014 that occurred along the deformation front marking the western boundary of the stable Canadian craton: an **M** 4.0 and an **M** 4.2 near Fort St. John (FSJ), British Columbia, and an **M** 3.9 near Rocky Mountain House (RMH), Alberta. The two FSJ events were likely induced by hydraulic fracturing activities in the region. Although the cause of the RMH event remains unclear, it is of interest because it is of similar magnitude to the other events and had significant consequences to the public. The event triggered an automatic shutdown of a nearby gas plant and a subsequent precautionary flaring of gas, and several hundred people were without power for a prolonged period. We examine the ground motions and intensities for these events. We find that ground motions at frequencies up to about 2 Hz are in agreement with corresponding observations for similar-sized events in California and with the predictions of applicable empirical ground-motion prediction equations. However, high-frequency ground motions appear to be lower than those predicted, suggesting that these events may be associated with a low stress drop; we believe that this is likely a focal depth effect, which may be a mitigating factor that limits high-frequency ground motions from induced events.

Our preliminary findings suggest that moderate-induced events (**M** 4–5) may be damaging to nearby infrastructure, because the shallow focal depth may result in localized strong ground motions to which some infrastructure may be vulnerable; this is a particular concern in low-to-moderate seismicity regions, because seismic design measures for structures in these regions may be minimal. Our results highlight the importance of seismic monitoring in the immediate vicinity of fluid injection sites (both wastewater disposal and hydraulic fracturing) to accurately characterize injection-induced seismicity and ultimately mitigate the associated risk.

March 31, 2015. [*Category:* Climate]

Direct Measurements Show Decreasing Methane Emissions from Natural Gas Local Distribution Systems in the United States.

- Lamb, Brian K.; Edburg, Steven L.; Ferrara, Thomas W.; Howard, Touché; Harrison, Matthew R.; Kolb, Charles E.; Townsend-Small, Amy; Dyck, Wesley; Possolo, Antonio; Whetstone, James R.
- In: *Environmental Science & Technology*, Vol. 49, Issue 8, pages 5161-5169.
- http://pubs.acs.org/doi/abs/10.1021/es505116p

Abstract: Fugitive losses from natural gas distribution systems are a significant source of anthropogenic methane. Here, we report on a national sampling program to measure methane emissions from 13 urban distribution systems across the U.S. Emission factors were derived from direct measurements at 230 underground pipeline leaks and 229 metering and regulating facilities using stratified random sampling. When these new emission factors are combined with estimates for customer meters, maintenance, and upsets, and current pipeline miles and numbers of facilities, the total estimate is 393 Gg/yr with a 95% upper confidence limit of 854 Gg/yr (0.10% to 0.22% of the methane delivered nationwide). This fraction includes emissions from city gates to the customer meter, but does not include other urban sources or those downstream of customer meters. The upper confidence limit accounts for the skewed distribution of measurements, where a few large emitters accounted for most of the emissions. This emission estimate is 36% to 70% less than the 2011 EPA inventory, (based largely on 1990s emission data), and reflects significant upgrades at metering and regulating stations, improvements in leak detection and maintenance activities, as well as potential effects from differences in methodologies between the two studies.

March 27, 2015. [*Category:* Water Usage]

Evolving water management practices in shale oil & gas development.

- Rodriguez, Rebecca S.; Soeder, Daniel J.
- In: *Journal of Unconventional Oil and Gas Resources*, Vol. 10, pages 18-24, June 2015.
- http://www.sciencedirect.com/science/article/pii/S2213397615000105

Abstract: Advances in horizontal drilling coupled with hydraulic fracturing have unlocked trillions of cubic feet (billions of cubic meters) of natural gas and billions of barrels (millions of cubic meters) of petroleum in shale plays across the United States. There are over 72,000 unconventional well sites in the United States, with anywhere from 2 to 13 million gallons (7500–49,000 cubic meters) of water used per unconventional well. While unconventional wells produce approximately 35% less waste water per unit of gas than conventional wells, the sheer number of wells and amount of oil and gas being produced means that water use has increased by as much as 500% in some areas. Such large water demands give rise to questions about water management, including acquisition, transportation, storage, treatment, and disposal. While these issues vary by play, some key concerns include competition for drinking water sources, impacts of fresh and wastewater transportation, the extent of wastewater recycling, contamination, and the effects of various treatment and disposal methods on communities and watersheds. These concerns have not been fully resolved, yet there is a noticeable, and largely quantifiable, evolution of management practices toward operating more sustainably and with smaller regional impacts. Here we explore water management issues as they arise throughout the unconventional drilling process, particularly focusing on how practices have changed since the beginning of the shale boom and how these issues vary by play.

March 26, 2015. [*Category:* Air Quality]

Regional air quality impacts of hydraulic fracturing and shale natural gas activity: Evidence from ambient VOC observations.

- Vinciguerra, Timothy; Yao, Simon; Dadzie, Joseph; Chittams, Alexa; Deskins, Thomas; Ehrman, Sheryl; Dickerson, Russell R.
- In: *Atmospheric Environment*, Vol. 110, pages 144-150.
- http://www.sciencedirect.com/science/article/pii/S1352231015002800

Abstract: Over the past decade, concentrations of many anthropogenic pollutants have been successfully reduced, improving air quality. However, a new influx of emissions associated with hydraulic fracturing and shale natural gas operations could be counteracting some of these benefits. Using hourly measurements from Photochemical Assessment Monitoring Stations (PAMS) in the Baltimore, MD and Washington, DC areas, we observed that following a period of decline, daytime ethane concentrations have increased significantly since 2010, growing from ∼7% of total measured nonmethane organic carbon to ∼15% in 2013. This trend appears to be linked with the rapidly increasing natural gas production in upwind, neighboring states, especially Pennsylvania and West Virginia. Ethane concentrations failed to display this trend at a PAMS site outside of Atlanta, GA, a region without new widespread natural gas operations.

March 25, 2015. [*Category:* Climate]

Measuring emissions from oil and natural gas well pads using the mobile flux plane technique.

- Rella, Chris W.; Tsai, Tracy R.; Botkin, Connor G.; Crosson, Eric R.; Steele, David.
- In: *Environmental Science & Technology*, Vol. 49, Issue 7, pages 4742-4748.
- http://www.ncbi.nlm.nih.gov/pubmed/25806837

Abstract: We present a study of methane emissions from oil and gas producing well pad facilities in the Barnett Shale region of Texas, measured using an innovative ground-based mobile flux plane (MFP) measurement system, as part of the Barnett Coordinated Campaign.1 Using only public roads, we measured the emissions from nearly 200 well pads over 2 weeks in October 2013. The population of measured well pads is split into well pads with detectable emissions (N = 115) and those with emissions below the detection limit of the MFP instrument (N = 67). For those well pads with nonzero emissions, the distribution was highly skewed, with a geometric mean of 0.63 kg/h, a geometric standard deviation of 4.2, and an arithmetic mean of 1.72 kg/h. Including the population of nonemitting well pads, we find that the arithmetic mean of the well pads sampled in this study is 1.1 kg/h. This distribution implies that 50% of the emissions is due to the 6.6% highest emitting well pads, and 80% of the emissions is from the 22% highest emitting well pads.

March 24, 2015. [*Category:* Climate]

Sensor transition failure in the high flow sampler: Implications for methane emission inventories of natural gas infrastructure.

- Howard, Touché; Ferrara, Thomas W.; Townsend-Small, Amy.
- In: *Journal of the Air & Waste Management Association*.
- http://dx.doi.org/10.1080/10962247.2015.1025925

Abstract: Quantification of leaks from natural gas (NG) infrastructure is a key step in reducing emissions of the greenhouse gas methane (CH_4), particularly as NG becomes a larger component of domestic energy supply. The United States Environmental Protection Agency (USEPA) requires measurement and reporting of emissions of CH_4 from NG transmission, storage, and processing facilities, and the high flow sampler (or high volume sampler) is one of the tools approved for this by the USEPA. The Bacharach Hi-Flow® Sampler (BHFS) is the only commercially available high flow instrument, and it is also used throughout the NG supply chain for directed inspection and maintenance, emission factor development, and greenhouse gas reduction programs. Here we document failure of the BHFS to transition from a catalytic oxidation sensor used to measure low NG (~5% or less) concentrations to a thermal conductivity sensor for higher concentrations (from ~5% to 100%), resulting in underestimation of NG emission rates. Our analysis includes both our own field testing as well as analysis of data from two other studies (Modrak et al., 2012; City of Ft Worth, 2011). Although this failure is not completely understood, and although we do not know if all BHFS models are similarly affected, sensor transition failure has been observed under one or more of these conditions: 1), calibration is more than ~2 weeks old; 2), firmware is out of date; or 3), the composition of the NG source is less than ~91% CH_4. The extent to which this issue has affected recent emission studies is uncertain, but the analysis presented here suggests that the problem could be widespread. Furthermore, it is critical that this problem be resolved before the onset of regulations on CH_4 emissions from the oil and gas industry, as the BHFS is a popular instrument for these measurements.

Implications

An instrument commonly used to measure leaks in natural gas infrastructure has a critical sensor transition failure issue that results in underestimation of leaks, with implications for greenhouse gas emissions estimates as well as safety.

March 20, 2015. [*Category:* Water Quality]

Establishing baseline water quality for household wells within the Marcellus Shale gas region, Susquehanna County, Pennsylvania, U.S.A.

- Rhodes, Amy L.; Horton, Nicholas J.
- In: *Applied Geochemistry* (ahead of print).
- http://www.sciencedirect.com/science/article/pii/S0883292715000621

Abstract: Flowback fluids associated with hydraulic fracturing shale gas extraction are a potential source of contamination for shallow aquifers. In the Marcellus Shale region of northeastern Pennsylvania, certified water tests have been used to establish baseline water chemistry of private drinking water wells. This study investigates whether a single, certified multiparameter water test is sufficient for establishing baseline water chemistry from which possible future contamination by flowback waters could be reliably recognized. We analyzed the water chemistry (major and minor inorganic elements and stable isotopic composition) of multiple samples collected from lake, spring, and well water from 35 houses around Fiddle Lake, Susquehanna County, PA that were collected over approximately a two-year period. Statistical models estimated variance of results within and between households and tested for significant differences between means of our repeated measurements and prior certified water tests.

Overall, groundwater chemistry varies more spatially due to heterogeneity of minerals within the bedrock aquifer and due to varying inputs of road salt runoff from paved roads than it does temporally at a single location. For wells located within road salt-runoff zones, Na^+ and Cl^- concentrations, although elevated, are generally consistent through repeated measurements. High acid neutralizing capacity (ANC) and base cation concentrations in well water sourced from mineral weathering reactions, and a uniform stable isotopic composition for well water, suggests long flowpaths for groundwater that dampen seasonal variability of most elements. Exceptions occur for two wells within road salt runoff zones that show the greatest range of concentrations for Na^+ and Cl^-, suggesting that these wells have a faster pathway to surficial recharge. Additionally, sampling protocols can induce variability for Fe, Mn, and Pb, making other elements identified in flowback fluids (Ba, Br, Ca, Cl, Mg, Na, Sr) more dependable indicators of contamination. Although there is general concordance between our repeated measurements and the certified test results, characterizing baseline chemistry is strengthened when results from multiple households are combined to establish regional upper baseline limits that will have a low probability of being exceeded by future samples unless conditions have changed.

March 18, 2015. [*Category:* Seismicity]

Impact of Induced Seismicity on the Evaluation of Seismic Hazard: Some Preliminary Considerations.

- Atkinson, Gail M.; Ghofrani, Hadi; Assatourians, Karen.
- In: *Seismological Research Letters*, Vol. 86, Issue 3, pages 1009-1021.
- http://srl.geoscienceworld.org/content/early/2015/03/17/0220140204

Abstract: A case study of seismicity induced by hydraulic fracturing operations near Fox Creek, Alberta, is used to evaluate the extent to which the potential for induced seismicity at a site alters the pre-existing hazard from natural seismicity. We find that in low-to-moderate seismicity environments, the hazard from an induced-seismicity source, if one is activated in close proximity to a site, can greatly exceed the hazard from natural background seismicity at most probabilities of engineering interest, over a wide frequency range. The most important parameters in determining the induced-seismicity hazard are the activation probability and the *b*-value of the initiated sequence. Uncertainty in the value of the key input parameters to a hazard analysis implies large uncertainty (more than an order of magnitude) in the likelihood of strong shaking.

March 18, 2015. [*Category:* Water Quality]

Stream measurements locate thermogenic methane fluxes in discharging groundwater.

- Heilweil, Victor Michael; Grieve, Paul L.; Hynek, Scott A.; Brantley, Susan L.; Salomon, D. Kip; Risser, Dennis W.
- In: *Environmental Science & Technology*, Vol. 49, Issue 7, pages 4057-4065.
- http://pubs.acs.org/doi/abs/10.1021/es503882b

Abstract: The environmental impacts of shale-gas development on water resources, including methane migration to shallow groundwater, have been difficult to assess. Monitoring around gas wells is generally limited to domestic water-supply wells, which often are not situated along predominant groundwater flow paths. A new concept is tested here: combining stream hydrocarbon and noble-gas measurements with reach mass-balance modeling to estimate thermogenic methane concentrations and fluxes in groundwater discharging to streams and to constrain methane sources. In the Marcellus Formation shale-gas play of northern Pennsylvania (U.S.A.), we sampled methane in 15 streams as a reconnaissance tool to locate methane-laden groundwater discharge: concentrations up to 69 $\mu g\ L^{-1}$ were observed, with four streams $\geq 5\ \mu g\ L^{-1}$. Geochemical analyses of water from one stream with high methane (Sugar Run, Lycoming County) were consistent with Middle Devonian gases. After sampling was completed, we learned of a state regulator investigation of stray-gas migration from a nearby Marcellus Formation gas well. Modeling indicates a groundwater thermogenic methane flux of about 0.5 kg d^{-1} discharging into Sugar Run, possibly from this fugitive gas source. Since flow paths often coalesce into gaining streams, stream methane monitoring provides the first watershed-scale method to assess groundwater contamination from shale-gas development.

March 13, 2015. [*Category:* Water Quality]

Effective Permeabilities of Abandoned Oil and Gas Wells: Analysis of Data from Pennsylvania.

- Kang, Mary; Baik, Ejeong; Miller, Alana R.; Bandilla, Karl W.; Celia, Michael K.
- In: *Environmental Science & Technology*, Vol. 49, Issue 7, pages 4757-4764.
- http://pubs.acs.org/doi/abs/10.1021/acs.est.5b00132

Abstract: Abandoned oil and gas (AOG) wells can provide pathways for subsurface fluid migration, which can lead to groundwater contamination and gas emissions to the atmosphere. Little is known about the millions of AOG wells in the U.S. and abroad. Recently, we acquired data on methane emissions from 42 plugged and unplugged AOG wells in five different counties across western Pennsylvania. We used historical documents to estimate well depths and used these depths with the emissions data to estimate the wells' effective permeabilities, which capture the combined effects of all leakage pathways within and around the wellbores. We find effective permeabilities to range from 10^{-6} to 10^{2} millidarcies, which are within the range of previous estimates. The effective permeability data presented here provide perspective on older AOG wells and are valuable when considering the leakage potential of AOG wells in a wide range of applications, including geologic storage of carbon dioxide, natural gas storage, and oil and gas development.

March 12, 2015. [Category: Water Quality]

Methane Concentrations in Water Wells Unrelated to Proximity to Existing Oil and Gas Wells in Northeastern Pennsylvania.

- Siegel, Donald I.; Azzolina, Nicholas A.; Smith, Bert J.; Perry, A. Elizabeth; Bothun, Rikka L.
- In: *Environmental Science & Technology*, Vol. 49, Issue 7, pages 4106-4112.
- http://pubs.acs.org/doi/abs/10.1021/es505775c

Abstract: Recent studies in northeastern Pennsylvania report higher concentrations of dissolved methane in domestic water wells associated with proximity to nearby gas-producing wells [Osborn et al. *Proc. Natl. Acad. Sci. U. S. A.* 2011, *108*, 8172] and [Jackson et al. *Proc. Natl. Acad. Sci. U. S. A.*, 2013, *110*, 11250]. We test this possible association by using Chesapeake Energy's baseline data set of over 11,300 dissolved methane analyses from domestic water wells, densely arrayed in Bradford and nearby counties (Pennsylvania), and near 661 pre-existing oil and gas wells. The majority of these, 92%, were unconventional wells, drilled with horizontal legs and hydraulically fractured. Our data set is hundreds of times larger than data sets used in prior studies. In contrast to prior findings, we found no statistically significant relationship between dissolved methane concentrations in groundwater from domestic water wells and proximity to pre-existing oil or gas wells. Previous analyses used small sample sets compared to the population of domestic wells available, which may explain the difference in prior findings compared to ours.

March 10, 2015. [*Categories:* Regulation; Water Quality]

Shale gas operator violations in the Marcellus and what they tell us about water resource risks.

- Rahm, Brian G.; Vedachalam, Sridhar; Bertoia, Lara R.; Mehta, Dhaval; Vanka, Veeravenkata Sandeep; Riha, Susan J.
- In: *Energy Policy*, Vol. 82, pages 1-11, July 2015.
- http://www.sciencedirect.com/science/article/pii/S0301421515001068

Abstract: Development of shale gas entails environmental risk, particularly with respect to water resources, and stakeholders are keen to assess such risks before making development decisions. We focus on Pennsylvania, USA and the Marcellus Shale, the most productive shale play in the country. We examine compliance data recorded by the state regulatory agency in order to assess environmental risks and their trends and drivers over time. Overall, we track 3267 shale gas violations, noting that environmental violation rates increase from 2007 to 2009, remain high through 2010, and then drop in 2011 and thereafter. Violations related to spills and erosion were most commonly issued. A single change in policy resulted in a 45% decrease in environmental violation rates. Furthermore, for every 1% increase in wells drilled per inspections conducted, there was a 0.56% decrease in environmental violation rates. Similar effects were not found for administrative violations. Operator identity, price of gas, and other major policies were not significantly correlated with violation rates. In comparing conventional and shale gas extraction compliance we found that shale gas development entails more risk related to spills and solid waste management, while conventional development entails more risk associated with cementing and casing issues, and site restoration.

March 9, 2015. [*Category:* General (Comment/Review)]

Ripple Effects of the Shale Gas Boom in the U.S.: Shift in the Balance of Energy Resources, Technology Deployment, Climate Policies, Energy Markets, Geopolitics and Policy Development.

- Haddadian, Ghazale; Shahidehpour, Mohammad.
- In: *The Electricity Journal*, Vol. 28, Issue 2, pages 17-38.
- http://www.sciencedirect.com/science/article/pii/S1040619015000275

Abstract: Huge quantities of unconventional U.S. shale gas augur nothing less than a shift in the global order. An appraisal of global energy trends suggests that the U.S., at the cusp of attaining energy self-sufficiency, should lean more toward a strategy of maintaining energy stability than wielding its new clout in the service of broader geopolitical or economic objectives.

March 9, 2015. [*Category:* Water Quality]

Methane Baseline Concentrations and Sources in Shallow Aquifers from the Shale Gas-Prone Region of the St. Lawrence Lowlands (Quebec, Canada).

- Moritz, Anja; Helie, Jean-Francois; Pinti, Daniele; Larocque, Marie; Barnatche, Diogo; Retailleau, Sophie; Lefebvre, René; Gelinas, Yves.
- In: *Environmental Science & Technology*, Vol. 49, Issue 7, pages 4765-4771.
- http://pubs.acs.org/doi/abs/10.1021/acs.est.5b00443?journalCode=esthag

Abstract: Hydraulic fracturing is becoming an important technique worldwide to recover hydrocarbons from unconventional sources such as shale gas. In Quebec (Canada), the Utica Shale has been identified as having unconventional gas production potential. However, there has been a moratorium on shale gas exploration since 2010. The work reported here was aimed at defining baseline concentrations of methane in shallow aquifers of the St. Lawrence Lowlands and its sources using $\delta^{13}C$ methane signatures. Since this study was performed prior to large-scale fracturing activities, it provides background data prior to the eventual exploitation of shale gas through hydraulic fracturing. Groundwater was sampled from private (n = 81), municipal (n = 34), and observation (n = 15) wells between August 2012 and May 2013. Methane was detected in 80% of the wells with an average concentration of 3.8 ± 8.8 mg/L, and a range of <0.0006 to 45.9 mg/L. Methane concentrations were linked to groundwater chemistry and distance to the major faults in the studied area. The methane $\delta^{13}C$ signature of 19 samples was > −50‰, indicating a potential thermogenic source. Localized areas of high methane concentrations from predominantly biogenic sources were found throughout the study area. In several samples, mixing, migration, and oxidation processes likely affected the chemical and isotopic composition of the gases, making it difficult to pinpoint their origin. Energy companies should respect a safe distance from major natural faults in the bedrock when planning the localization of hydraulic fracturation activities to minimize the risk of contaminating the surrounding groundwater since natural faults are likely to be a preferential migration pathway for methane.

March 9, 2015. [*Category:* Climate]

Mobile Laboratory Observations of Methane Emissions in the Barnett Shale Region.

- Yacovitch, Tara I.; Herndon, Scott C.; Pétron, Gabrielle; Kofler, Jonathan; Lyon, David; Zahniser, Mark S.; Kolb, Charles E.
- In: *Environmental Science & Technology*.
- http://pubs.acs.org/doi/abs/10.1021/es506352j

Abstract: Results of mobile ground-based atmospheric measurements conducted during the Barnett Shale Coordinated Campaign in spring and fall of 2013 are presented. Methane and ethane are continuously measured downwind of facilities such as natural gas processing plants, compressor stations, and production well pads. Gaussian dispersion simulations of these methane plumes, using an iterative forward plume dispersion algorithm, are used to estimate both the source location and the emission magnitude. The distribution of emitters is peaked in the 0-5 kg/h range, with a significant tail. The ethane/methane molar enhancement ratio for this same distribution is investigated, showing a peak at ∼1.5% and a broad distribution between ∼4% and ∼17%. The regional distributions of source emissions and ethane/methane enhancement ratios are examined: the largest methane emissions appear between Fort Worth and Dallas, while the highest ethane/methane enhancement ratios occur for plumes observed in the northwestern potion of the region. Individual facilities, focusing on large emitters, are further analyzed by constraining the source location.

March 3, 2015. [*Category:* Water Quality]

Well water contamination in a rural community in southwestern Pennsylvania near unconventional shale gas extraction.

- Alawattegama, Shyama K.; Kondratyuk, Tetiana; Krynock, Renee; Bricker, Matthew; Rutter, Jennifer K.; Bain, Daniel J.; Stolz, John F.
- In: *Journal of Environmental Science and Health*, *Part A*, Vol. 50, Issue 5, pages 516-518.
- http://www.tandfonline.com/toc/lesa20/current#/doi/full/10.1080/10934529.2015.992684#abstract

Abstract: Reports of ground water contamination in a southwestern Pennsylvania community coincided with unconventional shale gas extraction activities that started late 2009. Residents participated in a survey and well water samples were collected and analyzed. Available pre-drill and post-drill water test results and legacy operations (e.g., gas and oil wells, coal mining) were reviewed. Fifty-six of the 143 respondents indicated changes in water quality or quantity while 63 respondents reported no issues. Color change (brown, black, or orange) was the most common (27 households). Well type, when known, was rotary or cable tool, and depths ranged from 19 to 274 m. Chloride, sulfate, nitrate, sodium, calcium, magnesium, iron, manganese and strontium were commonly found, with 25 households exceeding the secondary maximum contaminate level (SMCL) for manganese. Methane was detected in 14 of the 18 houses tested. The 26 wells tested for total coliforms (2 positives) and E. coli (1 positive) indicated that septic contamination was not a factor. Repeated sampling of two wells in close proximity (204 m) but drawing from different depths (32 m and 54 m), revealed temporal variability. Since 2009, 65 horizontal wells were drilled within a 4 km (2.5 mile) radius of the community, each well was stimulated on average with 3.5 million gal of fluids and 3.2 million lbs of proppant. PA DEP cited violations included an improperly plugged well and at least one failed well casing. This study underscores the need for thorough analyses of data, documentation of legacy activity, pre-drill testing, and long term monitoring.

March 3, 2015. [*Category:* Waste / Fluids]

Scintillation gamma spectrometer for analysis of hydraulic fracturing waste products.

- Ying, Leong; O'Conner, Frank; Stolz, John F.
- In: *Journal of Environmental Science and Health, Part A,* Vol. 50, Issue 5, pages 511-515.
- http://www.tandfonline.com/toc/lesa20/current#/doi/full/10.1080/10934529.2015.992682%23abstract

Abstract: Flowback and produced wastewaters from unconventional hydraulic fracturing during oil and gas explorations typically brings to the surface Naturally Occurring Radioactive Materials (NORM), predominantly radioisotopes from the U238 and Th232 decay chains. Traditionally, radiological sampling are performed by sending collected small samples for laboratory tests either by radiochemical analysis or measurements by a high-resolution High-Purity Germanium (HPGe) gamma spectrometer. One of the main isotopes of concern is Ra226 which requires an extended 21-days quantification period to allow for full secular equilibrium to be established for the alpha counting of its progeny daughter Rn222. Field trials of a sodium iodide (NaI) scintillation detector offers a more economic solution for rapid screenings of radiological samples. To achieve the quantification accuracy, this gamma spectrometer must be efficiency calibrated with known standard sources prior to field deployments to analyze the radioactivity concentrations in hydraulic fracturing waste products.

March 3, 2015. [*Category:* General (Comment / Review]

Data inconsistencies from states with unconventional oil and gas activity.

- Malone, Samantha; Kelso, Matthew; Auch, Ted; Edelstein, Karen; Ferrar, Kyle; Jalbert, Kirk.
- In: *Journal of Environmental Science and Health, Part A*, Vol. 50, Issue 5, pages 501-510.
- http://www.tandfonline.com/toc/lesa20/current#/doi/full/10.1080/10934529.2015.992678#abstract

Abstract: The quality and availability of unconventional oil and gas (O&G) data in the United States have never been compared methodically state-to-state. By conducting such an assessment, this study seeks to better understand private and publicly sourced data variability and to identify data availability gaps. We developed an exploratory data-grading tool - Data Accessibility and Usability Index (DAUI) - to guide the review of O&G data quality. Between July and October 2013, we requested, collected, and assessed 5 categories of unconventional O&G data (wells drilled, violations, production, waste, and Class II disposal wells) from 10 states with active drilling activity. We based our assessment on eight data quality parameters (accessibility, usability, point location, completeness, metadata, agency responsiveness, accuracy, and cost). Using the DAUI, two authors graded the 10 states and then averaged their scores. The average score received across all states, data categories, and parameters was 67.1 out of 100, largely insufficient for proper data transparency. By state, Pennsylvania received the highest average (= 93.5) and ranked first in all but one data category. The lowest scoring state was Texas (= 44) largely due to its policy of charging for certain data. This article discusses the various reasons for scores received, as well as methodological limitations of the assessment metrics. We argue that the significant variability of unconventional O&G data—and its availability to the public—is a barrier to regulatory and industry transparency. The lack of transparency also impacts public education and broader participation in industry governance. This study supports the need to develop a set of data best management practices (BMPs) for state regulatory agencies and the O&G industry, and suggests potential BMPs for this purpose.

March 3, 2015. [*Category:* Water Quality]

Marcellus and mercury: Assessing potential impacts of unconventional natural gas extraction on aquatic ecosystems in northwestern Pennsylvania.

- Grant, Christopher J.; Weimer, Alexander B.; Marks, Nicole K.; Perow, Elliott S.; Oster, Jacob M.; Brubaker, Kristen M.; Trexler, Ryan V.; Solomon, Caroline M.; Lamendella, Regina.
- In: *Journal of Environmental Science and Health, Part A*, Vol. 50, Issue 5, pages 482-500.
- http://www.tandfonline.com/toc/lesa20/current#/doi/full/10.1080/10934529.2015.992670#abstract

Abstract: Mercury (Hg) is a persistent element in the environment that has the ability to bioaccumulate and biomagnify up the food chain with potentially harmful effects on ecosystems and human health. Twenty-four streams remotely located in forested watersheds in northwestern PA containing naturally reproducing Salvelinus fontinalis (brook trout), were targeted to gain a better understanding of how Marcellus shale natural gas exploration may be impacting water quality, aquatic biodiversity, and Hg bioaccumulation in aquatic ecosystems. During the summer of 2012, stream water, stream bed sediments, aquatic mosses, macroinvertebrates, crayfish, brook trout, and microbial samples were collected. All streams either had experienced hydraulic fracturing (fracked, $n = 14$) or not yet experienced hydraulic fracturing (non-fracked, $n = 10$) within their watersheds at the time of sampling. Analysis of watershed characteristics (GIS) for fracked vs non-fracked sites showed no significant differences ($P > 0.05$), justifying comparisons between groups. Results showed significantly higher dissolved total mercury (FTHg) in stream water ($P = 0.007$), lower pH ($P = 0.033$), and higher dissolved organic matter ($P = 0.001$) at fracked sites. Total mercury (THg) concentrations in crayfish ($P = 0.01$), macroinvertebrates ($P = 0.089$), and predatory macroinvertebrates ($P = 0.039$) were observed to be higher for fracked sites. A number of positive correlations between amount of well pads within a watershed and THg in crayfish ($r = 0.76$, $P < 0.001$), THg in predatory macroinvertebrates ($r = 0.71$, $P < 0.001$), and THg in brook trout ($r = 0.52$, $P < 0.01$) were observed. Stream-water microbial communities within the Deltaproteobacteria also shared a positive correlation with FTHg and to the number of well pads, while stream pH ($r = -0.71$, $P < 0.001$), fish biodiversity ($r = -0.60$, $P = 0.02$), and macroinvertebrate taxa richness ($r = -0.60$, $P = 0.01$) were negatively correlated with the number of well pads within a watershed. Further investigation is needed to better elucidate relationships and pathways of observed differences in stream water chemistry, biodiversity, and Hg bioaccumulation, however, initial findings suggest Marcellus shale natural gas exploration is having an effect on aquatic ecosystems.

March 3, 2015. [*Category:* Health]

Reported health conditions in animals residing near natural gas wells in southwestern Pennsylvania.

- Slizovskiy, Ilya B.; Conti, L.A.; Trufan, Sally J.; Reif, John S.; Lamers, V.T.; Stowe, Meredith H.; Dziura, James; Rabinowitz, Peter MacGarr.
- In: *Journal of Environmental Science and Health*, *Part A*, Vol. 50, Issue 5, pages 473-481.
- http://www.tandfonline.com/toc/lesa20/current#/doi/full/10.1080/10934529.2015.992666#abstract

Abstract: Natural gas extraction activities, including the use of horizontal drilling and hydraulic fracturing, may pose potential health risks to both human and animal populations in close proximity to sites of extraction activity. Because animals may have increased exposure to contaminated water and air as well as increased susceptibility to contaminant exposures compared to nearby humans, animal disease events in communities living near natural gas extraction may provide "sentinel" information useful for human health risk assessment. Community health evaluations as well as health impact assessments (HIAs) of natural gas exploration should therefore consider the inclusion of animal health metrics in their assessment process. We report on a community environmental health survey conducted in an area of active natural gas drilling, which included the collection of health data on 2452 companion and backyard animals residing in 157 randomly-selected households of Washington County, Pennsylvania (USA). There were a total of 127 reported health conditions, most commonly among dogs. When reports from all animals were considered, there were no significant associations between reported health condition and household proximity to natural gas wells. When dogs were analyzed separately, we found an elevated risk of 'any' reported health condition in households less than 1km from the nearest gas well (OR = 3.2, 95% CI 1.07–9.7), with dermal conditions being the most common of canine disorders. While these results should be considered hypothesis generating and preliminary, they suggest value in ongoing assessments of pet dogs as well as other animals to better elucidate the health impacts of natural gas extraction on nearby communities.

March 3, 2015. [*Category:* Health]

Human exposure to unconventional natural gas development: A public health demonstration of periodic high exposure to chemical mixtures in ambient air.

- Brown, David R.; Lewis, Celia; Weinberger, Beth I.
- In: *Journal of Environmental Science and Health, Part A,* Vol. 50, Issue 5, pages 460-472.
- http://www.tandfonline.com/toc/lesa20/current#/doi/full/10.1080/10934529.2015.992663#abstract

Abstract: Directional drilling and hydraulic fracturing of shale gas and oil bring industrial activity into close proximity to residences, schools, daycare centers and places where people spend their time. Multiple gas production sources can be sited near residences. Health care providers evaluating patient health need to know the chemicals present, the emissions from different sites and the intensity and frequency of the exposures. This research describes a hypothetical case study designed to provide a basic model that demonstrates the direct effect of weather on exposure patterns of particulate matter smaller than 2.5 microns (PM2.5) and volatile organic chemicals (VOCs). Because emissions from unconventional natural gas development (UNGD) sites are variable, a short term exposure profile is proposed that determines 6-hour assessments of emissions estimates, a time scale needed to assist physicians in the evaluation of individual exposures. The hypothetical case is based on observed conditions in shale gas development in Washington County, Pennsylvania, and on estimated emissions from facilities during gas development and production. An air exposure screening model was applied to determine the ambient concentration of VOCs and PM2.5 at different 6-hour periods of the day and night. Hourly wind speed, wind direction and cloud cover data from Pittsburgh International Airport were used to calculate the expected exposures. Fourteen months of daily observations were modeled. Higher than yearly average source terms were used to predict health impacts at periods when emissions are high. The frequency and intensity of exposures to PM2.5 and VOCs at a residence surrounded by three UNGD facilities was determined. The findings show that peak PM2.5 and VOC exposures occurred 83 times over the course of 14 months of well development. Among the stages of well development, the drilling, flaring and finishing, and gas production stages produced higher intensity exposures than the hydraulic fracturing stage. Over one year, compressor station emissions created 118 peak exposure levels and a gas processing plant produced 99 peak exposures over one year. The screening model identified the periods during the day and the specific weather conditions when the highest potential exposures would occur. The periodicity of occurrence of extreme exposures is similar to the episodic nature of the health complaints reported in Washington County and in the literature. This study demonstrates the need to determine the aggregate quantitative impact on health when multiple facilities are placed near residences, schools, daycare centers and other locations where people are present. It shows that understanding the influence of air stability and wind direction is essential to exposure assessment at the residential level. The model can be applied to other emissions and similar sites. Profiles such as this will assist health providers in understanding the frequency and intensity of the human exposures when diagnosing and treating patients living near unconventional natural gas development.

March 3, 2015. [*Category:* Health]

Long-term impacts of unconventional drilling operations on human and animal health.

- Bamberger, Michelle; Oswald, Robert E.
- In: *Journal of Environmental Science and Health, Part A,* Vol. 50, Issue 5, pages 447-459.
- http://www.tandfonline.com/toc/lesa20/current#/doi/full/10.1080/10934529.2015.992655#abstract

Abstract: Public health concerns related to the expansion of unconventional oil and gas drilling have sparked intense debate. In 2012, we published case reports of animals and humans affected by nearby drilling operations. Because of the potential for long-term effects of even low doses of environmental toxicants and the cumulative impact of exposures of multiple chemicals by multiple routes of exposure, a longitudinal study of these cases is necessary. Twenty-one cases from five states were followed longitudinally; the follow-up period averaged 25 months. In addition to humans, cases involved food animals, companion animals and wildlife. More than half of all exposures were related to drilling and hydraulic fracturing operations; these decreased slightly over time. More than a third of all exposures were associated with wastewater, processing and production operations; these exposures increased slightly over time. Health impacts decreased for families and animals moving from intensively drilled areas or remaining in areas where drilling activity decreased. In cases of families remaining in the same area and for which drilling activity either remained the same or increased, no change in health impacts was observed. Over the course of the study, the distribution of symptoms was unchanged for humans and companion animals, but in food animals, reproductive problems decreased and both respiratory and growth problems increased. This longitudinal case study illustrates the importance of obtaining detailed epidemiological data on the long-term health effects of multiple chemical exposures and multiple routes of exposure that are characteristic of the environmental impacts of unconventional drilling operations.

March 3, 2015. [*Category:* General (Comment / Review)]

Current perspectives on unconventional shale gas extraction in the Appalachian Basin.

- Lampe, David J.
- In: *Journal of Environmental Science and Health, Part A,* Vol. 50, Issue 5, pages 434 - 446.
- http://www.tandfonline.com/toc/lesa20/current#/doi/full/10.1080/10934529.2015.992653#abstract

Abstract: The Appalachian Basin is home to three major shales, the Upper Devonian, Marcellus, and Utica. Together, they contain significant quantities of tight oil, gas, and mixed hydrocarbons. The Marcellus alone is estimated to contain upwards of 500 trillion cubic feet of natural gas. The extraction of these deposits is facilitated by a combination of horizontal drilling and slick water stimulation (e.g., hydraulic fracturing) or "fracking." The process of fracking requires large volumes of water, proppant, and chemicals as well as a large well pad (3–7 acres) and an extensive network of gathering and transmission pipelines. Drilling can generate about 1,000 tons of drill cuttings depending on the depth of the formation and the length of the horizontal bore. The flowback and produced waters that return to the surface during production are high in total dissolved solids (TDS, 60,000–350,000 mg L^{-1}) and contain halides (e.g., chloride, bromide, fluoride), strontium, barium, and often naturally occurring radioactive materials (NORMs) as well as organics. The condensate tanks used to store these fluids can off gas a plethora of volatile organic compounds. The waste water, with its high TDS may be recycled, treated, or disposed of through deep well injection. Where allowed, open impoundments used for recycling are a source of air borne contamination as they are often aerated. The gas may be "dry" (mostly methane) or "wet," the latter containing a mixture of light hydrocarbons and liquids that need to be separated from the methane. Although the wells can produce significant quantities of natural gas, from 2–7 bcf, their initial decline rates are significant (50–75%) and may cease to be economic within a few years. This review presents an overview of unconventional gas extraction highlighting the environmental impacts and challenges.

March 1, 2015. [*Category:* General (Comment/Review)]

Shale gas extraction - the case for a multi-disciplinary study.

- McAleenan, Ciaran; Weatherup, Robert; Bogle, Gary; McAleenan, Philip.
- In: *Proceedings of the Institution of Civil Engineers-Energy*, Vol. 168, Issue 1, pages 41-46.
- http://www.icevirtuallibrary.com/content/article/10.1680/ener.14.00022

Abstract: Shale gas extraction (SGE) and, more precisely, hydraulic fracturing, also known as fracking, has a propensity to court controversy wherever it is proposed. Many processes within SGE are essentially civil engineering processes and while numerous studies into the efficacy of SGE exist, answers to ethical and societal questions relating to safety, health and environmental sustainability remain unanswered. Recently, the UK Department of Energy and Climate Change announced its intention to support studies that encourage the development of innovative technologies for safe and responsible exploitation of the UK's shale gas resources. This paper explores the current state of knowledge regarding safety, health and wellbeing in the SGE industry, and presents the case for a detailed multi-disciplinary value-engineering study to develop pre-drill assessments and to provide ongoing monitoring tools that will assure public authorities, market operators and citizens that best-practice environmental, safety and sustainability approaches are available and feasible.

March 2015. [*Category:* General (Comment/Review)]

Zagrożenia chemiczne związane z eksploatacją gazu łupkowego. [Chemical hazards arising from shale gas extraction.]

- Pakulska, Daria.
- In: *Medycyna Pracy*, 2015, Vol. 66, Issue 1, pages 99-117.
- http://www.ncbi.nlm.nih.gov/pubmed/26016049; http://medpr.imp.lodz.pl/Autor-Daria-Pakulska/3854

Abstract (translation from Polish): The development of the shale industry is gaining momentum and hence the analysis of chemical hazards to the environment and health of the local population is extremely timely and important. Chemical hazards are created during the exploitation of all minerals, but in the case of shale gas production, there is much more uncertainty as regards to the effects of new technologies application. American experience suggests the increasing risk of environmental contamination, mainly groundwater. The greatest, concern is the incomplete knowledge of the composition of fluids used for fracturing shale rock and unpredictability of long-term effects of hydraulic fracturing for the environment and health of residents. High population density in the old continent causes the problem of chemical hazards which is much larger than in the USA. Despite the growing public discontent data on this subject are limited. First of all, there is no epidemiological studies to assess the relationship between risk factors, such as air and water pollution, and health effects in populations living in close proximity to gas wells. The aim of this article is to identify and discuss existing concepts on the sources of environmental contamination, an indication of the environment elements under pressure and potential health risks arising from shale gas extraction.

February 27, 2015. [*Category:* Air Quality]

Regional ozone impacts of increased natural gas use in the Texas power sector and development in the Eagle Ford shale.

- Pacsi, Adam Philip; Kimura, Yosuke; McGaughey, Gary; Mcdonald-Buller, Elena C.; Allen, David Thomas.
- In: *Environmental Science & Technology* (published online before print).
- http://pubs.acs.org/doi/abs/10.1021/es5055012

Abstract: The combined emissions and air quality impacts of electricity generation in the Texas grid and natural gas production in the Eagle Ford shale were estimated at various natural gas price points for the power sector. The increased use of natural gas in the power sector, in place of coal-fired power generation, drove reductions in average daily maximum 8-hr ozone concentration of 0.6 ppb to 1.3 ppb in northeastern Texas for a high ozone episode used in air quality planning. The associated increase in Eagle Ford upstream oil and gas production nitrogen oxide (NOx) emissions caused an estimated local increase, in South Texas, of 0.3 ppb to 0.7 ppb in the same ozone metric. In addition, the potential ozone impacts of Eagle Ford emissions on nearby urban areas were estimated. Based on evidence from this work and a previous study on the Barnett shale, the combined ozone impact of increased natural gas development and use in the power sector is likely to vary regionally and must be analyzed on a case by case basis.

February 26, 2015. [*Category:* Health]

Spatial analysis of environment and population at risk of natural gas fracking in the state of Pennsylvania, USA.

- Meng, Qingmin.
- In: *Science of the Total Environment*, Vol. 515-516, pages 198-206, May 15, 2015.
- http://www.sciencedirect.com/science/article/pii/S0048969715001667

Abstract: Hydraulic fracturing, also known as fracking, has been increasing exponentially across the United States, which holds the largest known shale gas reserves in the world. Studies have found that the high-volume horizontal hydraulic fracturing process (HVHFP) threatens water resources, harms air quality, changes landscapes, and damages ecosystems. However, there is minimal research focusing on the spatial study of environmental and human risks of HVHFP, which is necessary for state and federal governments to administer, regulate, and assess fracking. Integrating GIS and spatial kernel functions, we study the presently operating fracking wells across the state of Pennsylvania (PA), which is the main part of the current hottest Marcellus Shale in US. We geographically process the location data of hydraulic fracturing wells, 2010 census block data, urbanized region data, railway data, local road data, open water data, river data, and wetland data for the state of PA. From this we develop a distance based risk assessment in order to understand the environmental and urban risks. We generate the surface data of fracking well intensity and population intensity by integrating spatial dependence, semivariogram modeling, and a quadratic kernel function. The surface data of population risk generated by the division of fracking well intensity and population intensity provide a novel insight into the local and regional regulation of hydraulic fracturing activities in terms of environmental and health related risks due to the proximity of fracking wells.

February 23, 2015. [*Category:* Water Quality]

Soil disturbance as a driver of increased stream salinity in a semiarid watershed undergoing energy development.

- Bern, Carleton R.; Clark, Melanie L.; Schmidt, Travis S.; Holloway, JoAnn M.; McDougal, Robert R.
- In: *Journal of Hydrology*, Vol. 524, May 2015, pages 123-136.
- http://www.sciencedirect.com/science/article/pii/S0022169415001328

Summary: Salinization is a global threat to the quality of streams and rivers, but it can have many causes. Oil and gas development were investigated as one of several potential causes of changes in the salinity of Muddy Creek, which drains 2470 km^2 of mostly public land in Wyoming, U.S.A. Stream discharge and salinity vary with seasonal snowmelt and define a primary salinity–discharge relationship. Salinity, measured by specific conductance, increased substantially in 2009 and was 53–71% higher at low discharge and 33–34% higher at high discharge for the years 2009–2012 compared to 2005–2008. Short-term processes (e.g., flushing of efflorescent salts) cause within-year deviations from the primary relation but do not obscure the overall increase in salinity. Dissolved elements associated with increased salinity include calcium, magnesium, and sulfate, a composition that points to native soil salts derived from marine shales as a likely source. Potential causes of the salinity increase were evaluated for consistency by using measured patterns in stream chemistry, slope of the salinity–discharge relationship, and inter-annual timing of the salinity increase. Potential causes that were inconsistent with one or more of those criteria included effects from precipitation, evapotranspiration, reservoirs, grazing, irrigation return flow, groundwater discharge, discharge of energy co-produced waters, and stream habitat restoration. In contrast, surface disturbance of naturally salt-rich soil by oil and gas development activities, such as pipeline, road, and well pad construction, is a reasonable candidate for explaining the salinity increase. As development continues to expand in semiarid lands worldwide, the potential for soil disturbance to increase stream salinity should be considered, particularly where soils host substantial quantities of native salts.

February 17, 2015. [*Category:* Water Quality]

Assessment of surface water chloride and conductivity trends in areas of unconventional oil and gas development—Why existing national data sets cannot tell us what we would like to know.

- Bowen, Zachary H.; Oelsner, Gretchen P.; Cade, Brian S.; Gallegos, Tanya J.; Farag, Aida M.; Mott, David N.; Potter, Christopher J.; Cinotto, Peter J.; Clark, Melanie L.; Kappel, William M.; Kresse, Timothy M.; Melcher, Cynthia P.; Paschke, Suzanne S.; Susong, David D.; Varela, Brian A.
- In: *Water Resources Research*, Vol. 51, Issue 1, pages 704-715.
- http://onlinelibrary.wiley.com/doi/10.1002/2014WR016382/abstract

Abstract: Heightened concern regarding the potential effects of unconventional oil and gas development on regional water quality has emerged, but the few studies on this topic are limited in geographic scope. Here we evaluate the potential utility of national and publicly available water-quality data sets for addressing questions regarding unconventional oil and gas development. We used existing U.S. Geological Survey and U.S. Environmental Protection Agency data sets to increase understanding of the spatial distribution of unconventional oil and gas development in the U.S. and broadly assess surface water quality trends in these areas. Based on sample size limitations, we were able to estimate trends in specific conductance (SC) and chloride (Cl^-) from 1970 to 2010 in 16% (n = 155) of the watersheds with unconventional oil and gas resources. We assessed these trends relative to spatiotemporal distributions of hydraulically fractured wells. Results from this limited analysis suggest no consistent and widespread trends in surface water quality for SC and Cl^- in areas with increasing unconventional oil and gas development and highlight limitations of existing national databases for addressing questions regarding unconventional oil and gas development and water quality.

February 15, 2015. [*Category:* Water Quality]

Isotope reversals and universal stages and trends of gas maturation in sealed, self-contained petroleum systems.

- Tilley, Barbara; Muehlenbachs, Karlis.
- In: *Chemical Geology*, Vol. 339, pages 194-204.
- http://www.sciencedirect.com/science/article/pii/S0009254112003610?np=y

Abstract: Isotope geochemistry is now a tool for shale gas exploration, largely due to the association of isotope reversals with mature, highly productive shale gas. Its utility, however, depends on an understanding of the isotope systematics for the particular region of interest, as well as for shale gas maturation in general. This paper reviews and re-examines isotope data from four published papers that include shale gas from the Barnett and Fayetteville Shales (Rodrigez and Philp, 2010; Zumberge et al., 2012), and gas from fractured reservoirs in the Appalachians (Burruss and Laughrey, 2010) and the Foothills of the Western Canada Sedimentary Basin (WCSB) (Tilley et al., 2011). New shale and tight sandstone gas data are also presented for the WCSB. Comparisons of these data show that the progression through three stages of gas maturation (pre-rollover zone, rollover zone and post-rollover zone) is universal in sealed, self-contained petroleum systems and that each zone has characteristic isotopic relationships and trends that are seen in all areas examined.

Gases in the pre-rollover zone are isotopically normal ($\delta^{13}C_{methane} < \delta^{13}C_{ethane} < \delta^{13}C_{propane}$) unless mixing of gases from different sources has occurred. In the rollover zone, $\delta^{13}C_{ethane}$ and $\delta^{13}C_{propane}$ become progressively more negative as $\delta^{13}C_{methane}$ becomes less negative, and ethane and methane are reversed ($\delta^{13}C_{ethane} < \delta^{13}C_{methane}$) only towards the most mature portion of the rollover zone. At the beginning of the post-rollover zone, $\delta^{13}C_{ethane} < \delta^{13}C_{methane}$, but as $\delta^{13}C_{ethane}$ and $\delta^{13}C_{propane}$ become increasingly less negative at varying rates, ethane and propane may or may not be reversed with respect to each other at the highest maturities. $\delta^{2}H_{methane}$ in gases of the post-rollover zone approaches isotopic equilibrium with local formation water, generally becoming more negative with increasing maturity. Correct assignment of maturity stage could be of importance because the rollover zone may represent the peak of high productivity shale gas whereas the post-rollover zone may represent a decline in productivity (Burruss and Laughrey, 2010).

February 11, 2015. [*Category:* Seismicity]

Analysis of Transportable Array (USArray) Data Shows Earthquakes Are Scarce near Injection Wells in the Williston Basin, 2008-2011.

- Frohlich, Cliff; Walter, Jacob I.; Gale, Julia F. W.
- In: *Seismological Research Letters*, Vol. 86, Issue 2, pages 492-499.
- http://srl.geoscienceworld.org/content/86/2A/492.abstract

Abstract: We investigate possible links between seismicity and fluid injection in the Williston basin in the north-central United States, focusing on the region around the Bakken formation unconventional hydrocarbon play. Here, we show earthquakes are rarer near injection wells in the Williston basin than in the Fort Worth basin of Texas or in central Oklahoma. To identify earthquakes, we analyze seismograms collected by EarthScope USArray temporary stations, deployed on a grid with 70 km spacing. During the September 2008–May 2011 study period, we identified only nine regional earthquakes; of these only three were situated near injection wells. The reason why Williston basin earthquakes are so scarce is unclear. In both the Bakken and Barnett Shale play regions, injection volumes increased significantly in late 2007, and both areas have very low levels of natural seismicity. Oklahoma has experienced much higher rates of apparently induced seismicity than either region, possibly because injection volumes are higher in some wells in Oklahoma.

February 10, 2015. [Category: Climate]

Measurements of Methane Emissions from Natural Gas Gathering Facilities and Processing Plants: Measurement Results.

- Mitchell, Austin L.; Tkacik, Daniel S.; Roscioli, Joseph R.; Herndon, Scott C.; Yacovitch, Tara I.; Martinez, David M.; Vaughn, Timothy L.; Williams, Laurie L.; Sullivan, Melissa R.; Floerchinger, Cody; Omara, Mark; Subramanian, R.; Zimmerle, Daniel; Marchese, Anthony J.; Robinson, Allen L.

- In: *Environmental Science & Technology*, Vol. 49, Issue 5, pages 3219-3227.
- http://pubs.acs.org/doi/abs/10.1021/es5052809

Abstract: Facility-level methane emissions were measured at 114 gathering facilities and 16 processing plants in the United States natural gas system. At gathering facilities, the measured methane emission rates ranged from 0.7 to 700 kg per hour (kg/h) (0.6 to 600 standard cubic feet per minute (scfm)). Normalized emissions (as a % of total methane throughput) were less than 1% for 85 gathering facilities and 19 had normalized emissions less than 0.1%. The range of methane emissions rates for processing plants was 3 to 600 kg/h (3 to 524 scfm), corresponding to normalized methane emissions rates <1% in all cases. The distributions of methane emissions, particularly for gathering facilities, are skewed. For example, 30% of gathering facilities contribute 80% of the total emissions. Normalized emissions rates are negatively correlated with facility throughput. The variation in methane emissions also appears driven by differences between inlet and outlet pressure, as well as venting and leaking equipment. Substantial venting from liquids storage tanks was observed at 20% of gathering facilities. Emissions rates at these facilities were, on average, around four times the rates observed at similar facilities without substantial venting.

February 10, 2015. [*Category:* Climate]

Methane Emissions from Natural Gas Compressor Stations in the Transmission and Storage Sector: Measurements and Comparisons with the EPA Greenhouse Gas Reporting Program Protocol.

- Subramanian, R.; Williams, Laurie L.; Vaughn, Timothy L.; Zimmerle, Daniel; Roscioli, Joseph R.; Herndon, Scott C.; Yacovitch, Tara I.; Floerchinger, Cody; Tkacik, Daniel S.; Mitchell, Austin L.; Sullivan, Melissa R.; Dallmann, Timothy R.; Robinson, Allen L.
- In: *Environmental Science & Technology*, Vol. 49, Issue 5, pages 3252-3261.
- http://pubs.acs.org/doi/abs/10.1021/es5060258

Abstract: Equipment- and site-level methane emissions from 45 compressor stations in the transmission and storage (T&S) sector of the US natural gas system were measured, including 25 sites required to report under the EPA greenhouse gas reporting program (GHGRP). Direct measurements of fugitive and vented sources were combined with AP-42-based exhaust emission factors (for operating reciprocating engines and turbines) to produce a study onsite estimate. Site-level methane emissions were also concurrently measured with downwind-tracer-flux techniques. At most sites, these two independent estimates agreed within experimental uncertainty. Site-level methane emissions varied from 2–880 SCFM. Compressor vents, leaky isolation valves, reciprocating engine exhaust, and equipment leaks were major sources, and substantial emissions were observed at both operating and standby compressor stations. The site-level methane emission rates were highly skewed; the highest emitting 10% of sites (including two superemitters) contributed 50% of the aggregate methane emissions, while the lowest emitting 50% of sites contributed less than 10% of the aggregate emissions. Excluding the two superemitters, study-average methane emissions from compressor housings and noncompressor sources are comparable to or lower than the corresponding effective emission factors used in the EPA greenhouse gas inventory. If the two superemitters are included in the analysis, then the average emission factors based on this study could exceed the EPA greenhouse gas inventory emission factors, which highlights the potentially important contribution of superemitters to national emissions. However, quantification of their influence requires knowledge of the magnitude and frequency of superemitters across the entire T&S sector. Only 38% of the methane emissions measured by the comprehensive onsite measurements were reportable under the new EPA GHGRP because of a combination of inaccurate emission factors for leakers and exhaust methane, and various exclusions. The bias is even larger if one accounts for the superemitters, which were not captured by the onsite measurements. The magnitude of the bias varied from site to site by site type and operating state. Therefore, while the GHGRP is a valuable new source of emissions information, care must be taken when incorporating these data into emission inventories. The value of the GHGRP can be increased by requiring more direct measurements of emissions (as opposed to using counts and emission factors), eliminating exclusions such as rod-packing vents on pressurized reciprocating compressors in standby mode under Subpart-W, and using more appropriate emission factors for exhaust methane from reciprocating engines under Subpart-C.

February 4, 2015. [*Category:* Seismicity]

A risk-mitigation approach to the management of induced seismicity.

- Bommer, Julian J.; Crowley, Helen; Pinho, Rui.
- In: *Journal of Seismology*, Vol. 19, Issue 2, pages 623-646.
- http://link.springer.com/article/10.1007%2Fs10950-015-9478-z

Abstract: Earthquakes may be induced by a wide range of anthropogenic activities such as mining, fluid injection and extraction, and hydraulic fracturing. In recent years, the increased occurrence of induced seismicity and the impact of some of these earthquakes on the built environment have heightened both public concern and regulatory scrutiny, motivating the need for a framework for the management of induced seismicity. Efforts to develop systems to enable control of seismicity have not yet resulted in solutions that can be applied with confidence in most cases. The more rational approach proposed herein is based on applying the same risk quantification and mitigation measures that are applied to the hazard from natural seismicity. This framework allows informed decision-making regarding the conduct of anthropogenic activities that may cause earthquakes. The consequent risk, if related to non-structural damage (when re-location is not an option), can be addressed by appropriate financial compensation. If the risk poses a threat to life and limb, then it may be reduced through the application of strengthening measures in the built environment—the cost of which can be balanced against the economic benefits of the activity in question—rather than attempting to ensure that some threshold on earthquake magnitude or ground-shaking amplitude is not exceeded. However, because of the specific characteristics of induced earthquakes—which may occur in regions with little or no natural seismicity—the procedures used in standard earthquake engineering need adaptation and modification for application to induced seismicity.

February 4, 2015. [*Category:* Climate]

Life Cycle Greenhouse Gas Emissions From U.S. Liquefied Natural Gas Exports: Implications for End Uses.

- Abrahams, Leslie S.; Samaras, Constantine; Griffin, W. Michael; Matthews, H. Scott.

- In: Environmental Science & Technology (published online before print).
- http://pubs.acs.org/doi/abs/10.1021/es505617p

Abstract: This study analyzes how incremental U.S. liquefied natural gas (LNG) exports affect global greenhouse gas (GHG) emissions. We find that exported U.S. LNG has mean precombustion emissions of 37 g CO_2-equiv/MJ when regasified in Europe and Asia. Shipping emissions of LNG exported from U.S. ports to Asian and European markets account for only 3.5−5.5% of precombustion life cycle emissions, hence shipping distance is not a major driver of GHGs. A scenario-based analysis addressing how potential end uses (electricity and industrial heating) and displacement of existing fuels (coal and Russian natural gas) affect GHG emissions shows the mean emissions for electricity generation using U.S. exported LNG were 655 g CO_2-equiv/kWh (with a 90% confidence interval of 562–770), an 11% increase over U.S. natural gas electricity generation. Mean emissions from industrial heating were 104 g CO_2-equiv/MJ (90% CI: 87–123). By displacing coal, LNG saves 550 g CO2-equiv per kWh of electricity and 20 g per MJ of heat. LNG saves GHGs under upstream fugitive emissions rates up to 9% and 5% for electricity and heating, respectively. GHG reductions were found if Russian pipeline natural gas was displaced for electricity and heating use regardless of GWP, as long as U.S. fugitive emission rates remain below the estimated 5–7% rate of Russian gas. However, from a country specific carbon accounting perspective, there is an imbalance in accrued social costs and benefits. Assuming a mean social cost of carbon of $49/metric ton, mean global savings from U.S. LNG displacement of coal for electricity generation are $1.50 per thousand cubic feet (Mcf) of gaseous natural gas exported as LNG ($.028/kWh). Conversely, the U.S. carbon cost of exporting the LNG is $1.80/Mcf ($.013/kWh), or $0.50-$5.50/Mcf across the range of potential discount rates. This spatial shift in embodied carbon emissions is important to consider in national interest estimates for LNG exports.

February 3, 2015. [*Category:* Waste / Fluids]

Characterization of hydraulic fracturing flowback water in Colorado: Implications for water treatment.

- Lester, Yaal; Ferrer, Imma; Thurman, E. Michael; Sitterley, Kurban A.; Korak, Julie A.; Aiken, George; Linden, Karl G.
- In: Science of the Total Environment, Vol. 512-513, pages 637-644 (published online before print).
- http://www.sciencedirect.com/science/article/pii/S0048969715000583

Abstract: A suite of analytical tools was applied to thoroughly analyze the chemical composition of an oil/gas well flowback water from the Denver–Julesburg (DJ) basin in Colorado, and the water quality data was translated to propose effective treatment solutions tailored to specific reuse goals. Analysis included bulk quality parameters, trace organic and inorganic constituents, and organic matter characterization. The flowback sample contained salts (TDS = 22,500 mg/L), metals (e.g., iron at 81.4 mg/L) and high concentration of dissolved organic matter (DOC = 590 mgC/L). The organic matter comprised fracturing fluid additives such as surfactants (e.g., linear alkyl ethoxylates) and high levels of acetic acid (an additives' degradation product), indicating the anthropogenic impact on this wastewater. Based on the water quality results and preliminary treatability tests, the removal of suspended solids and iron by aeration/precipitation (and/or filtration) followed by disinfection was identified as appropriate for flowback recycling in future fracturing operations. In addition to these treatments, a biological treatment (to remove dissolved organic matter) followed by reverse osmosis desalination was determined to be necessary to attain water quality standards appropriate for other water reuse options (e.g., crop irrigation). The study provides a framework for evaluating site-specific hydraulic fracturing wastewaters, proposing a suite of analytical methods for characterization, and a process for guiding the choice of a tailored treatment approach.

February 2, 2015. [*Category:* Waste / Fluids]

Analysis of Radium-226 in high salinity wastewater from unconventional gas extraction by Inductively Coupled Plasma-Mass Spectrometry (ICP-MS).

- Zhang, Tieyuan; Bain, Daniel J.; Hammack, Richard Warren; Vidic, Radisav D.

- In: Environmental Science & Technology, (manuscript accepted before print).
- http://pubs.acs.org/doi/abs/10.1021/es504656q

Abstract: Elevated concentration of naturally occurring radioactive material (NORM) in wastewater generated from Marcellus Shale gas extraction is of great concern due to potential environmental and public health impacts. Development of a rapid and robust method for analysis of Ra-226, which is the major NORM component in this water, is critical for the selection of appropriate management approaches to properly address regulatory and public concerns. Traditional methods for Ra-226 determination require long sample holding time or long detection time. A novel method combining Inductively Coupled Mass Spectrometry (ICP-MS) with solid-phase extraction (SPE) to separate and purify radium isotopes from the matrix elements in high salinity solutions is developed in this study. This method reduces analysis time while maintaining requisite precision and detection limit. Radium separation is accomplished using a combination of a strong-acid cation exchange resin to separate barium and radium from other ions in the solution and a strontium-specific resin to isolate radium from barium and obtain a sample suitable for analysis by ICP-MS. Method optimization achieved high radium recovery (101 ± 6% for standard mode and 97 ± 7% for collision mode) for synthetic Marcellus Shale wastewater (MSW) samples with total dissolved solids as high as 171,000 mg/L. Ra-226 concentration in actual MSW samples with TDS as high as 415,000 mg/L measured using ICP-MS matched very well with the results from gamma spectrometry. The Ra-226 analysis method developed in this study requires several hours for sample preparation and several minutes for analysis with the detection limit of 100 pCi/L with RSD of 45% (standard mode) and 67% (collision mode). The RSD decreased to below 15% when Ra-226 concentration increased over 500 pCi/L.

February 1, 2015. [*Category:* Climate]

Quantifying atmospheric methane emissions from the Haynesville, Fayetteville, and northeastern Marcellus shale gas production regions.

- Peischl, J.; Ryerson, T. B.; Aikin, K. C.; de Gouw, J. A.; Gilman, J. B.; Holloway, J. S.; Lerner, B. M.; Nadkarni, R.; Neuman, J. A.; Nowak, J. B.; Trainer, M.; Warneke, C.; Parrish, D. D.
- In: Journal of Geophysical Research: Atmospheres (published online before print).
- http://onlinelibrary.wiley.com/doi/10.1002/2014JD022697/abstract

Abstract: We present measurements of methane (CH_4) taken aboard a NOAA WP-3D research aircraft in 2013 over the Haynesville shale region in eastern Texas/northwestern Louisiana, the Fayetteville shale region in Arkansas, and the northeastern Pennsylvania portion of the Marcellus shale region, which accounted for the majority of Marcellus shale gas production that year. We calculate emission rates from the horizontal CH_4 flux in the planetary boundary layer downwind of each region after subtracting the CH_4 flux entering the region upwind. We find one-day CH_4 emissions of $(8.0 \pm 2.7) \times 10^7$ g/hr from the Haynesville region, $(3.9 \pm 1.8) \times 10^7$ g/hr from the Fayetteville region, and $(1.5 \pm 0.6) \times 10^7$ g/hr from the Marcellus region in northeastern Pennsylvania. Finally, we compare the CH_4 emissions to the total volume of natural gas extracted from each region to derive a loss rate from production operations of 1.0–2.1% from the Haynesville region, 1.0–2.8% from the Fayetteville region, and 0.18–0.41% from the Marcellus region in northeastern Pennsylvania. The climate impact of CH_4 loss from shale gas production depends upon the total leakage from all production regions. The regions investigated in this work represented over half of the U.S. shale gas production in 2013, and we find generally lower loss rates than those reported in earlier studies of regions that made smaller contributions to total production. Hence, the national average CH_4 loss rate from shale gas production may be lower than values extrapolated from the earlier studies.

February, 2015. [*Category:* Seismicity]

Induced seismicity constraints on subsurface geological structure, Paradox Valley, Colorado.

- Block, Lisa V.; Wood, Christopher K.; Yeck, William L.; King, Vanessa M.
- In: *Geophysical Journal International*, Vol. 200, Issue 2, pages 1170-1193.
- http://gji.oxfordjournals.org/content/200/2/1172

Summary: Precise relative hypocentres of seismic events induced by long-term fluid injection at the Paradox Valley Unit (PVU) brine disposal well provide constraints on the subsurface geological structure and compliment information available from deep seismic reflection and well data. We use the 3-D spatial distribution of the hypocentres to refine the locations, strikes, and throws of subsurface faults interpreted previously from geophysical surveys and to infer the existence of previously unidentified subsurface faults. From distinct epicentre lineations and focal mechanism trends, we identify a set of conjugate fracture orientations consistent with shear-slip reactivation of late-Palaeozoic fractures over a widespread area, as well as an additional fracture orientation present only near the injection well. We propose simple Mohr–Coulomb fracture models to explain these observations. The observation that induced seismicity preferentially occurs along one of the identified conjugate fracture orientations can be explained by a rotation in the direction of the regional maximum compressive stress from the time when the fractures were formed to the present. Shear slip along the third fracture orientation observed near the injection well is inconsistent with the current regional stress field and suggests a local rotation of the horizontal stresses. The detailed subsurface model produced by this analysis provides important insights for anticipating spatial patterns of future induced seismicity and for evaluation of possible additional injection well sites that are likely to be seismically and hydrologically isolated from the current well. In addition, the interpreted fault patterns provide constraints for estimating the maximum magnitude earthquake that may be induced, and for building geomechanical models to simulate pore pressure diffusion, stress changes and earthquake triggering.

January 28, 2015. [*Category:* Climate]

Allocating Methane Emissions to Natural Gas and Oil Production from Shale Formations.

- Zavala-Araiza, Daniel; Allen, David T.; Harrison, Matthew; George, Fiji C.; Jersey, Gilbert R.
- In: *Acs Sustainable Chemistry & Engineering*, Vol. 3, Issue 3, pages 492-498.
- http://pubs.acs.org/doi/abs/10.1021/sc500730x

Abstract: The natural gas supply chain includes production, processing, and transmission of natural gas, which originates from conventional, shale, coal bed, and other reservoirs. Because the hydrocarbon products and the emissions associated with extraction from different reservoir types can differ, when expressing methane emissions from the natural gas supply chain, it is important to allocate emissions to particular hydrocarbon products and reservoir types. In this work, life cycle allocation methods have been used to assign methane emissions from production wells operating in shale formations to oil, condensate, and gas products from the wells. The emission allocations are based on a data set of 489 gas wells in routine operation and 19 well completion events. The methane emissions allocated to natural gas production are approximately 85% of total emissions (mass based allocation), but there is regional variability in the data and therefore this work demonstrates the need to track natural gas sources by both formation type and production region. Methane emissions allocated to salable natural gas production from shale formations, based on this work, are a factor of 2 to 7 lower than those reported in commonly used life cycle data sets.

January 28, 2015. [*Category:* Waste/Fluids]

Chemical constituents and analytical approaches for hydraulic fracturing waters.

- Ferrer, Imma; Thurman, E. Michael.
- In: *Trends in Environmental Analytical Chemistry*, Vol. 5, pages 18-25.
- http://www.sciencedirect.com/science/article/pii/S2214158815000045

Abstract: Hydraulic fracturing fluids contain a mix of organic and inorganic additives in an aqueous media. The compositions of these mixtures vary according to the region or company use, thus making the process of identifying individual compounds difficult. The analytical characterization of such mixtures is important in order to understand the transport, environmental fate and ultimate potential health impact in various water compartments associated with hydraulic fracturing. Organic compound classes include solvents, gels, biocides, scale inhibitors, friction reducers, surfactants and other related compounds. These contaminants are usually present in trace amounts, so sophisticated analytical methodologies are needed in order to fully characterize the chemical composition of fracking fluids. The current state of knowledge of chemical components and approaches for their analysis is reviewed here. In recent years, modern analytical methodologies, such as gas chromatography–mass spectrometry (GC–MS) have been specifically used to identify organic chemical components of fracking fluids and/or flowback and produced waters associated with the process of hydraulic fracturing. Other techniques such as liquid chromatography–mass spectrometry (LC–MS) have not been explored in detail yet. In this review a detailed description of chemical constituents present in hydraulic fracturing waters will be given, as well as an evaluation of the analytical techniques used for their unequivocal determination.

January 23, 2015. [*Category:* Climate]

Methane emissions from natural gas infrastructure and use in the urban region of Boston, Massachusetts.

- McKain, Kathryn; Down, Adrian; Raciti, Steve M.; Budney, John; Hutyra, Lucy R.; Floerchinger, Cody; Herndon, Scott C.; Nehrkorn, Thomas; Zahniser, Mark S.; Jackson, Robert B.; Phillips, Nathan; Wofsy, Steven C.
- In: *Proceedings of the National Academy of Sciences*, Vol. 112, Issue 7, pages 1941-1946.
- http://www.pnas.org/content/112/7/1941.abstract

Abstract: Methane emissions from natural gas delivery and end use must be quantified to evaluate the environmental impacts of natural gas and to develop and assess the efficacy of emission reduction strategies. We report natural gas emission rates for 1 y in the urban region of Boston, using a comprehensive atmospheric measurement and modeling framework. Continuous methane observations from four stations are combined with a high-resolution transport model to quantify the regional average emission flux, 18.5 ± 3.7 (95% confidence interval) g $CH_4{\cdot}m^{-2}{\cdot}y^{-1}$. Simultaneous observations of atmospheric ethane, compared with the ethane-to-methane ratio in the pipeline gas delivered to the region, demonstrate that natural gas accounted for ~60–100% of methane emissions, depending on season. Using government statistics and geospatial data on natural gas use, we find the average fractional loss rate to the atmosphere from all downstream components of the natural gas system, including transmission, distribution, and end use, was 2.7 ± 0.6% in the Boston urban region, with little seasonal variability. This fraction is notably higher than the 1.1% implied by the most closely comparable emission inventory.

January 23, 2015. [*Category:* Water Quality]

Monitoring radionuclides in subsurface drinking water sources near unconventional drilling operations: a pilot study.

- Nelson, Andrew W.; Knight, Andrew W.; Eitrheim, Eric S.; Schultz, Michael K.
- In: *Journal of Environmental Radioactivity*, Vol. 142, April 2015, pages 24-28.
- http://www.sciencedirect.com/science/article/pii/S0265931X15000065

Abstract: Unconventional drilling (the combination of hydraulic fracturing and horizontal drilling) to extract oil and natural gas is expanding rapidly around the world. The rate of expansion challenges scientists and regulators to assess the risks of the new technologies on drinking water resources. One concern is the potential for subsurface drinking water resource contamination by naturally occurring radioactive materials co-extracted during unconventional drilling activities. Given the rate of expansion, opportunities to test drinking water resources in the pre- and post-fracturing setting are rare. This pilot study investigated the levels of natural uranium, lead-210, and polonium-210 in private drinking wells within 2000 m of a large-volume hydraulic fracturing operation – before and approximately one-year following the fracturing activities. Observed radionuclide concentrations in well waters tested did not exceed maximum contaminant levels recommended by state and federal agencies. No statistically-significant differences in radionuclide concentrations were observed in well-water samples collected before and after the hydraulic fracturing activities. Expanded monitoring of private drinking wells before and after hydraulic fracturing activities is needed to develop understanding of the potential for drinking water resource contamination from unconventional drilling and gas extraction activities.

January 21, 2015. [*Category:* Air Quality]

A Multiyear Assessment of Air Quality Benefits from China's Emerging Shale Gas Revolution: Urumqi as a Case Study.

- Song, Wei; Chang, Yunhua; Liu, Xuejun; Li, Kaihui; Gong, Yanming; He, Guixiang; Wang, Xiaoli; Christie, Peter; Zheng, Mei; Dore, Anthony J.; Tian, Changyan.

- In: *Environmental Science & Technology*, Vol. 49, Issue 4, pages 2066-2072.
- http://pubs.acs.org/doi/abs/10.1021/es5050024

Abstract: China is seeking to unlock its shale gas in order to curb its notorious urban air pollution, but robust assessment of the impact on $PM_{2.5}$ pollution of replacing coal with natural gas for winter heating is lacking. Here, using a whole-city heating energy shift opportunity offered by substantial reductions in coal combustion during the heating periods in Urumqi, northwest China, we conducted a four-year study to reveal the impact of replacing coal with natural gas on the mass concentrations and chemical components of $PM_{2.5}$. We found a significant decline in $PM_{2.5}$, major soluble ions and metal elements in $PM_{2.5}$ in January of 2013 and 2014 compared with the same periods in 2012 and 2011, reflecting the positive effects on air quality of using natural gas as a heating fuel throughout the city. This occurred following complete replacement with natural gas for heating energy in October 2012. The weather conditions during winter did not show any significant variation over the four years of the study. Our results indicate that China and other developing nations will benefit greatly from a change in energy source, that is, increasing the contribution of either natural gas or shale gas to total energy consumption with a concomitant reduction in coal consumption.

January 19, 2015. [*Category:* General (Comment / Review)]

Considerations for the development of shale gas in the United Kingdom.

- Hays, Jake; Finkel, Madelon L.; Depledge, Michael; Law, Adam; Shonkoff, Seth B. C.
- In: *Science of the Total Environment*, Vol. 512-513, pages 36-42 (published online before print).
- http://www.sciencedirect.com/science/article/pii/S0048969715000078

Abstract: The United States shale gas boom has precipitated global interest in the development of unconventional oil and gas resources. Recently, government ministers in the United Kingdom started granting licenses that will enable companies to begin initial exploration for shale gas. Meanwhile, concern is increasing among the scientific community about the potential impacts of shale gas and other types of unconventional natural gas development (UGD) on human health and the environment. Although significant data gaps remain, there has been a surge in the number of articles appearing in the scientific literature, nearly three-quarters of which has been published since the beginning of 2013. Important lessons can be drawn from the UGD experience in the United States. Here we explore these considerations and argue that shale gas development policies in the UK and elsewhere should be informed by empirical evidence generated on environmental, public health, and social risks. Additionally, policy decisions should take into account the measured effectiveness of harm reduction strategies as opposed to hypothetical scenarios and purported best practices that lack empirical support.

January 16, 2015. [*Category:* Air Quality]

Impact of Marcellus Shale Natural Gas Development in Southwest Pennsylvania on Volatile Organic Compound Emissions and Regional Air Quality.

- Swarthout, Robert F.; Russo, Rachel S.; Zhou, Yong; Miller, Brandon M.; Mitchell, Brittney; Horsman, Emily; Lipsky, Eric; McCabe, David C.; Baum, Ellen; Sive, Barkley C.
- In: *Environmental Science & Technology*, Vol. 49, Issue 5, pages 3175-3184.
- http://pubs.acs.org/doi/abs/10.1021/es504315f

Abstract: The Marcellus Shale is the largest natural gas deposit in the U.S. and rapid development of this resource has raised concerns about regional air pollution. A field campaign was conducted in the southwestern Pennsylvania region of the Marcellus Shale to investigate the impact of unconventional natural gas (UNG) production operations on regional air quality. Whole air samples were collected throughout an 8050 km^2 grid surrounding Pittsburgh and analyzed for methane, carbon dioxide, and C_1–C_{10} volatile organic compounds (VOCs). Elevated mixing ratios of methane and C_2–C_8 alkanes were observed in areas with the highest density of UNG wells. Source apportionment was used to identify characteristic emission ratios for UNG sources, and results indicated that UNG emissions were responsible for the majority of mixing ratios of C_2–C_8 alkanes, but accounted for a small proportion of alkene and aromatic compounds. The VOC emissions from UNG operations accounted for 17 ± 19% of the regional kinetic hydroxyl radical reactivity of nonbiogenic VOCs suggesting that natural gas emissions may affect compliance with federal ozone standards. A first approximation of methane emissions from the study area of 10.0 ± 5.2 kg s^{-1} provides a baseline for determining the efficacy of regulatory emission control efforts.

January 14, 2015. [*Category:* Waste / Fluids]

Iodide, Bromide, and Ammonium in Hydraulic Fracturing and Oil and Gas Wastewaters: Environmental Implications.

- Harkness, Jennifer S.; Dwyer, Gary S.; Warner, Nathaniel R.; Parker, Kimberly M.; Mitch, William A.; Vengosh, Avner.
- In: *Environmental Science & Technology*, Vol. 49, Issue 3, pages 1955-1963.
- http://pubs.acs.org/doi/abs/10.1021/es504654n

Abstract: The expansion of unconventional shale gas and hydraulic fracturing has increased the volume of the oil and gas wastewater (OGW) generated in the U.S. Here we demonstrate that OGW from Marcellus and Fayetteville hydraulic fracturing flowback fluids and Appalachian conventional produced waters is characterized by high chloride, bromide, iodide (up to 56 mg/L), and ammonium (up to 420 mg/L). Br/Cl ratios were consistent for all Appalachian brines, which reflect an origin from a common parent brine, while the I/Cl and NH4/Cl ratios varied among brines from different geological formations, reflecting geogenic processes. There were no differences in halides and ammonium concentrations between OGW originating from hydraulic fracturing and conventional oil and gas operations. Analysis of discharged effluents from three brine treatment sites in Pennsylvania and a spill site in West Virginia show elevated levels of halides (iodide up to 28 mg/L) and ammonium (12 to 106 mg/L) that mimic the composition of OGW and mix conservatively in downstream surface waters. Bromide, iodide, and ammonium in surface waters can impact stream ecosystems and promote the formation of toxic brominated-, iodinated-, and nitrogen disinfection byproducts during chlorination at downstream drinking water treatment plants. Our findings indicate that discharge and accidental spills of OGW to waterways pose risks to both human health and the environment.

January 8, 2015. [*Category:* Ecology]

Habitat Loss and Modification Due to Gas Development in the Fayetteville Shale.

- Moran, Matthew D.; Cox, A. Brandon; Wells, Rachel L.; Benichou, Chloe C.; McClung, Maureen R.
- In: *Environmental Management* (published online before print).
- http://www.ncbi.nlm.nih.gov/pubmed/25566834

Abstract: Hydraulic fracturing and horizontal drilling have become major methods to extract new oil and gas deposits, many of which exist in shale formations in the temperate deciduous biome of the eastern United States. While these technologies have increased natural gas production to new highs, they can have substantial environmental effects. We measured the changes in land use within the maturing Fayetteville Shale gas development region in Arkansas between 2001/2002 and 2012. Our goal was to estimate the land use impact of these new technologies in natural gas drilling and predict future consequences for habitat loss and fragmentation. Loss of natural forest in the gas field was significantly higher compared to areas outside the gas field. The creation of edge habitat, roads, and developed areas was also greater in the gas field. The Fayetteville Shale gas field fully developed about 2 % of the natural habitat within the region and increased edge habitat by 1,067 linear km. Our data indicate that without shale gas activities, forest cover would have increased slightly and edge habitat would have decreased slightly, similar to patterns seen recently in many areas of the southern U.S. On average, individual gas wells fully developed about 2.5 ha of land and modified an additional 0.5 ha of natural forest. Considering the large number of wells drilled in other parts of the eastern U.S. and projections for new wells in the future, shale gas development will likely have substantial negative effects on forested habitats and the organisms that depend upon them.

January 7, 2015. [*Category:* Waste / Fluids]

Stretched arc discharge in produced water.

- Cho, Y. I.; Wright, K. C.; Kim, H. S.; Cho, D. J.; Rabinovich, A.; Fridman, A.
- In: *Review of Scientific Instruments*, Vol. 86, Issue 1, page 013501.
- http://scitation.aip.org/content/aip/journal/rsi/86/1/10.1063/1.4905169

Abstract: The objective of the present study was to investigate the feasibility of stretching an arc discharge in produced water to increase the volume of produced water treated by plasma. Produced water is the wastewater generated by hydraulic fracturing of shale during the production phase in shale-oil or shale-gas exploration. The electric conductivity of produced water is in the range of 50-200 mS/cm, which provides both a challenge and opportunity for the application of plasmas. Stretching of an arc discharge in produced water was accomplished using a ground electrode and two high-voltage electrodes: one positioned close to the ground electrode and the other positioned farther away from the ground. The benefit of stretching the arc is that the contact between the arc and water is significantly increased, resulting in more efficient plasma treatment in both performance and energy cost.

January 6, 2015. [*Category:* Seismicity]

Earthquakes Induced by Hydraulic Fracturing in Poland Township, Ohio.

- Skoumal, Robert J.; Brudzinski, Michael R.; Currie, Brian S.
- In: Bulletin of the Seismological Society of America (published online before print).
- http://www.bssaonline.org/content/early/2015/01/01/0120140168

Abstract: Felt seismicity induced by hydraulic fracturing is very rare, with only a handful of reported cases worldwide. Using an optimized multistation cross-correlation template-matching routine, 77 earthquakes were identified in Poland Township, Mahoning County, Ohio, that were closely related spatially and temporally to active hydraulic fracturing operations. We identified earthquakes as small as local magnitudes (M_L) ~1 up to 3, potentially one of the largest earthquakes induced by hydraulic fracturing in the United States. These events all occurred from 4 to 12 March 2014, and the rate decayed once the Ohio Department of Natural Resources issued a shutdown of hydraulic fracturing at a nearby well on 10 March. Using a locally derived velocity model and double-difference relocation, the earthquakes occurred during six stimulation stages along two horizontal well legs that were located ~0.8 km away. Nearly 100 stimulation stages in nearby wells at greater distances from the earthquake source region did not coincide with detected seismicity. During the sequence, hypocenters migrated ~600 m along an azimuth of 083°, defining a vertically oriented plane of seismicity close to the top of the Precambrian basement. The focal mechanism determined for the M_L 3 event had a vertically oriented left-lateral fault plane consistent with the earthquake distribution and the regional stress field. The focal mechanism, orientation, and depth of hypocenters were similar to those of the 2011 Youngstown earthquake sequence that occurred 18 km to the northwest and was correlated with wastewater injection instead of hydraulic fracturing. Considering the relatively large magnitude of the Poland Township events and the *b*-value of 0.89, it appears the hydraulic fracturing induced slip along a pre-existing fault/fracture zone optimally oriented in the regional stress field.

January 6, 2015. [*Category:* Seismicity]

Investigation of regional seismicity before and after hydraulic fracturing in the Horn River Basin, northeast British Columbia.

- Farahbod, Amir Mansour; Kao, Honn; Walker, Dan M.; Cassidy, John F.
- In: *Canadian Journal of Earth Sciences*, Vol. 52, Issue 2.
- http://www.nrcresearchpress.com/doi/abs/10.1139/cjes-2014-0162?src=recsys#.VYIYTnsXfEY

Abstract: We systematically re-analyzed historical seismograms to verify the existence of background seismicity in the Horn River Basin of northeast British Columbia before the start of regional shale gas development. We also carefully relocated local earthquakes that occurred between December 2006 and December 2011 to delineate their spatiotemporal relationship with hydraulic fracturing (HF) operations in the region. Scattered seismic events were detected in the Horn River Basin throughout the study periods. The located seismicity within 100 km of the Fort Nelson seismic station had a clearly increasing trend, specifically in the Etsho area where most local HF operations were performed. The number of events was increased from 24 in 2002–2003 (prior to HF operations) to 131 in 2011 (peak period of HF operations). In addition, maximum magnitude of the events was shifted from M_L 2.9 to M_L 3.6 as the scale of HF operation expanded from 2006–2007 to 2011. Based on our relocated earthquake catalog, the overall b value is estimated at 1.21, which is higher than the average of tectonic/natural earthquakes of ~1.0. Our observations highly support the likelihood of a physical relationship between HF operation and induced seismicity in the Horn River Basin. Unfortunately, due to the sparse station density in the region, depth resolution is poor for the vast majority of events in our study area. As new seismograph stations are established in northeast British Columbia, both epicentral mislocation and depth uncertainty for future events are expected to improve significantly.

January 3, 2015. [*Category:* Water Quality]

Identification of local groundwater pollution in northeastern Pennsylvania: Marcellus flowback or not?

- Reilly, Darren; Singer, David; Jefferson, Anne; Eckstein, Yoram.
- In: *Environmental Earth Sciences*, Vol. 73, Issue 12, pages 8097-8109.
- http://link.springer.com/article/10.1007%2Fs12665-014-3968-0

Abstract: Northeastern Pennsylvania has rapidly changed over the past 5 years from an area with no unconventional natural gas drilling, to the most productive shale gas region within the Marcellus shale play, causing concerns about environmental safety. One issue that has caught the attention of homeowners and media is the possibility that flow-back fluids from drilling and fracturing processes have contaminated private water wells. Major and trace ion water chemistry was analyzed from 21 groundwater wells suspected by homeowners to be contaminated by flow-back fluids. These data, collected in 2012–2013, were compared to historical groundwater data, Marcellus flow-back fluid, and other sources of common groundwater contamination in rural areas (agricultural waste, septic waste, and road salt). Results from graphical and statistical tests indicate that flow-back fluids have not impacted these wells. However, some of the 2012–2013 wells do plot graphically within zones identified as waters that have been influenced by animal waste, septic, or road salt. The remaining 2012–2013 wells are geochemically similar to historical groundwater wells. These findings suggest that the major and trace element geochemistry of local groundwater in the northeastern Pennsylvania study area has not been detectably influenced by flow-back fluid spills.

January 1, 2015. [*Categories:* General (Comment / Review), Water Quality]

Drinking water while fracking: now and in the future.

[In: *Column Theme: Unconventional Shale Gas Development and Potential Impacts to Groundwater*]

- Brantley, Susan L.
- In: *Groundwater*, Vol. 53, Issue 1, pages 21-23.
- http://www.ncbi.nlm.nih.gov/pubmed/25713828

Abstract: The data provided by the PA DEP are incomplete because confidential data are not released. It is impossible to make firm conclusions about water quality impacts when data availability is limited. Nonetheless, the PA experience appears to be characterized by a low rate of problems per gas well or unit of gas produced. Only about 160 of the complaints from homeowners about groundwater to the PA DEP between 2008 and 2012 were problems attributed to oil and gas activity—and only half of these were caused by companies known to drill unconventional shale wells. These problematic wells in turn represent only 0.1 to 1% of the unconventional shale gas wells drilled in that time period (Brantley et al. 2014). Management practices appear to be improving as well; the rate of problems has decreased since 2010 (Figure 1). Apparently, however, the public responds not only to the number of problems per gas well or per unit of gas produced but rather to the number of problems per unit time and per unit area. Thus, even though the r ate of problems with shale gas wells has remained small on a per well basis, pushback has grown in areas of increasing density of drilling and fracking. This may be especially true when consequences are fearsome such as flaming tapwater, toxic contamination, or earthquakes. It is natural that the social license for shale gas development is influenced by short-term, local thinking. But, such thinking may not be helpful given that Marcellus Shale gas wells generate one third the waste per unit volume of gas as compared to conventional shallow gas wells (Vidic et al. 2013). In addition, the release of pollutants such as carbon dioxide, particulates, mercury, nitrogen, and sulfur generated per unit of heat energy is lower f or unconventional shale gas than for fuels such as coal (Heath et al. 2014). Public pushback could nonetheless be a blessing. After all, pushback represents intensified interest in environmental issues. This interest may be seen in the PA DEP data for the rate of well integrity issues in conventional oil and gas wells—the increase in problem rate from 2008 to 2012 (Figure 1) is more likely due to heightened public attention and inspector scrutiny rather than a sudden deterioration in the management practices of the drilling companies (Brantley et al. 2014) During the next decades, the rate of hydraulic fracturing in PA will eventually slow. At some point, the use of produced brines to hydrofracture new wells will cease. Once recycling of brine to frack new wells stops, hundreds of gallons of brine will accumulate as waste at each well per day (Rahm et al. 2013). Disposal of this slightly radioactive brine will then become increasingly problematic. Interest on the part of the public for such issues is warranted. Public engagement today is needed to develop sustainable waste management and sustainable energy practices for the future.

January 1, 2015. [*Category:* Water Quality]

Unconventional Shale Gas Development and Potential Impacts to Groundwater.

- Kretsinger Grabert, Vicki; Kaback, Dawn Samara; Briskin, Jeanne; Brantley, Susan L.; Darrah, Thomas H.; Jackson, Robert B.; Vengosh, Avner; Warner, Nathaniel R.; Poreda, Robert J.
- In: *Groundwater*, Vol. 53, Issue 1, pages 19-28.
- http://onlinelibrary.wiley.com/doi/10.1111/gwat.12307/abstract

Abstract: In this column, we focus on technical aspects of a controversial timely topic, unconventional shale gas development and potential impacts to groundwater resources. This subject has become of great interest in the public domain and articles are often found daily in our newspapers and other news media. A significant amount of research is currently underway to improve understanding of the technical aspects. Over the last few years, several articles have been published in the Groundwater journal, by the National Academy of Science, and other peer reviewed journals as well. The first article in this column, by Jeanne Briskin, EPA, presents a summary of the Congressionally supported groundwater research program on the topic. The second article, by Susan Brantley, Pennsylvania State University, provides a summary of publicly available data on environmental impacts over the last five or so years in Pennsylvania's Marcellus Shale Gas Area, as this was one of the areas where environmental impacts of this industry became a significant stakeholder issue and brought the topic to the forefront of the news. The last article, by Tom Darrah of Ohio State University and co-authors, discusses the application of noble gas and isotope geochemistry to distinguish between natural and anthropogenic sources of hydrocarbons in shallow aquifers and to determine the source and mechanisms of anthropogenic gas contamination.

January 2015. [*Category:* Seismicity]

Maximum magnitude estimations of induced earthquakes at Paradox Valley, Colorado, from cumulative injection volume and geometry of seismicity clusters.

- Yeck, William L.; Block, Lisa V.; Wood, Christopher K.; King, Vanessa M.
- In: *Geophysical Journal International*, Vol. 200, Issue 1, pages 322-336.
- http://gji.oxfordjournals.org/content/200/1/322.refs

Abstract: The Paradox Valley Unit (PVU), a salinity control project in southwest Colorado, disposes of brine in a single deep injection well. Since the initiation of injection at the PVU in 1991, earthquakes have been repeatedly induced. PVU closely monitors all seismicity in the Paradox Valley region with a dense surface seismic network. A key factor for understanding the seismic hazard from PVU injection is the maximum magnitude earthquake that can be induced. The estimate of maximum magnitude of induced earthquakes is difficult to constrain as, unlike naturally occurring earthquakes, the maximum magnitude of induced earthquakes changes over time and is affected by injection parameters. We investigate temporal variations in maximum magnitudes of induced earthquakes at the PVU using two methods. First, we consider the relationship between the total cumulative injected volume and the history of observed largest earthquakes at the PVU. Second, we explore the relationship between maximum magnitude and the geometry of individual seismicity clusters. Under the assumptions that: (i) elevated pore pressures must be distributed over an entire fault surface to initiate rupture and (ii) the location of induced events delineates volumes of sufficiently high pore-pressure to induce rupture, we calculate the largest allowable vertical penny-shaped faults, and investigate the potential earthquake magnitudes represented by their rupture. Results from both the injection volume and geometrical methods suggest that the PVU has the potential to induce events up to roughly MW 5 in the region directly surrounding the well; however, the largest observed earthquake to date has been about a magnitude unit smaller than this predicted maximum. In the seismicity cluster surrounding the injection well, the maximum potential earthquake size estimated by these methods and the observed maximum magnitudes have remained steady since the mid-2000s. These observations suggest that either these methods overpredict maximum magnitude for this area or that long time delays are required for sufficient pore-pressure diffusion to occur to cause rupture along an entire fault segment. We note that earthquake clusters can initiate and grow rapidly over the course of 1 or 2 yr, thus making it difficult to predict maximum earthquake magnitudes far into the future. The abrupt onset of seismicity with injection indicates that pore-pressure increases near the well have been sufficient to trigger earthquakes under pre-existing tectonic stresses. However, we do not observe remote triggering from large teleseismic earthquakes, which suggests that the stress perturbations generated from those events are too small to trigger rupture, even with the increased pore pressures.

December 24, 2014. [*Categories:* Economics; General (Comment/Review)]

Evaluation of socioeconomic impacts on and risks for shale gas exploration in China.

- Yu, Shiwei.
- In: *Energy Strategy Reviews*, Vol. 6, pages 30-38, January 2015.
- http://www.sciencedirect.com/science/article/pii/S2211467X14000698

Abstract: The remarkable growth of shale gas production in the U.S. has given rise to increasing interest in the exploration of shale resources in other areas of the world, especially in China. This study focuses on analyzing the socioeconomic impacts of China's nearly six years' shale exploration and in the process of exploitation practices. Findings reveal that China's shale gas resource potential is unconfirmed and its contribution to improving the structure of energy consumption is limited. The plans for shale gas exploration and development reflect the desire to achieve quick success and instant benefits despite a lack of long-term strategy. The exploitation of shale gas remains a pollute first, pay later model, which brings many ecological and environmental risks. To accelerate the progress of shale gas exploration, China should formulate a long-term plan and strengthen basic technology research into shale gas exploitation. Moreover, the strength and breadth of government incentives must be expanded, and water resources should be reasonably allocated during shale gas exploitation.

December 14, 2014. [*Category:* Seismicity]

Felt Seismicity Associated with Shale Gas Hydraulic Fracturing: The First Documented Example in Europe.

- Clarke, Huw; Eisner, Leo; Styles, Peter; Turner, Peter.
- In: *Geophysical Research Letters* (early view).
- http://onlinelibrary.wiley.com/doi/10.1002/2014GL062047/abstract

Abstract: We describe the origin of felt seismicity during the hydraulic fracturing of the Carboniferous Bowland Shale at the Preese Hall-1 exploration well near Blackpool in the UK during 2011. The seismicity resulted from the interaction of hydraulic fracturing and a fault, the location of which was unknown at the time, but has subsequently been located and does not intersect the well borehole. Waveform cross-correlation is used to detect 50 events in the sequence. A representative hypocenter and strike-slip focal mechanism is calculated using the best recorded seismic event. The hypocenter is calculated to lie 300-400 m east, and 330-360 m below the injection point and shown to lie on a fault imaged using 3D seismic at a depth of about 2930 m. The 3D survey shows that, not only the event hypocenter, but also the focal mechanism, correlate strongly with a subsequently identifiable transpressional fault formed during Late Carboniferous (Variscan) basin inversion.

December 12, 2014. [*Category:* General (Comment/Review)]

Natural resource development for science, technology, and environmental policy issues: the case of hydraulic fracturing.

- Jain, Ravi.
- In: *Clean Technologies and Environmental Policy*, Vol. 17, Issue 1, pages 3-8.
- http://link.springer.com/article/10.1007%2Fs10098-014-0856-y

Abstract: The development and effective use of natural resources is essential for meeting crucial societal needs and for the economic development of a nation. Discussed here is the case of hydraulic fracturing which is used to fracture underground formations to recover natural gas and oil. Described in the article are economic benefits and environmental and human health implications of this technology; views on these aspects rapidly become controversial. Presented here is a consensus building paradigm to address and mitigate controversies related to the implementation of this technology.

December 9, 2014. [*Category:* Climate]

Methane Emissions from Process Equipment at Natural Gas Production Sites in the United States: Liquid Unloadings.

- Allen, David T.; Sullivan, David W.; Zavala-Araiza, Daniel; Pacsi, Adam P.; Harrison, Matthew; Keen, Kindal; Fraser, Matthew P.; Daniel Hill, A.; Lamb, Brian K.; Sawyer, Robert F.; Seinfeld, John H.
- In: *Environmental Science & Technology*, Vol. 49, Issue 1, pages 641-648.
- http://dx.doi.org/10.1021/es504016r

Abstract: Methane emissions from liquid unloadings were measured at 107 wells in natural gas production regions throughout the United States. Liquid unloadings clear wells of accumulated liquids to increase production, employing a variety of liquid lifting mechanisms. In this work, wells with and without plunger lifts were sampled. Most wells without plunger lifts unload less than 10 times per year with emissions averaging 21 000–35 000 scf methane (0.4–0.7 Mg) per event (95% confidence limits of 10 000–50 000 scf/event). For wells with plunger lifts, emissions averaged 1000–10 000 scf methane (0.02–0.2 Mg) per event (95% confidence limits of 500–12 000 scf/event). Some wells with plunger lifts are automatically triggered and unload thousands of times per year and these wells account for the majority of the emissions from all wells with liquid unloadings. If the data collected in this work are assumed to be representative of national populations, the data suggest that the central estimate of emissions from unloadings (270 Gg/yr, 95% confidence range of 190–400 Gg) are within a few percent of the emissions estimated in the EPA 2012 Greenhouse Gas National Emission Inventory (released in 2014), with emissions dominated by wells with high frequencies of unloadings.

December 9, 2014. [*Category:* Climate]

Methane Emissions from Process Equipment at Natural Gas Production Sites in the United States: Pneumatic Controllers.

- Allen, David T.; Pacsi, Adam P.; Sullivan, David W.; Zavala-Araiza, Daniel; Harrison, Matthew; Keen, Kindal; Fraser, Matthew P.; Daniel Hill, A.; Sawyer, Robert F.; Seinfeld, John H.

- In: *Environmental Science & Technology*, Vol. 49, Issue 1, pages 633-640.
- http://dx.doi.org/10.1021/es5040156

Abstract: Emissions from 377 gas actuated (pneumatic) controllers were measured at natural gas production sites and a small number of oil production sites, throughout the United States. A small subset of the devices (19%), with whole gas emission rates in excess of 6 standard cubic feet per hour (scf/h), accounted for 95% of emissions. More than half of the controllers recorded emissions of 0.001 scf/h or less during 15 min of measurement. Pneumatic controllers in level control applications on separators and in compressor applications had higher emission rates than controllers in other types of applications. Regional differences in emissions were observed, with the lowest emissions measured in the Rocky Mountains and the highest emissions in the Gulf Coast. Average methane emissions per controller reported in this work are 17% higher than the average emissions per controller in the 2012 EPA greenhouse gas national emission inventory (2012 GHG NEI, released in 2014); the average of 2.7 controllers per well observed in this work is higher than the 1.0 controllers per well reported in the 2012 GHG NEI.

December 8, 2014. [*Category:* Water Usage]

Will water scarcity in semiarid regions limit hydraulic fracturing of shale plays?

- Scanlon, Bridget R.; Reedy, Robert C.; Nicot, Jean Philippe.
- In: *Environmental Research Letters,* Vol. 9, Issue 12.
- http://iopscience.iop.org/1748-9326/9/12/124011

Abstract: There is increasing concern about water constraints limiting oil and gas production using hydraulic fracturing (HF) in shale plays, particularly in semiarid regions and during droughts. Here we evaluate HF vulnerability by comparing HF water demand with supply in the semiarid Texas Eagle Ford play, the largest shale oil producer globally. Current HF water demand (18 billion gallons, bgal; 68 billion liters, bL in 2013) equates to ~16% of total water consumption in the play area. Projected HF water demand of ~330 bgal with ~62 000 additional wells over the next 20 years equates to ~10% of historic groundwater depletion from regional irrigation. Estimated potential freshwater supplies include ~1000 bgal over 20 yr from recharge and ~10 000 bgal from aquifer storage, with land-owner lease agreements often stipulating purchase of freshwater. However, pumpage has resulted in excessive drawdown locally with estimated declines of ~100–200 ft in ~6% of the western play area since HF began in 2009–2013. Non-freshwater sources include initial flowback water, which is ≤5% of HF water demand, limiting reuse/recycling. Operators report shifting to brackish groundwater with estimated groundwater storage of 80 000 bgal. Comparison with other semiarid plays indicates increasing brackish groundwater and produced water use in the Permian Basin and large surface water inputs from the Missouri River in the Bakken play. The variety of water sources in semiarid regions, with projected HF water demand representing ~3% of fresh and ~1% of brackish water storage in the Eagle Ford footprint indicates that, with appropriate management, water availability should not physically limit future shale energy production.

December 5, 2014. [*Category:* Health]

Developmental and reproductive effects of chemicals associated with unconventional oil and natural gas operations.

- Webb, Ellen; Bushkin-Bedient, Sheila; Cheng, Amanda; Kassotis, Christopher D.; Balise, Victoria; Nagel, Susan C.
- In: *Reviews on Environmental Health*, Vol. 29, Issue 4, pages 307-318.
- http://www.degruyter.com/view/j/reveh.2014.29.issue-4/reveh-2014-0057/reveh-2014-0057.xml

Abstract: Unconventional oil and gas (UOG) operations have the potential to increase air and water pollution in communities located near UOG operations. Every stage of UOG operation from well construction to extraction, operations, transportation, and distribution can lead to air and water contamination. Hundreds of chemicals are associated with the process of unconventional oil and natural gas production. In this work, we review the scientific literature providing evidence that adult and early life exposure to chemicals associated with UOG operations can result in adverse reproductive health and developmental effects in humans. Volatile organic compounds (VOCs) [including benzene, toluene, ethyl benzene, and xylene (BTEX) and formaldehyde] and heavy metals (including arsenic, cadmium and lead) are just a few of the known contributors to reduced air and water quality that pose a threat to human developmental and reproductive health. The developing fetus is particularly sensitive to environmental factors, which include air and water pollution. Research shows that there are critical windows of vulnerability during prenatal and early postnatal development, during which chemical exposures can cause potentially permanent damage to the growing embryo and fetus. Many of the air and water pollutants found near UOG operation sites are recognized as being developmental and reproductive toxicants; therefore there is a compelling need to increase our knowledge of the potential health consequences for adults, infants, and children from these chemicals through rapid and thorough health research investigation.

December 2, 2014. [*Category:* Ecology]

Monitoring and modeling wetland chloride concentrations in relationship to oil and gas development.

- Post van der Burg, Max; Tangen, Brian A.
- In: *Journal of Environmental Management*, Vol. 150, March 2015, pages 12-127.
- http://www.sciencedirect.com/science/article/pii/S0301479714005209

Abstract: Extraction of oil and gas via unconventional methods is becoming an important aspect of energy production worldwide. Studying the effects of this development in countries where these technologies are being widely used may provide other countries, where development may be proposed, with some insight in terms of concerns associated with development. A fairly recent expansion of unconventional oil and gas development in North America provides such an opportunity. Rapid increases in energy development in North America have caught the attention of managers and scientists as a potential stressor for wildlife and their habitats. Of particular concern in the Northern Great Plains of the U.S. is the potential for chloride-rich produced water associated with unconventional oil and gas development to alter the water chemistry of wetlands. We describe a landscape scale modeling approach designed to examine the relationship between potential chloride contamination in wetlands and patterns of oil and gas development. We used a spatial Bayesian hierarchical modeling approach to assess multiple models explaining chloride concentrations in wetlands. These models included effects related to oil and gas wells (e.g. age of wells, number of wells) and surficial geology (e.g. glacial till, outwash). We found that the model containing the number of wells and the surficial geology surrounding a wetland best explained variation in chloride concentrations. Our spatial predictions showed regions of localized high chloride concentrations. Given the spatiotemporal variability of regional wetland water chemistry, we do not regard our results as predictions of contamination, but rather as a way to identify locations that may require more intensive sampling or further investigation. We suggest that an approach like the one outlined here could easily be extended to more of an adaptive monitoring approach to answer questions about chloride contamination risk that are of interest to managers.

December, 2014. [*Category:* Air Quality]

Impact of emissions from natural gas production facilities on ambient air quality in the Barnett Shale area: a pilot study.

- Zielinska, Barbara; Campbell, Dave; Samburova, Vera.
- In: *Journal of the Air & Waste Management Association*, Vol. 64, Issue 12, December 2014, pages 1369-1383.
- http://www.ncbi.nlm.nih.gov/pubmed/25562933

Abstract: Rapid and extensive development of shale gas resources in the Barnett Shale region of Texas in recent years has created concerns about potential environmental impacts on water and air quality. The purpose of this study was to provide a better understanding of the potential contributions of emissions from gas production operations to population exposure to air toxics in the Barnett Shale region. This goal was approached using a combination of chemical characterization of the volatile organic compound (VOC) emissions from active wells, saturation monitoring for gaseous and particulate pollutants in a residential community located near active gas/oil extraction and processing facilities, source apportionment of VOCs measured in the community using the Chemical Mass Balance (CMB) receptor model, and direct measurements of the pollutant gradient downwind of a gas well with high VOC emissions. Overall, the study results indicate that air quality impacts due to individual gas wells and compressor stations are not likely to be discernible beyond a distance of approximately 100 m in the downwind direction. However, source apportionment results indicate a significant contribution to regional VOCs from gas production sources, particularly for lower-molecular-weight alkanes (< C6). Although measured ambient VOC concentrations were well below health-based safe exposure levels, the existence of urban-level mean concentrations of benzene and other mobile source air toxics combined with soot to total carbon ratios that were high for an area with little residential or commercial development may be indicative of the impact of increased heavy-duty vehicle traffic related to gas production. Implications: Rapid and extensive development of shale gas resources in recent years has created concerns about potential environmental impacts on water and air quality. This study focused on directly measuring the ambient air pollutant levels occurring at residential properties located near natural gas extraction and processing facilities, and estimating the relative contributions from gas production and motor vehicle emissions to ambient VOC concentrations. Although only a small-scale case study, the results may be useful for guidance in planning future ambient air quality studies and human exposure estimates in areas of intensive shale gas production.

November 26, 2014. [*Category:* General (Comment / Review)]

Ethical concerns surrounding unconventional oil and gas development and vulnerable populations.

- Hays, Jake.
- In: *Reviews on Environmental Health*, Vol. 29, Issue 4, pages 275-276.
- http://www.degruyter.com/view/j/reveh.2014.29.issue-4/reveh-2014-0071/reveh-2014-0071.xml

Extract: Oil and gas production from unconventional resources has sparked intense policy debates in the US and abroad. Since the development of shale and other tight formations became commercially viable, questions have arisen concerning potential economic gains, employment increases, and energy independence as well as about potential harms to the environment and public health. A spate of scientific literature has accompanied the boom in oil and gas production, addressing many of the aforementioned concerns. (A near exhaustive collection of the peer-reviewed scientific literature on shale gas development is available at http://psehealthyenergy.org/site/view/1180)

November 24, 2014. [*Category:* Health]

Traumatic Injuries Incidental to Hydraulic Well Fracturing: A Case Series.

- Williams, James F.; Lundy, Jonathan B.; Chung, Kevin K.; Chan, Rodney K.; King, Booker T.; Renz, Evan M.; Cancio, Leopoldo C.
- To be published in: *Journal of Burn Care & Research* (2015).
- http://journals.lww.com/burncareresearch/Citation/publishahead/Traumatic_Injuries_Incidental_to_Hydraulic_Well.98760.aspx

Extract: In 1991, the U.S. National Safety Council deemed the oil and gas extraction industry has having 49% higher nonfatal injury rate than all other U.S. industries combined. Given the increase of hydraulic well fracturing and the past record of nonfatal injury within the oil and gas extraction industry, we anticipate that hydraulic fracturing will contribute to increasing number of injuries. The purpose of this report is to describe injuries related to hydraulic well fracturing (or “fracking”) in patients admitted to our burn center over a 14-month period.

November 26, 2014. [*Category:* Waste / Fluids]

Biocides in Hydraulic Fracturing Fluids: A Critical Review of Their Usage, Mobility, Degradation, and Toxicity.

- Kahrilas, Genevieve A.; Blotevogel, Jens; Stewart, Phil; Borch, Thomas.

- In: *Environmental Science & Technology*, Vol. 49, Issue 1, pages 16-32.
- http://dx.doi.org/10.1021/es503724k

Abstract: Biocides are critical components of hydraulic fracturing ("fracking") fluids used for unconventional shale gas development. Bacteria may cause bioclogging and inhibit gas extraction, produce toxic hydrogen sulfide, and induce corrosion leading to downhole equipment failure. The use of biocides such as glutaraldehyde and quaternary ammonium compounds has spurred a public concern and debate among regulators regarding the impact of inadvertent releases into the environment on ecosystem and human health. This article provides a critical review of the potential fate and toxicity of biocides used in hydraulic fracturing operations. We identified the following physicochemical and toxicological aspects as well as knowledge gaps that should be considered when selecting biocides: (1) uncharged species will dominate in the aqueous phase and be subject to degradation and transport whereas charged species will sorb to soils and be less bioavailable; (2) many biocides are short-lived or degradable through abiotic and biotic processes but some may transform into more toxic or persistent compounds; (3) understanding of biocides' fate under downhole conditions (high pressure, temperature, salt and organic matter concentrations) is limited; (4) several biocidal alternatives exist, but high cost, high energy demands, and/or formation of disinfection byproducts limit their use. This review may serve as a guide for environmental risk assessment and identification of microbial control strategies to help develop a sustainable path for managing hydraulic fracturing fluids.

November 17, 2014. [*Category:* Climate]

Emission Factors for Hydraulically Fractured Gas Wells Derived Using Well- and Battery-level Reported Data for Alberta, Canada.

- Tyner, David R.; Johnson, Matthew R.

- In: *Environmental Science & Technology*, Vol. 48, Issue 24, pages 14772-14781.
- http://pubs.acs.org/doi/abs/10.1021/es502815b

Abstract: A comprehensive technical analysis of available industry-reported well activity and production data for Alberta in 2011 has been used to derive flaring, venting, and diesel combustion greenhouse gas and criteria air contaminant emission factors specifically linked to drilling, completion, and operation of hydraulically fractured natural gas wells. Analysis revealed that in-line ("green") completions were used at approximately 53% of wells completed in 2011, and in other cases the majority (99.5%) of flowback gases were flared rather than vented. Comparisons with limited analogous data available in the literature revealed that reported total flared and vented natural gas volumes attributable to tight gas well-completions were ~6 times larger than Canadian Association of Petroleum Producers (CAPP) estimates for natural gas well-completion based on wells ca. 2000, but 62% less than an equivalent emission factor that can be derived from U.S. EPA data. Newly derived emission factors for diesel combustion during well drilling and completion are thought to be among the first such data available in the open literature, where drilling-related emissions for tight gas wells drilled in Alberta in 2011 were found to have increased by a factor of 2.8 relative to a typical well drilled in Canada in 2000 due to increased drilling lengths. From well-by-well analysis of production phase flared, vented, and fuel usage natural gas volumes reported at 3846 operating tight gas wells in 2011, operational emission factors were developed. Overall results highlight the importance of operational phase GHG emissions at upstream well sites (including on-site natural gas fuel use), and the critical levels of uncertainty in current estimates of liquid unloading emissions.

November 14, 2014. [*Category:* General (Comment / Review)]

Information Collection, Access, and Dissemination to Support Evidence-Based Shale Gas Policies.

- Gamper-Rabindran, Shanti.
- In: *Energy Technology*, Vol. 2, Issue 12, pages 977-987.
- http://onlinelibrary.wiley.com/doi/10.1002/ente.201402114/abstract

Abstract: To ensure that unconventional shale gas development (UGD) yields net social benefits, we need to identify the magnitude and distribution of its benefits and costs and develop effective technological, management, and regulatory strategies to minimize potential adverse effects. A major obstacle to achieve these goals is the gaps in the collection, access, and dissemination of information. This paper focuses on information gaps to assess a narrow subset of the potential links between UGD and well-water contamination, drawing particularly from the experience in Pennsylvania. It suggests strategies for legislators, regulators, industry, and researchers to address these information gaps, while protecting legitimate privacy concerns. The benefits from an improved understanding of the impact of this industry and resulting innovations to mitigate its impacts justifies the cost of data collection, access, and dissemination.

November 14, 2014. [*Category:* Air Quality]

Influence of oil and gas emissions on ambient atmospheric non-methane hydrocarbons in residential areas of Northeastern Colorado.

- Thompson, Chelsea R.; Hueber, Jacques; Helmig, Detlev.
- In: *Elementa: Science of the Anthropocene*, Vol. 2, 17 pages.
- http://www.elementascience.org/article/info:doi/10.12952/journal.elementa.000035

Abstract: The Northern Front Range (NFR) region of Colorado has experienced rapid expansion of oil and gas extraction from shale and tight sands reservoirs in recent years due to advances in hydraulic fracturing technology, with over 25,000 wells currently in operation. This region has also been designated as a federal ozone non-attainment area by the U.S. EPA. High ozone levels are a significant health concern, as are potential health impacts from chronic exposure to primary emissions of non-methane hydrocarbons (NMHC) for residents living near wells. From measurements of ambient atmospheric NMHC present in residential areas located in close proximity to wells in Erie, Colorado, we find that mean mole fractions of the C2–C5 alkanes are enhanced by a factor of 18–77 relative to the regional background, and present at higher levels than typically found in large urban centers. When combined with NMHC observations from downtown Denver and Platteville, it is apparent that these compounds are elevated across the NFR, with highest levels within the Greater Wattenberg Gas Field. This represents a large area source for ozone precursors in the NFR. The BTEX aromatic compounds in Erie were comparable to (e.g., benzene) or lower than (e.g., toluene, ethylbenzene, xylene) in large urban centers, however, benzene was significantly higher in Platteville, and within the range of chronic health-based exposure levels. An initial look at comparisons with data sets from previous years reveal that ambient levels for oil and gas-related NMHC in Erie, as well as further downwind in Boulder, have not decreased, but appear to have been increasing, despite tightening of emissions standards for the oil and gas industries in 2008. - See more at: http://www.elementascience.org/article/info:doi/10.12952/journal.elementa.000035#sthash.LI052GSI.dpuf

November 14, 2014. [*Category:* Health]

Increased traffic accident rates associated with shale gas drilling in Pennsylvania.

- Graham, Jove; Irving, Jennifer; Tang, Xiaoqin; Sellers, Stephen; Crisp, Joshua; Horwitz, Daniel; Muehlenbachs, Lucija; Krupnick, Alan; Carey, David.
- In: *Accident Analysis & Prevention*, Vol. 74, January 2015, pages 203-209.
- http://www.sciencedirect.com/science/article/pii/S000145751400325X

Abstract

Objectives. We examined the association between shale gas drilling and motor vehicle accident rates in Pennsylvania.

Methods. Using publicly available data on all reported vehicle crashes in Pennsylvania, we compared accident rates in counties with and without shale gas drilling, in periods with and without intermittent drilling (using data from 2005 to 2012). Counties with drilling were matched to non-drilling counties with similar population and traffic in the pre-drilling period.

Results. Heavily drilled counties in the north experienced 15–23% higher vehicle crash rates in 2010–2012 and 61–65% higher heavy truck crash rates in 2011–2012 than control counties. We estimated 5–23% increases in crash rates when comparing months with drilling and months without, but did not find significant effects on fatalities and major injury crashes. Heavily drilled counties in the southwest showed 45–47% higher rates of fatal and major injury crashes in 2012 than control counties, but monthly comparisons of drilling activity showed no significant differences associated with drilling.

Conclusions. Vehicle accidents have measurably increased in conjunction with shale gas drilling.

November 13, 2014. [*Categories:* Community; Health]

Popular Epidemiology and "Fracking": Citizens' Concerns Regarding the Economic, Environmental, Health and Social Impacts of Unconventional Natural Gas Drilling Operations.

- Powers, Martha; Saberi, Poune; Pepino, Richard; Strupp, Emily; Bugos, Eva; Cannuscio, Carolyn C.
- In: *Journal of Community Health*, Vol. 40, Issue 3, pages 534-541.
- http://link.springer.com/article/10.1007%2Fs10900-014-9968-x

Abstract: Pennsylvania sits atop the Marcellus Shale, a reservoir of natural gas that was untapped until the 2004 introduction of unconventional natural gas drilling operations (UNGDO) in the state. Colloquially known as fracking, UNGDO is a controversial process that employs large volumes of water to fracture the shale and capture gas; it has become a multi-billion dollar industry in Pennsylvania. We analyzed letters to the editor of the most widely circulated local newspaper in the most heavily drilled county in Pennsylvania (Bradford County) in order to characterize residents' concerns and their involvement in popular epidemiology—the process by which citizens investigate risks associated with a perceived environmental threat. We reviewed 215 letters to the editor that referenced natural gas operations and were published by *The Daily Review* between January 1, 2008 and June 8, 2013. We used NVivo 10 to code and analyze letters and identify major themes. Nvivo is qualitative data analysis software (http://www.qsrinternational.com/products_nvivo.aspx) that allows researchers to code and analyze "unstructured" data, including text files of any type (e.g., interview transcripts, news articles, letters, archival materials) as well as photographs and videos. Nvivo can be used to classify, sort, query, comment on, and share data across a research group. Letters demonstrated citizen engagement in beginning and intermediate stages of lay epidemiology, as well as discord and stress regarding four main issues: socio-economic impacts, perceived threats to water, population growth and implications, and changes to the rural landscape. Residents called for stronger scientific evidence and a balance of economic development and health and environmental protections. Citizens' distress regarding UNGDO appeared to be exacerbated by a dearth of information to guide economic growth and health, environmental, and social concerns. This analysis proposes locally informed questions to guide future surveillance and research.

November 12, 2014. [*Category:* Health]

Environmental health impacts of unconventional natural gas development: A review of the current strength of evidence.

- Werner, Angela K.; Vink, Sue; Watt, Kerrianne; Jagals, Paul.

- In: *Science of the Total Environment*, Vol. 505, February 1, 2015, pages 1127-1141.
- http://www.sciencedirect.com/science/article/pii/S0048969714015290

Abstract: Rapid global expansion of unconventional natural gas development (UNGD) raises environmental health concerns. Many studies present information on these concerns, yet the strength of epidemiological evidence remains tenuous. This paper is a review of the strength of evidence in scientific reporting of environmental hazards from UNGD activities associated with adverse human health outcomes. Studies were drawn from peer-reviewed and grey literature following a systematic search. Five databases were searched for studies published from January 1995 through March 2014 using key search terms relevant to environmental health. Studies were screened, ranked and then reviewed according to the strength of the evidence presented on adverse environmental health outcomes associated with UNGD. The initial searches yielded > 1000 studies, but this was reduced to 109 relevant studies after the ranking process. Only seven studies were considered highly relevant based on strength of evidence. Articles spanned several relevant topics, but most focussed on impacts on typical environmental media, such as water and air, with much of the health impacts inferred rather than evidenced. Additionally, the majority of studies focussed on short-term, rather than long-term, health impacts, which is expected considering the timeframe of UNGD; therefore, very few studies examined health outcomes with longer latencies such as cancer or developmental outcomes. Current scientific evidence for UNGD that demonstrates associations between adverse health outcomes directly with environmental health hazards resulting from UNGD activities generally lacks methodological rigour. Importantly, however, there is also no evidence to rule out such health impacts. While the current evidence in the scientific research reporting leaves questions unanswered about the actual environmental health impacts, public health concerns remain intense. This is a clear gap in the scientific knowledge that requires urgent attention.

November 11, 2014. [*Category:* Seismicity]

Quantification of potential macroseismic effects of the induced seismicity that might result from hydraulic fracturing for shale gas exploitation in the UK.

- Westaway, Rob; Younger, Paul L.

- In: *Quarterly Journal of Engineering Geology and Hydrogeology*, Vol. 47, Issue 4, pages 333-350.
- http://eprints.gla.ac.uk/96201/

Abstract: The furore that has arisen in the UK over induced microseismicity from 'fracking' for shale gas development, which has resulted in ground vibrations strong enough to be felt, requires the urgent development of an appropriate regulatory framework. We suggest that the existing regulatory limits applicable to quarry blasting (i.e. peak ground velocities (PGV) in the seismic wavefield incident on any residential property of 10 mm s^{-1} during the working day, 2 mm s^{-1} at night, and 4.5 mm s^{-1}1 at other times) can be readily applied to cover such induced seismicity. Levels of vibration of this order do not constitute a hazard: they are similar in magnitude to the 'nuisance' vibrations that may be caused by activities such as walking on wooden floors, or by large vehicles passing on a road outside a building. Using a simple technique based on analysis of the spectra of seismic S-waves, we show that this proposed daytime regulatory limit for PGV is likely to be satisfied directly above the source of a magnitude 3 induced earthquake at a depth of 2.5 km, and illustrate how the proposed limits scale in terms of magnitudes of induced earthquakes at other distances. Previous experience indicates that the length of the fracture networks that are produced by 'fracking' cannot exceed 600 m; the development of a fracture network of this size in one single rupture would correspond to an induced earthquake c. magnitude 3.6. Events of that magnitude would result in PGV above our proposed regulatory limit and might be sufficient to cause minor damage to property, such as cracked plaster; we propose that any such rare occurrences could readily be covered by a system of compensation similar to that used over many decades for damage caused by coal mining. However, it is highly unlikely that future 'fracking' in the UK would cause even this minor damage, because the amount of 'force' applied in 'fracking' tends to be strictly limited by operators: this is because there is an inherent disincentive to fracture sterile overburden, especially where this may contain groundwater that could flood-out the underlying gas-producing zones just developed. For the same reason, seismic monitoring of 'fracking' is routine; the data that it generates could be used directly to police compliance with any regulatory framework. Although inspired by UK conditions and debates, our proposals might also be useful for other regulatory jurisdictions.

November 10, 2014. [*Category:* Climate]

Direct measurements of methane emissions from abandoned oil and gas wells in Pennsylvania.

- Kang, Mary; Kanno, Cynthia M.; Reid, Matthew C.; Zhang, Xin; Mauzerall, Denise L.; Celia, Michael A.; Chen, Yuheng; Onstott, Tullis C.
- In: *Proceedings of the National Academy of Sciences*, Vol. 111, No. 51, pages 18273-18177.
- http://www.pnas.org/content/early/2014/12/04/1408315111

Abstract: Abandoned oil and gas wells provide a potential pathway for subsurface migration and emissions of methane and other fluids to the atmosphere. Little is known about methane fluxes from the millions of abandoned wells that exist in the United States. Here, we report direct measurements of methane fluxes from abandoned oil and gas wells in Pennsylvania, using static flux chambers. A total of 42 and 52 direct measurements were made at wells and at locations near the wells ("controls") in forested, wetland, grassland, and river areas in July, August, October 2013 and January 2014, respectively. The mean methane flow rates at these well locations were 0.27 kg/d/well, and the mean methane flow rate at the control locations was 4.5×10^{-6} kg/d/location. Three out of the 19 measured wells were high emitters that had methane flow rates that were three orders of magnitude larger than the median flow rate of 1.3×10^{-3} kg/d/well. Assuming the mean flow rate found here is representative of all abandoned wells in Pennsylvania, we scaled the methane emissions to be 4–7% of estimated total anthropogenic methane emissions in Pennsylvania. The presence of ethane, propane, and n-butane, along with the methane isotopic composition, indicate that the emitted methane is predominantly of thermogenic origin. These measurements show that methane emissions from abandoned oil and gas wells can be significant. The research required to quantify these emissions nationally should be undertaken so they can be accurately described and included in greenhouse gas emissions inventories.

November 5, 2014. [*Category:* Economics]

Income and Employment Effects of Shale Gas Extraction Windfalls: Evidence from the Marcellus Region.

- Paredes, Dusan; Komarek, Timothy; Loveridge, Scott.
- In: *Energy Economics*, Vol. 47, January 2015, pages 112-120.
- http://www.sciencedirect.com/science/article/pii/S0140988314002540

Abstract: New technologies combining hydraulic fracturing and horizontal drilling in oil and gas extraction are creating a sudden expansion of production. Residents of places where deep underground oil and gas deposits are found want to know about the broader economic, social, and environmental impacts of these activities that generate windfall income for some residents. We first review the literature on windfall spending patterns. Then, using the Marcellus region, the earliest area to be tapped using the new techniques, we estimate county-level employment and income effects. For robustness, we employ two methods. Using a propensity score matching approach we find no effect of fracking on income or employment. A panel-fixed effects regression approach suggests statistically significant employment effects in six out of seven alternative specifications, but significant income effects in only one out of seven specifications. In short, the income spillover effects in the Marcellus region appear to be minimal, meaning there's little incentive at the county level to incur current or potential future costs that may be associated with this activity. We conclude with some ideas on how localities might employ policies that would allow natural gas extraction to move forward, benefitting landowners, while establishing some financial safeguards for the broader community.

November 4, 2014. [*Category:* Economics]

Regional Economic Impacts of the Shale Gas and Tight Oil Boom: A Synthetic Control Analysis.

- Munasib, Abdul; Rickman, Dan S.
- In: *Regional Science and Urban Economics*, Vol. 50, January 2015, pages 1-17.
- http://www.sciencedirect.com/science/article/pii/S0166046214001094

Abstract: The dramatic increase in oil and gas production from shale formations has led to intense interest in its impact on local area economies. Exploration, drilling and extraction are associated with direct increases in employment and income in the energy industry, but little is known about the impacts on other parts of local economies. Increased energy sector employment and income can have positive spillover effects through increased purchases of intermediate goods and induced local spending. Negative spillover effects can occur through rising local factor and goods prices and adverse effects on the local area quality of life. Therefore, this paper examines the net economic impacts of oil and gas production from shale formations for key shale oil and gas producing areas in Arkansas, North Dakota and Pennsylvania. The synthetic control method (Abadie and Gardeazabal 2003; Abadie et al., 2010) is used to establish a baseline projection for the local economies in the absence of increased energy development, allowing for estimation of the net regional economic effects of increased shale oil and gas production.

November 4, 2014. [*Category:* Water Quality]

Assessing impacts of unconventional natural gas extraction on microbial communities in headwater stream ecosystems in Northwestern Pennsylvania.

- Trexler, Ryan; Solomon, Caroline; Brislawn, Colin J.; Wright, Justin R.; Rosenberger, Abigail; McClure, Erin E.; Grube, Alyssa M.; Peterson, Mark P.; Keddache, Mehdi; Mason, Olivia U.; Hazen, Terry C.; Grant, Christopher J.; Lamendella, Regina.
- In: *Aquatic Microbiology*, Vol. 5.
- http://journal.frontiersin.org/Journal/10.3389/fmicb.2014.00522/abstract

Abstract: Hydraulic fracturing and horizontal drilling have increased dramatically in Pennsylvania Marcellus shale formations, however the potential for major environmental impacts are still incompletely understood. High-throughput sequencing of the 16S rRNA gene was performed to characterize the microbial community structure of water, sediment, bryophyte, and biofilm samples from 26 headwater stream sites in northwestern Pennsylvania with different histories of fracking activity within Marcellus shale formations. Further, we describe the relationship between microbial community structure and environmental parameters measured. Approximately 3.2 million 16S rRNA gene sequences were retrieved from a total of 58 samples. Microbial community analyses showed significant reductions in species richness as well as evenness in sites with Marcellus shale activity. Beta diversity analyses revealed distinct microbial community structure between sites with and without Marcellus shale activity. For example, operational taxonomic units (OTUs) within the Acetobacteracea, Methylocystaceae, Acidobacteriaceae, and Phenylobacterium were greater than three log-fold more abundant in MSA+ sites as compared to MSA− sites. Further, several of these OTUs were strongly negatively correlated with pH and positively correlated with the number of wellpads in a watershed. It should be noted that many of the OTUs enriched in MSA+ sites are putative acidophilic and/or methanotrophic populations. This study revealed apparent shifts in the autochthonous microbial communities and highlighted potential members that could be responding to changing stream conditions as a result of nascent industrial activity in these aquatic ecosystems.

November 3, 2014. [*Category:* Climate]

Ground Gas Monitoring: Implications for Hydraulic Fracturing and CO2 Storage.

- Teasdale, Christopher J.; Hall, Jean A.; Martin, John P.; Manning, David A. C.
- In: *Environmental Science & Technology*, Vol. 48, Issue 23, pages 13610-13616.
- http://pubs.acs.org/doi/full/10.1021/es502528c & http://pubs.acs.org/doi/pdf/10.1021/es502528c

Abstract: Understanding the exchange of carbon dioxide (CO2) and methane (CH4) between the geosphere and atmosphere is essential for the management of anthropogenic emissions. Human activities such as Carbon Capture and Storage and hydraulic fracturing ('fracking') affect the natural system and pose risks to future global warming and to human health and safety if not engineered to a high standard. In this paper an innovative approach of expressing ground gas compositions is presented, using data derived from regulatory monitoring of boreholes in the unsaturated zone at infrequent intervals (typically 3 months) with data from a high frequency monitoring instrument deployed over periods of weeks. Similar highly variable trends are observed for timescales ranging from decades to hourly for boreholes located close to sanitary landfill sites. Additionally, high frequency monitoring data confirm the effect of meteorological controls on ground gas emissions; the maximum observed CH4 and CO2 concentrations in a borehole monitored over two weeks were 40.1% v/v and 8.5% v/v respectively, but for 70% of the monitoring period only air was present. There is a clear weakness in current point monitoring strategies that may miss emission events and this needs to be considered along with obtaining baseline data prior to starting any engineering activity.

November 1, 2014. [*Category:* Waste / Fluids]

Influence of softening sequencing on electrocoagulation treatment of produced water.

- Esmaeilirad, Nasim; Carlson, Ken; Omur Ozbek, Pinar.
- In: *Journal of Hazardous Materials*, Vol. 283C, pages 721-729.
- http://www.ncbi.nlm.nih.gov/pubmed/25464315

Abstract: Electrocoagulation has been used to remove solids and some metals from both water and wastewater sources for decades. Additionally, chemical softening is commonly employed in water treatment systems to remove hardness. This paper assesses the combination and sequence of softening and EC methods to treat hydraulic fracturing flowback and produced water from shale oil and gas operations. EC is one of the available technologies to treat produced water for reuse in frac fluids, eliminating not only the need to transport more water but also the costs of providing fresh water. In this paper, the influence of chemical softening on EC was studied. In the softening process, pH was raised to 9.5 and 10.2 before and after EC, respectively. Softening, when practiced before EC was more effective for removing turbidity with samples from wells older than one month (99% versus 88%). However, neither method was successful in treating samples collected from early flowback (1-day and 2-day samples), likely due to the high concentration of organic matter. For total organic carbon, hardness, Ba, Sr, and B removal, application of softening before EC appeared to be the most efficient approach, likely due to the formation of solids before the coagulation process.

November, 2014. [*Category:* Regulation]

Regulation of hydraulic fracturing operations at the federal and state levels.

- Hertzler, Patricia Carroll.
- In: *Journal American Water Works Association,* Vol. 106, Issue 11, pages 58-65.
- http://www.awwa.org/publications/journal-awwa/abstract/articleid/47898896.aspx

Abstract: Despite the abundance of federal and state legislation intended to regulate hydraulic fracturing, numerous studies indicate that there are gaps in these efforts.

November, 2014. [*Category:* Water Quality]

Direct and indirect challenges for water quality from the hydraulic fracturing industry.

- Long, Sharon C.
- In: *Journal American Water Works Association*, Vol. 106, Issue 11, pages 53-57.
- http://www.awwa.org/publications/journal-awwa/abstract/articleid/47899154.aspx

Abstract: This article describes proactive water-quality monitoring approaches that are useful for water utilities and suppliers concerned with the increased use of hydraulic fracturing in the production of domestic oil and gas.

October 30, 2014. [*Categories:* Air Quality, Health]

Air concentrations of volatile compounds near oil and gas production: a community-based exploratory study.

- Macey, Gregg P.; Breech, Ruth; Chernaik, Mark; Cox, Caroline; Larson, Denny; Thomas, Deb; Carpenter, David O.
- In: *Environmental Health*, Vol. 13, Issue 1 (82 pages).
- http://www.ehjournal.net/content/13/1/82/abstract

Abstract: Horizontal drilling, hydraulic fracturing, and other drilling and well stimulation technologies are now used widely in the United States and increasingly in other countries. They enable increases in oil and gas production, but there has been inadequate attention to human health impacts. Air quality near oil and gas operations is an underexplored human health concern for five reasons: (1) prior focus on threats to water quality; (2) an evolving understanding of contributions of certain oil and gas production processes to air quality; (3) limited state air quality monitoring networks; (4) significant variability in air emissions and concentrations; and (5) air quality research that misses impacts important to residents. Preliminary research suggests that volatile compounds, including hazardous air pollutants, are of potential concern. This study differs from prior research in its use of a community-based process to identify sampling locations. Through this approach, we determine concentrations of volatile compounds in air near operations that reflect community concerns and point to the need for more fine-grained and frequent monitoring at points along the production life cycle.

October 22, 2014. [*Category:* Waste / Fluids]

Shale gas produced water treatment using innovative microbial capacitive desalination cell.

- Stoll, Zachary A.; Forrestal, Casey; Ren, Zhiyong Jason; Xu, Pei.
- In: *Journal of Hazardous Waste Materials*, Vol. 283C, pages 847-855.
- http://www.ncbi.nlm.nih.gov/pubmed/25464328

Abstract: The rapid development of unconventional oil and gas production has generated large amounts of wastewater for disposal, raising significant environmental and public health concerns. Treatment and beneficial use of produced water presents many challenges due to its high concentrations of petroleum hydrocarbons and salinity. The objectives of this study were to investigate the feasibility of treating actual shale gas produced water using a bioelectrochemical system integrated with capacitive deionization-a microbial capacitive desalination cell (MCDC). Microbial degradation of organic compounds in the anode generated an electric potential that drove the desalination of produced water. Sorption and biodegradation resulted in a combined organic removal rate of 6.4mg dissolved organic carbon per hour in the reactor, and the MCDC removed 36mg salt per gram of carbon electrode per hour from produced water. This study is a proof-of-concept that the MCDC can be used to combine organic degradation with desalination of contaminated water without external energy input.

October 22, 2014. [*Category:* General (Comment / Review)]

Shale Gas: Current Perspectives and Future Prospects in Turkey and the World.

- Kok, M. V.; Merey, S.
- In: *Energy Sources, Part A: Recovery, Utilization, and Environmental Effects*, Vol. 36, Issue 22, pages 2492-2501.
- http://dx.doi.org/10.1080/15567036.2014.943854

Abstract: With the increased natural gas prices and advancement in the horizontal drilling and hydraulic fracturing technology, there is a high interest in shale gas reservoirs in the world and in Turkey. However, gas production from shale gas reservoirs is quite different than conventional gas reservoirs because permeability in shale gas reservoirs is very low and production mechanism is different due to adsorbed gas and free gas together in these reservoirs. The aim of study is to clarify shale gas reservoirs in terms of the world and Turkey's shale gas potential, gas production mechanism, and current techniques applied.

October 22, 2014. [*Category:* Waste / Fluids]

The Functional Potential of Microbial Communities in Hydraulic Fracturing Source Water and Produced Water from Natural Gas Extraction Characterized by Metagenomic Sequencing.

- Mohan, Arvind Murali; Bibby, Kyle J.; Lipus, Daniel; Hammack, Richard W.; Gregory, Kelvin B.

- In: *PLOS ONE*, Vol. 9, Issue 10, page e107682.
- http://dx.doi.org/10.1371/journal.pone.0107682

Abstract: Microbial activity in produced water from hydraulic fracturing operations can lead to undesired environmental impacts and increase gas production costs. However, the metabolic profile of these microbial communities is not well understood. Here, for the first time, we present results from a shotgun metagenome of microbial communities in both hydraulic fracturing source water and wastewater produced by hydraulic fracturing. Taxonomic analyses showed an increase in anaerobic/facultative anaerobic classes related to Clostridia, Gammaproteobacteria, Bacteroidia and Epsilonproteobacteria in produced water as compared to predominantly aerobic Alphaproteobacteria in the fracturing source water. The metabolic profile revealed a relative increase in genes responsible for carbohydrate metabolism, respiration, sporulation and dormancy, iron acquisition and metabolism, stress response and sulfur metabolism in the produced water samples. These results suggest that microbial communities in produced water have an increased genetic ability to handle stress, which has significant implications for produced water management, such as disinfection.

October 20, 2014. [*Categories:* Air Quality, Climate]

Emissions Implications of Future Natural Gas Production and Use in the U.S. and in the Rocky Mountain Region.

- McLeod, Jeffrey D.; Brinkman, Gregory L.; Milford, Jana B.

- In: *Environmental Science & Technology*, Vol. 48, Issue 22, pages 13036-13044.
- http://pubs.acs.org/doi/abs/10.1021/es5029537

Abstract: Enhanced prospects for natural gas production raise questions about the balance of impacts on air quality, as increased emissions from production activities are considered alongside the reductions expected when natural gas is burned in place of other fossil fuels. This study explores how trends in natural gas production over the coming decades might affect emissions of greenhouse gases (GHG), volatile organic compounds (VOCs) and nitrogen oxides (NO_x) for the United States and its Rocky Mountain region. The MARKAL (MARKet ALlocation) energy system optimization model is used with the U.S. Environmental Protection Agency's nine-region database to compare scenarios for natural gas supply and demand, constraints on the electricity generation mix, and GHG emissions fees. Through 2050, total energy system GHG emissions show little response to natural gas supply assumptions, due to offsetting changes across sectors. Policy-driven constraints or emissions fees are needed to achieve net reductions. In most scenarios, wind is a less expensive source of new electricity supplies in the Rocky Mountain region than natural gas. U.S. NO_x emissions decline in all the scenarios considered. Increased VOC emissions from natural gas production offset part of the anticipated reductions from the transportation sector, especially in the Rocky Mountain region.

October 20, 2014. [*Category:* Water Quality]

New Tracers Identify Hydraulic Fracturing Fluids and Accidental Releases from Oil and Gas Operations.

- Warner, N. R.; Darrah, T. H.; Jackson, R. B.; Millot, R.; Kloppmann, W.; Vengosh, A.
- In: Environmental Science & Technology, Vol. 48, Issue 21, pages 12552-12560.
- http://dx.doi.org/10.1021/es5032135

Abstract: Identifying the geochemical fingerprints of fluids that return to the surface after high volume hydraulic fracturing of unconventional oil and gas reservoirs has important applications for assessing hydrocarbon resource recovery, environmental impacts, and wastewater treatment and disposal. Here, we report for the first time, novel diagnostic elemental and isotopic signatures (B/Cl, Li/Cl, $\delta^{11}B$, and $\delta^{7}Li$) useful for characterizing hydraulic fracturing flowback fluids (HFFF) and distinguishing sources of HFFF in the environment. Data from 39 HFFFs and produced water samples show that B/Cl (>0.001), Li/Cl (>0.002), $\delta^{11}B$ (25–31‰) and $\delta^{7}Li$ (6–10‰) compositions of HFFF from the Marcellus and Fayetteville black shale formations were distinct in most cases from produced waters sampled from conventional oil and gas wells. We posit that boron isotope geochemistry can be used to quantify small fractions (~0.1%) of HFFF in contaminated fresh water and likely be applied universally to trace HFFF in other basins. The novel environmental application of this diagnostic isotopic tool is validated by examining the composition of effluent discharge from an oil and gas brine treatment facility in Pennsylvania and an accidental spill site in West Virginia. We hypothesize that the boron and lithium are mobilized from exchangeable sites on clay minerals in the shale formations during the hydraulic fracturing process, resulting in the relative enrichment of boron and lithium in HFFF.

October 15, 2014. [*Category:* Climate]

Limited impact on decadal-scale climate change from increased use of natural gas.

- McJeon, Haewon; Edmonds, Jae; Bauer, Nico; Clarke, Leon; Fisher, Brian; Flannery, Brian P.; Hilaire, Jerome; Krey, Volker; Marangoni, Giacomo; Mi, Raymond; Riahi, Keywan; Rogner, Holger; Tavoni, Massimo.
- In: *Nature*, Vol. 514, pages 482-485.
- http://www.nature.com/nature/journal/v514/n7523/full/nature13837.html

Abstract: The most important energy development of the past decade has been the wide deployment of hydraulic fracturing technologies that enable the production of previously uneconomic shale gas resources in North America. If these advanced gas production technologies were to be deployed globally, the energy market could see a large influx of economically competitive unconventional gas resources. The climate implications of such abundant natural gas have been hotly debated. Some researchers have observed that abundant natural gas substituting for coal could reduce carbon dioxide (CO_2) emissions. Others have reported that the non-CO_2 greenhouse gas emissions associated with shale gas production make its lifecycle emissions higher than those of coal. Assessment of the full impact of abundant gas on climate change requires an integrated approach to the global energy–economy–climate systems, but the literature has been limited in either its geographic scope or its coverage of greenhouse gases. Here we show that market-driven increases in global supplies of unconventional natural gas do not discernibly reduce the trajectory of greenhouse gas emissions or climate forcing. Our results, based on simulations from five state-of-the-art integrated assessment models of energy–economy–climate systems independently forced by an abundant gas scenario, project large additional natural gas consumption of up to +170 per cent by 2050. The impact on CO_2 emissions, however, is found to be much smaller (from −2 per cent to +11 per cent), and a majority of the models reported a small increase in climate forcing (from −0.3 per cent to +7 per cent) associated with the increased use of abundant gas. Our results show that although market penetration of globally abundant gas may substantially change the future energy system, it is not necessarily an effective substitute for climate change mitigation policy.

October 9, 2014. [*Category:* Climate]

Four corners: The largest US methane anomaly viewed from space.

- Kort, Eric A.; Frankenberg, Christian; Costigan, Keeley R.; Lindenmaier, Rodica; Dubey, Manvendra K.; Wunch, Debra.
- In: *Geophysical Research Letters*, Vol. 41, Issue 19, pages 6898-6903.
- http://onlinelibrary.wiley.com/doi/10.1002/2014GL061503/abstract

Abstract: Methane (CH4) is a potent greenhouse gas and ozone precursor. Quantifying methane emissions is critical for projecting and mitigating changes to climate and air quality. Here we present CH4 observations made from space combined with Earth-based remote sensing column measurements. Results indicate the largest anomalous CH4 levels viewable from space over the conterminous U.S. are located at the Four Corners region in the Southwest U.S. Emissions exceeding inventory estimates, totaling 0.59 Tg CH4/yr [0.50–0.67; 2σ], are necessary to bring high-resolution simulations and observations into agreement. This underestimated source approaches 10% of the EPA estimate of total U.S. CH4 emissions from natural gas. The persistence of this CH4 signal from 2003 onward indicates that the source is likely from established gas, coal, and coalbed methane mining and processing. This work demonstrates that space-based observations can identify anomalous CH4 emission source regions and quantify their emissions with the use of a transport model.

October 7, 2014. [*Category:* Ecology]

Ecological Risks of Shale Oil and Gas Development to Wildlife, Aquatic Resources and their Habitats.

- Brittingham, Margaret C.; Maloney, Kelly O.; Farag, Aïda M.; Harper, David D.; Bowen, Zachary H.

- In: *Environmental Science & Technology*, Vol. 48, Issue 19, pages 11034-11047.
- http://dx.doi.org/10.1021/es5020482

Abstract: Technological advances in hydraulic fracturing and horizontal drilling have led to the exploration and exploitation of shale oil and gas both nationally and internationally. Extensive development of shale resources has occurred within the United States over the past decade, yet full build out is not expected to occur for years. Moreover, countries across the globe have large shale resources and are beginning to explore extraction of these resources. Extraction of shale resources is a multistep process that includes site identification, well pad and infrastructure development, well drilling, high-volume hydraulic fracturing and production; each with its own propensity to affect associated ecosystems. Some potential effects, for example from well pad, road and pipeline development, will likely be similar to other anthropogenic activities like conventional gas drilling, land clearing, exurban and agricultural development and surface mining (e.g., habitat fragmentation and sedimentation). Therefore, we can use the large body of literature available on the ecological effects of these activities to estimate potential effects from shale development on nearby ecosystems. However, other effects, such as accidental release of wastewaters, are novel to the shale gas extraction process making it harder to predict potential outcomes. Here, we review current knowledge of the effects of high-volume hydraulic fracturing coupled with horizontal drilling on terrestrial and aquatic ecosystems in the contiguous United States, an area that includes 20 shale plays many of which have experienced extensive development over the past decade. We conclude that species and habitats most at risk are ones where there is an extensive overlap between a species range or habitat type and one of the shale plays (leading to high vulnerability) coupled with intrinsic characteristics such as limited range, small population size, specialized habitat requirements, and high sensitivity to disturbance. Examples include core forest habitat and forest specialists, sagebrush habitat and specialists, vernal pond inhabitants and stream biota. We suggest five general areas of research and monitoring that could aid in development of effective guidelines and policies to minimize negative impacts and protect vulnerable species and ecosystems: (1) spatial analyses, (2) species-based modeling, (3) vulnerability assessments, (4) ecoregional assessments, and (5) threshold and toxicity evaluations.

October 6, 2014. [*Category:* Climate]

Remote sensing of fugitive methane emissions from oil and gas production in North American tight geologic formations.

- Schneising, Oliver; Burrows, John P.; Dickerson, Russell R.; Buchwitz, Michael; Reuter, Maximilian; Bovensmann, Heinrich.
- In: *Earth's Future*, Vol. 2, Issue 10, pages 548-558.
- http://onlinelibrary.wiley.com/doi/10.1002/2014EF000265/full

Abstract: In the past decade there has been a massive growth in the horizontal drilling and hydraulic fracturing of shale gas and tight oil reservoirs to exploit formerly inaccessible or unprofitable energy resources in rock formations with low permeability. In North America, these unconventional domestic sources of natural gas and oil provide an opportunity to achieve energy self-sufficiency and to reduce greenhouse gas emissions when displacing coal as a source of energy in power plants. However, fugitive methane emissions in the production process may counter the benefit over coal with respect to climate change and therefore need to be well quantified. Here we demonstrate that positive methane anomalies associated with the oil and gas industries can be detected from space and that corresponding regional emissions can be constrained using satellite observations. Based on a mass-balance approach, we estimate that methane emissions for two of the fastest growing production regions in the United States, the Bakken and Eagle Ford formations, have increased by 990 ± 650 ktCH 4 yr − 1 and 530 ± 330 ktCH 4 yr − 1 between the periods 2006–2008 and 2009–2011. Relative to the respective increases in oil and gas production, these emission estimates correspond to leakages of $10.1 \pm 7.3\%$ and $9.1 \pm 6.2\%$ in terms of energy content, calling immediate climate benefit into question and indicating that current inventories likely underestimate fugitive emissions from Bakken and Eagle Ford.

October 1, 2014. [*Category:* Air Quality]

High winter ozone pollution from carbonyl photolysis in an oil and gas basin.

- Peter M. Edwards; Steven S. Brown; James M. Roberts; Ravan Ahmadov; Robert M. Banta; Joost A. DeGouw; William P. Dubé; Robert A. Field; James H. Flynn; Jessica B. Gilman; Martin Graus; Detlev Helmig; Abigail Koss; Andrew O. Langford; Barry L. Lefer; Brian M. Lerner; Rui Li; Shao-Meng Li; Stuart A. McKeen; Shane M. Murphy; David D. Parrish; Christoph J. Senff; Jeffrey Soltis; Jochen Stutz; Colm Sweeney; Thompson, Chelsea R; Trainer, Michael K.; Tsai, Catalina; Veres, Patrick R.; Washenfelder, Rebecca A.; Warneke, Carsten; Wild, Robert J.; Young, Cora J.; Yuan, Bin; Zamora, Robert.

- In: *Nature*, Vol. 514, pages 351-354.
- http://www.nature.com/nature/journal/vaop/ncurrent/full/nature13767.html

Abstract: The United States is now experiencing the most rapid expansion in oil and gas production in four decades, owing in large part to implementation of new extraction technologies such as horizontal drilling combined with hydraulic fracturing. The environmental impacts of this development, from its effect on water quality to the influence of increased methane leakage on climate, have been a matter of intense debate. Air quality impacts are associated with emissions of nitrogen oxides ($NO_x = NO + NO_2$) and volatile organic compounds (VOCs), whose photochemistry leads to production of ozone, a secondary pollutant with negative health effects. Recent observations in oil- and gas-producing basins in the western United States have identified ozone mixing ratios well in excess of present air quality standards, but only during winter. Understanding winter ozone production in these regions is scientifically challenging. It occurs during cold periods of snow cover when meteorological inversions concentrate air pollutants from oil and gas activities, but when solar irradiance and absolute humidity, which are both required to initiate conventional photochemistry essential for ozone production, are at a minimum. Here, using data from a remote location in the oil and gas basin of northeastern Utah and a box model, we provide a quantitative assessment of the photochemistry that leads to these extreme winter ozone pollution events, and identify key factors that control ozone production in this unique environment. We find that ozone production occurs at lower NO_x and much larger VOC concentrations than does its summertime urban counterpart, leading to carbonyl (oxygenated VOCs with a C = O moiety) photolysis as a dominant oxidant source. Extreme VOC concentrations optimize the ozone production efficiency of NO_x. There is considerable potential for global growth in oil and gas extraction from shale. This analysis could help inform strategies to monitor and mitigate air quality impacts and provide broader insight into the response of winter ozone to primary pollutants.

September 26, 2014. [*Category:* General (Comment / Review)]

Fracking in the Polish press: Geopolitics and national identity.

- Jaspal, Rusi; Nerlich, Brigitte; Lemańcyzk, Szczepan.
- In: *Energy Policy*, Vol. 74, November 2014, pages 253-261.
- http://www.sciencedirect.com/science/article/pii/S0301421514004984

Abstract: In a context of resource scarcity and political instability, new energy sources and technologies are being explored in many parts of the world and exploited in some. One of these new energy sources is shale gas and one of the countries seeking to decrease its energy dependence and increase its energy security is Poland which is largely dependent on gas and oil imports from Russia. This article presents the results of a thematic content analysis of articles reporting on shale gas/fracking published in Gazeta Wyborcza and Rzeczpospolita, two leading Polish newspapers, from 1 January 2010 to 31 December 2012. Findings suggest that in media reporting the geopolitical dimension of fracking overrides the technological / scientific dimension and that representations are overwhelmingly positive. Positive representations are bolstered through particular linguistic framings. It is argued that the Polish press has polarized the debate on fracking in a particular (positive) direction, which has silenced an open and constructive debate concerning energy policy in Poland and constructed criticism of fracking as counter-normative and "un-Polish." The potential socio-political and policy implications of these media representations are discussed.

September 24, 2014. [*Category:* Water Quality]

Enhanced Formation of Disinfection By-Products in Shale Gas Wastewater-Impacted Drinking Water Supplies.

- Parker, Kimberly M.; Zeng, Teng; Harkness, Jennifer; Vengosh, Avner; Mitch, William Armistead.

- In: *Environmental Science & Technology*, Vol. 48, Issue 19, pages 11161-11169.
- http://www.ncbi.nlm.nih.gov/pubmed/25203743

Abstract: The disposal and leaks of hydraulic fracturing wastewater (HFW) to the environment pose human health risks. Since HFW is typically characterized by elevated salinity, concerns have been raised whether the high bromide and iodide in HFW may promote the formation of disinfection byproducts (DBPs) and alter their speciation to more toxic brominated and iodinated analogues. This study evaluated the minimum volume percentage of two Marcellus Shale and one Fayetteville Shale HFWs diluted by fresh water collected from the Ohio and Allegheny Rivers that would generate and/or alter the formation and speciation of DBPs following chlorination, chloramination and ozonation treatments of the blended solutions. During chlorination, dilutions as low as 0.01% HFW altered the speciation towards formation of brominated and iodinated trihalomethanes (THMs) and brominated haloacetonitriles (HANs), and dilutions as low as 0.03% increased the overall formation of both compound classes. The increase in bromide concentration associated with 0.01%-0.03% contribution of Marcellus HFW (a range of 70 to 200 μg/L for HFW with bromide = 600 mg/L) mimics the increased bromide levels observed in western Pennsylvanian surface waters following the Marcellus Shale gas production boom. Chloramination reduced HAN and regulated THM formation; however iodinated trihalomethane formation was observed at lower pH. For municipal wastewater-impacted river water, the presence of 0.1% HFW increased the formation of N-nitrosodimethylamine (NDMA) during chloramination, particularly for the high iodide (54 ppm) Fayetteville Shale HFW. Finally, ozonation of 0.01%-0.03% HFW-impacted river water resulted in significant increases in bromate formation. The results suggest that total elimination of HFW discharge and/or installation of halide-specific removal techniques in centralized brine treatment facilities may be a better strategy to mitigate impacts on downstream drinking water treatment plants than altering disinfection strategies. The potential formation of multiple DBPs in drinking water utilities in areas of shale gas development requires comprehensive monitoring plans beyond the common regulated DBPs.

September 20, 2014. [*Category:* Seismicity]

Optimizing multi-station earthquake template matching through re-examination of the Youngstown, Ohio, sequence.

- Skoumal, Robert J.; Brudzinski, Michael R.; Currie, Brian S.; Levy, Jonathan.
- In: *Earth and Planetary Science Letters*, Vol. 405, November 1, 2014, pages 274-280.
- http://www.sciencedirect.com/science/article/pii/S0012821X14005391

Abstract: A series of earthquakes in 2011 near Youngstown, OH, has been a focal point for discussions of seismicity induced by a nearby wastewater disposal well. Utilizing an efficient waveform template matching procedure, the optimal correlation template to study the Youngstown sequence was identified by varying parameters such as the stations utilized, frequency passband, and seismogram length. A catalog composed of 566 events was identified between January 2011 and February 2014. Double-difference relocation refines seismicity to a ~800 m linear streak from the Northstar 1 injection well to the WSW along the same strike as the fault plane of the largest event. Calculated Gutenberg–Richter b-values are consistent with trends observed in other regions with seismicity induced by fluid injection.

September 18, 2014. [*Category:* Water Quality]

Wellbore stability model for shale gas reservoir considering the coupling of multi-weakness planes and porous flow.

- Liang, Chuan; Chen, Mian; Jin, Yan; Lu, Yunhu.
- In: *Journal of Natural Gas Science and Engineering*, Vol. 21, November 2014, pages 364-378.
- http://www.sciencedirect.com/science/article/pii/S1875510014002595

Abstract: Irregular wellbore collapse phenomena and accidents frequently occur during drilling operations in Longmaxi shale gas reservoir. Considering shale formation with natural cross beddings and fractures, we propose a multi-weakness plane instead of a single weakness plane failure model. Shale samples obtained from the Lower Silurian Longmaxi Strata of Sichuan Basin are investigated based on characterization and analysis of mineralogy, pore structure, sliding failure condition, and rock mechanics to study the impact of porous flow on jointed shale masses. Results show that Longmaxi gas shale is a brittle and fracture-prone material with poor hydrating capacity and extremely low permeability in rock matrices. Reduction of rock strength under porous flow may contribute to changes in intensity parameters of the weakness planes. Therefore, considering the failure of multi-weakness planes under porous flow, we present a wellbore stability model for shale gas reservoir. Two types of weakness plane distribution patterns are examined to discuss the effect of the occurrence, numbers, and water saturation of weakness planes. The results demonstrate that the number of weakness planes, difference in weakness plane occurrence, and diverse water saturation levels significantly affect wellbore stability during drilling.

September 18, 2014. [*Category:* Water Usage]

Comparison of Water Use for Hydraulic Fracturing for Shale Oil and Gas Production versus Conventional Oil.

- Scanlon, Bridget R.; Reedy, Robert C.; Nicot, Jean-Philippe.

- In: *Environmental Science & Technology*, Vol. 48, Issue 20, pages 12386-12393.
- http://www.ncbi.nlm.nih.gov/pubmed/25233450

Abstract: We compared water use for hydraulic fracturing (HF) for oil versus gas production within the Eagle Ford shale. We then compared HF water use for Eagle Ford oil with Bakken oil, both plays accounting for two thirds of U.S. unconventional oil production in 2013. In the Eagle Ford, we found similar average water use in oil and gas zones per well (4.7-4.9×10(6) gallons [gal]/well). However, about twice as much water is used per unit of energy (water-to-oil ratio, WOR, vol water/vol oil) in the oil zone (WOR: 1.4) as in the gas zone (water-to-oil-equivalent-ratio, WOER: 0.6). We also found large differences in water use for oil between the two plays, with mean Bakken water use/well (2.0×10(6) gal/well) about half that in the Eagle Ford, and a third per energy unit. We attribute these variations mostly to geological differences. Water-to-oil ratios for these plays (0.6-1.4) will further decrease (0.2-0.4) based on estimated ultimate oil recovery of wells. These unconventional water-to-oil ratios (0.2-1.4) are within the lower range of those for U.S. conventional oil production (WOR: 0.1-5). Therefore, the U.S. is using more water because HF has expanded oil production, not because HF is using more water per unit of oil production.

September 17, 2014. [*Categories:* General (Comment / Review), Water Quality]

Analysis of the Groundwater Monitoring Controversy at the Pavillion, Wyoming Natural Gas Field.

- Stephens, Daniel B.
- In: *Groundwater*, Vol. 53, Issue 1, pages 29-37 (January 2015).
- http://www.ncbi.nlm.nih.gov/pubmed/25231140

Abstract: The U.S. Environmental Protection Agency (EPA) was contacted by citizens of Pavillion, Wyoming 6 years ago regarding taste and odor in their water wells in an area where hydraulic fracturing operations were occurring. EPA conducted a field investigation, including drilling two deep monitor wells, and concluded in a draft report that constituents associated with hydraulic fracturing had impacted the drinking water aquifer. Following extensive media coverage, pressure from state and other federal agencies, and extensive technical criticism from industry, EPA stated the draft report would not undergo peer review, that it would not rely on the conclusions, and that it had relinquished its lead role in the investigation to the State of Wyoming for further investigation without resolving the source of the taste and odor problem. Review of the events leading up to EPA's decision suggests that much of the criticism could have been avoided through improved preproject planning with clear objectives. Such planning would have identified the high national significance and potential implications of the proposed work. Expanded stakeholder involvement and technical input could have eliminated some of the difficulties that plagued the investigation. However, collecting baseline groundwater quality data prior to initiating hydraulic fracturing likely would have been an effective way to evaluate potential impacts. The Pavillion groundwater investigation provides an excellent opportunity for improving field methods, report transparency, clarity of communication, and the peer review process in future investigations of the impacts of hydraulic fracturing on groundwater.

September 16, 2014. [*Categories:* Air Quality; Health]

Assessing worker exposure to inhaled volatile organic compounds from Marcellus Shale flowback pits.

- Bloomdahl, Ry; Abualfaraj, Noura; Olson, Mira; Gurian, Patrick L.
- In: *Journal of Natural Gas Science and Engineering*, Vol. 21, November 2014, pages 348-356.
- http://www.sciencedirect.com/science/article/pii/S1875510014002522

Abstract: Natural gas drilling sites employing hydraulic fracturing present a potential source of inhalation exposure to volatile organic compounds (VOCs) via the use of flowback pits. These open-air pits are used as a means of storing flowback water, a waste product of hydraulic fracturing, and represent an understudied source of VOC exposure for workers. The objective of this study was to assess this worker exposure and the resulting health risks for 12 VOCs present in flowback water stored in such an open reservoir on a drilling site. Flowback pit VOC mean, 2.5 percentile, and 97.5 percentile concentrations were used to model aqueous phase concentrations, and two models of volatilization were applied to estimate flux to the gas phase. A mass-balance approach was used to estimate gas phase concentrations that were, in turn, used to estimate worker exposure. A literature review was performed to determine VOC health effects, exposure limits, and worker protection methods. Neither model demonstrated an increased risk of adverse effects due to subchronic exposure at the 2.5 percentile and mean concentration values for the 12 VOCs as indicated by hazard quotients, hazard indices, or excess lifetime cancer risks; however, 97.5 percentile hazard indices approached 1 in one model and did demonstrate unacceptable risks in the evaluation of limitations. Either model may apply to worker health assessment depending upon industry practice; however, differing weather conditions, industry practice, and the small number of VOCs evaluated necessitate further research regarding worker risks and health effects.

September 15, 2014. [*Category:* Water Quality]

Noble gases identify the mechanisms of fugitive gas contamination in drinking-water wells overlying the Marcellus and Barnett Shales.

- Darrah, Thomas H.; Vengosh, Avner; Jackson, Robert B.; Warner, Nathaniel R.; Poreda, Robert J.
- In: *Proceedings of the National Academy of Sciences*, Vol. 111, Issue 39, pages 14076-14081.
- http://www.pnas.org/content/early/2014/09/12/1322107111

Abstract: Horizontal drilling and hydraulic fracturing have enhanced energy production but raised concerns about drinking-water contamination and other environmental impacts. Identifying the sources and mechanisms of contamination can help improve the environmental and economic sustainability of shale-gas extraction. We analyzed 113 and 20 samples from drinking-water wells overlying the Marcellus and Barnett Shales, respectively, examining hydrocarbon abundance and isotopic compositions (e.g., C2H6/CH4, δ13C-CH4) and providing, to our knowledge, the first comprehensive analyses of noble gases and their isotopes (e.g., 4He, 20Ne, 36Ar) in groundwater near shale-gas wells. We addressed two questions. (i) Are elevated levels of hydrocarbon gases in drinking-water aquifers near gas wells natural or anthropogenic? (ii) If fugitive gas contamination exists, what mechanisms cause it? Against a backdrop of naturally occurring salt- and gas-rich groundwater, we identified eight discrete clusters of fugitive gas contamination, seven in Pennsylvania and one in Texas that showed increased contamination through time. Where fugitive gas contamination occurred, the relative proportions of thermogenic hydrocarbon gas (e.g., CH4, 4He) were significantly higher ($P < 0.01$) and the proportions of atmospheric gases (air-saturated water; e.g., N2, 36Ar) were significantly lower ($P < 0.01$) relative to background groundwater. Noble gas isotope and hydrocarbon data link four contamination clusters to gas leakage from intermediate-depth strata through failures of annulus cement, three to target production gases that seem to implicate faulty production casings, and one to an underground gas well failure. Noble gas data appear to rule out gas contamination by upward migration from depth through overlying geological strata triggered by horizontal drilling or hydraulic fracturing.

September 10, 2014. [*Category:* Health]

Proximity to Natural Gas Wells and Reported Health Status: Results of a Household Survey in Washington County, Pennsylvania.

- Rabinowitz, Peter MacGarr; Slizovskiy, Ilya B.; Lamers, Vanessa; Trufan, Sally J.; Holford, Theodore R.; Dziura, James D.; Peduzzi, Peter N.; Kane, Michael J.; Reif, John S.; Weiss, Theresa R.; Stowe, Meredith H.
- In: *Environmental Health Perspectives*, Vol. 123, Issue 1, January 2015.
- http://ehp.niehs.nih.gov/1307732

Abstract:

Background: Little is known about the environmental and public health impact of unconventional natural gas extraction activities, including hydraulic fracturing, that occur near residential areas.

Objectives: Our aim was to assess the relationship between household proximity to natural gas wells and reported health symptoms.

Methods: We conducted a hypothesis-generating health symptom survey of 492 persons in 180 randomly selected households with ground-fed wells in an area of active natural gas drilling. Gas well proximity for each household was compared with the prevalence and frequency of reported dermal, respiratory, gastrointestinal, cardiovascular, and neurological symptoms.

Results: The number of reported health symptoms per person was higher among residents living < 1 km (mean ± SD, 3.27 ± 3.72) compared with > 2 km from the nearest gas well (mean ± SD, 1.60 ± 2.14; $p = 0.0002$). In a model that adjusted for age, sex, household education, smoking, awareness of environmental risk, work type, and animals in house, reported skin conditions were more common in households < 1 km compared with > 2 km from the nearest gas well (odds ratio = 4.1; 95% CI: 1.4, 12.3; $p = 0.01$). Upper respiratory symptoms were also more frequently reported in persons living in households < 1 km from gas wells (39%) compared with households 1–2 km or > 2 km from the nearest well (31 and 18%, respectively) ($p = 0.004$). No equivalent correlation was found between well proximity and other reported groups of respiratory, neurological, cardiovascular, or gastrointestinal conditions.

Conclusion: Although these results should be viewed as hypothesis generating, and the population studied was limited to households with a ground-fed water supply, proximity of natural gas wells may be associated with the prevalence of health symptoms including dermal and respiratory conditions in residents living near natural gas extraction activities. Further study of these associations, including the role of specific air and water exposures, is warranted.

September 6, 2014. [*Category:* Water Quality]

Surface water geochemical and isotopic variations in an area of accelerating Marcellus Shale gas development.

- Pelak, Adam J.; Sharma, Shikha.
- In: *Environmental Pollution*, Vol. 195, December 2014, pages 91-100.
- http://www.sciencedirect.com/science/article/pii/S0269749114003558

Abstract: Water samples were collected from 50 streams in an area of accelerating shale gas development in the eastern U.S.A. The geochemical/isotopic characteristics show no correlation with the five categories of Marcellus Shale production. The sub-watersheds with the greatest density of Marcellus Shale development have also undergone extensive coal mining. Hence, geochemical/isotopic compositions were used to understand sources of salinity and effects of coal mining and shale gas development in the area. The data indicates that while some streams appear to be impacted by mine drainage; none appear to have received sustained contribution from deep brines or produced waters associated with shale gas production. However, it is important to note that our interpretations are based on one time synoptic base flow sampling of a few sampling stations and hence do account potential intermittent changes in chemistry that may result from major/minor spills or specific mine discharges on the surface water chemistry.

September 6, 2014. [*Category:* General (Comment / Review)]

Life cycle environmental impacts of UK shale gas.

- Stamford, Laurence; Azapagic, Adisa.
- In: *Applied Energy*, Vol. 134, pages 506-518.
- http://www.sciencedirect.com/science/article/pii/S0306261914008745

Abstract: Exploitation of shale gas in the UK is at a very early stage, but with the latest estimates suggesting potential resources of 3.8 × 1013 cubic metres – enough to supply the UK for next 470 years – it is viewed by many as an exciting economic prospect. However, its environmental impacts are currently unknown. This is the focus of this paper which estimates for the first time the life cycle impacts of UK shale gas, assuming its use for electricity generation. Shale gas is compared to fossil-fuel alternatives (conventional gas and coal) and low-carbon options (nuclear, offshore wind and solar photovoltaics). The results suggest that the impacts range widely, depending on the assumptions. For example, the global warming potential (GWP100) of electricity from shale gas ranges from 412 to 1102 g CO2-eq./kWh with a central estimate of 462 g. The central estimates suggest that shale gas is comparable or superior to conventional gas and low-carbon technologies for depletion of abiotic resources, eutrophication, and freshwater, marine and human toxicities. Conversely, it has a higher potential for creation of photochemical oxidants (smog) and terrestrial toxicity than any other option considered. For acidification, shale gas is a better option than coal power but an order of magnitude worse than the other options. The impact on ozone layer depletion is within the range found for conventional gas, but nuclear and wind power are better options still. The results of this research highlight the need for tight regulation and further analysis once typical UK values of key parameters for shale gas are established, including its composition, recovery per well, fugitive emissions and disposal of drilling waste.

September 2, 2014. [*Category:* Climate]

Natural Gas versus Coal: Is Natural Gas Better for the Climate?

- Busch, Chris; Gimon, Eric.
- In: *The Electricity Journal*, Vol. 27, Issue 7, pages 97-111.
- http://www.sciencedirect.com/science/article/pii/S1040619014001687

Abstract: This article analyzes the level of greenhouse gas emissions attributable to electricity from natural-gas-fired power plants and coal-fired power plants, then compares the two. An analytical framework is employed that considers the key greenhouse gases released during the production and combustion of coal and natural gas: carbon dioxide and methane.

September 1, 2014. [*Category:* Health]

Birth Outcomes and Natural Gas Development: Methodological Limitations.

- Fedak, Kristen; Gross, Sherilyn; Jacobsen, Megan; Tvermoes, Brooke.
- In: *Environmental Health Perspectives*, Vol. 122, Issue 9, pages 232 ff.
- http://ehp.niehs.nih.gov/1408647

Extract: We read with interest the article "Birth Outcomes and Maternal Residential Proximity to Natural Gas Development in Rural Colorado" by McKenzie et al. (2014). We agree with the authors that it is important to determine whether any adverse health effects may be associated with active natural gas wells, especially for susceptible subpopulations.

On the basis of the prevalence of neural tube and congenital heart defects reported in infants born to mothers that lived within a 10-mile radius of natural gas wells, McKenzie et al. (2014) reported an association between natural gas development and these specific birth defects. They suggested that "potential teratogens"—particularly benzene and polycyclic aromatic hydrocarbons—emitted from the wells, related infrastructures, or drilling processes could be a causal factor related to the health effects. They generally weaved a cautionary tale regarding natural gas development and negative reproductive/developmental consequences. Although we applaud the authors' efforts to investigate potential human health concerns related to oil and gas development, we would like to highlight key weaknesses within the study design that were underemphasized in their article. Specifically, we believe that the chosen exposure metric—inverse distance weighted gas well counts in a 10-mile radius of maternal residence during the child's birth year—is a poor surrogate for an actual (i.e., chemical) exposure that might be causally linked to the outcomes of interest, which severely limits the ability to interpret results. In addition, the exposure metric raises issues regarding the biologic plausibility of benzene as the underlying causal agent for the observed effects.

McKenzie et al. (2014) used the gas well density and the distance of gas wells to maternal residence as a proxy for maternal chemical exposure, including in their count any well listed as "existing" within the Colorado Oil and Gas Information System (COGIS) registry during the entire birth year of the infant. However, the neural plate and heart are known to develop during the first trimester, and it is recognized that this is the critical period of sensitivity for induction of defects due to toxicological insult (Rogers and Kavlock 2008). Thus, it would be more appropriate to limit the maternal exposure metric to a window representative of only the first trimester of pregnancy. Additionally, the first trimester of a pregnancy may fall in a different calendar year than the child's birth. Therefore, the authors may have inaccurately characterized maternal exposures for most subjects and severely misrepresented exposures for some. Although McKenzie et al. briefly noted in their "Discussion" that there was insufficient data to determine well counts tied to trimesters as opposed to birth year, we feel that this limitation is understated considering the potential impact.

We have previously determined that benzene is a highly volatile compound with a short atmospheric residence time and is unlikely to travel long distances from the emission source [Voluntary Children's Chemical Evaluation Program (VCCEP) 2006]; the most relevant benzene exposures occur from nearby sources [Agency for Toxic Substances and Disease Registry (ATSDR) 2007; VCCEP 2006]. Interestingly, when McKenzie et al.'s analysis was restricted to wells within a closer proximity (e.g., 1- and 5-mile radii), results were not significant, leading one to question whether the reported results are truly indicative of a causal relationship or simply an artifact of arbitrarily selected parameters. Further, there are many inactive wells on the COGIS registry, which have different benzene emissions than active wells, a distinction that was not captured by the exposure metric. Moreover, McKenzie et al. implied that a causal link between benzene and congenital heart defects has been established and therefore their exposure proxy is justified—although the cited references do not actually provide such evidence, and current consensus documents do not recognize such an association [ATSDR 2007; International Agency for Research on Cancer (IARC) 2012; Lupo et al. 2010; VCCEP 2006; Wennborg et al. 2005].

McKenzie et al. (2014) acknowledged in their article that there is a "lack of temporal and spatial specificity" in their exposure metric, but they appear to primarily relate this to uncertainties such as potential maternal mobility and relative well activity levels. These are minor concerns compared with the larger issue of whether the chemical of interest and the parameters chosen were meaningful, appropriate, and well categorized. As scientists, we have an obligation to appropriately and effectively communicate to the public not just positive and negative findings but also some sense of the magnitude of risk in order to ensure that we do not create or perpetuate an unnecessary level of alarm. Based on the inherent limitations of this study, including that no true exposure to any chemical was actually measured or modeled and that the proxy exposure metric was weak, the suggested association between specific birth defects and natural gas exploration and production reported by McKenzie et al. (2014) should be viewed cautiously and critically.

September 1, 2014. [*Category:* Climate]

The effect of natural gas supply on US renewable energy and CO2 emissions.

- Shearer, Christine; Bistline, John; Inman, Mason; Davis, Steven J.
- In: *Environmental Research Letters*, Vol. 9, Issue 9, page 94008.
- http://iopscience.iop.org/1748-9326/9/9/094008

Abstract: Increased use of natural gas has been promoted as a means of decarbonizing the US power sector, because of superior generator efficiency and lower CO2 emissions per unit of electricity than coal. We model the effect of different gas supplies on the US power sector and greenhouse gas (GHG) emissions. Across a range of climate policies, we find that abundant natural gas decreases use of both coal and renewable energy technologies in the future. Without a climate policy, overall electricity use also increases as the gas supply increases. With reduced deployment of lower-carbon renewable energies and increased electricity consumption, the effect of higher gas supplies on GHG emissions is small: cumulative emissions 2013–55 in our high gas supply scenario are 2% less than in our low gas supply scenario, when there are no new climate policies and a methane leakage rate of 1.5% is assumed. Assuming leakage rates of 0 or 3% does not substantially alter this finding. In our results, only climate policies bring about a significant reduction in future CO2 emissions within the US electricity sector. Our results suggest that without strong limits on GHG emissions or policies that explicitly encourage renewable electricity, abundant natural gas may actually slow the process of decarbonization, primarily by delaying deployment of renewable energy technologies.

September, 2014. [*Category:* Health]

Unconventional natural gas development and public health: toward a community-informed research agenda.

- Korfmacher, Katrina Smith; Elam, Sarah; Gray, Kathleen M.; Haynes, Erin; Hughes, Megan Hoert.
- In: *Reviews on Environmental Health*, Vol. 29, Issue 4, pages 293-306.
- http://www.degruyter.com/view/j/reveh.2014.29.issue-4/reveh-2014-0049/reveh-2014-0049.xml

  (see also: http://www.urmc.rochester.edu/MediaLibraries/URMCMedia/environmental-health-sciences-center/COEC/documents/UNGD-information-needs-asssessment-Final-project-report-091514.pdf)

Abstract: Unconventional natural gas development (UNGD) using high-volume horizontal hydraulic fracturing ("fracking") has vastly increased the potential for domestic natural gas production in recent years. However, the rapid expansion of UNGD has also raised concerns about its potential impacts on public health. Academics and government agencies are developing research programs to explore these concerns. Community involvement in activities such as planning, conducting, and communicating research is widely recognized as having an important role in promoting environmental health. Historically, however, communities most often engage in research after environmental health concerns have emerged. This community information needs assessment took a prospective approach to integrating community leaders' knowledge, perceptions, and concerns into the research agenda prior to initiation of local UNGD. We interviewed community leaders about their views on environmental health information needs in three states (New York, North Carolina, and Ohio) prior to widespread UNGD. Interviewees emphasized the cumulative, long-term, and indirect determinants of health, as opposed to specific disease outcomes. Responses focused not only on information needs, but also on communication and transparency with respect to research processes and funding. Interviewees also prioritized investigation of policy approaches to effectively protect human health over the long term. Although universities were most often cited as a credible source of information, interviewees emphasized the need for multiple strategies for disseminating information. By including community leaders' concerns, insights, and questions from the outset, the research agenda on UNGD is more likely to effectively inform decision making that ultimately protects public health.

August 24, 2014. [*Category:* Seismicity]

Anisotropy in Fracking: A Percolation Model for Observed Microseismicity.

- Norris, J. Quinn; Turcotte, Donald L.; Rundle, John B.
- In: *Pure and Applied Geophysics*, Vol. 172, Issue 1, pages 7-21.
- http://link.springer.com/article/10.1007%2Fs00024-014-0921-9

Abstract: Hydraulic fracturing (fracking), using high pressures and a low viscosity fluid, allow the extraction of large quantiles of oil and gas from very low permeability shale formations. The initial production of oil and gas at depth leads to high pressures and an extensive distribution of natural fractures which reduce the pressures. With time these fractures heal, sealing the remaining oil and gas in place. High volume fracking opens the healed fractures allowing the oil and gas to flow to horizontal production wells. We model the injection process using invasion percolation. We use a 2D square lattice of bonds to model the sealed natural fractures. The bonds are assigned random strengths and the fluid, injected at a point, opens the weakest bond adjacent to the growing cluster of opened bonds. Our model exhibits burst dynamics in which the clusters extend rapidly into regions with weak bonds. We associate these bursts with the microseismic activity generated by fracking injections. A principal object of this paper is to study the role of anisotropic stress distributions. Bonds in the *y*-direction are assigned higher random strengths than bonds in the *x*-direction. We illustrate the spatial distribution of clusters and the spatial distribution of bursts (small earthquakes) for several degrees of anisotropy. The results are compared with observed distributions of microseismicity in a fracking injection. Both our bursts and the observed microseismicity satisfy Gutenberg–Richter frequency-size statistics.

August 23, 2014. [*Category:* General (Comment / Review)]

The energy, water, and air pollution implications of tapping China's shale gas reserves.

- Chang, Yuan; Huang, Runze; Masanet, Eric.
- In: *Resources, Conservation and Recycling*, Vol. 91, September 2014, pages 100-108.
- http://www.sciencedirect.com/science/article/pii/S0921344914001682

Abstract: China has laid out an ambitious strategy for developing its vast shale gas reserves. This study developed an input–output based hybrid life-cycle inventory model to estimate the energy use, water consumption, and air emissions implications of shale gas infrastructure development in China over the period 2013–2020, including well drilling and operation, land rig and fracturing fleet manufacture, and pipeline construction. Multiple scenarios were analyzed based on different combinations of well development rates, well productivities, and success rates. Results suggest that 700–5100 petajoules (PJ) of primary energy will be required for shale gas infrastructure development, while the net primary energy yield of shale gas production over 2013–2020 was estimated at 1650–7150 PJ, suggesting a favorable energy balance. Associated emissions of CO2e were estimated at 80–580 million metric tons, and were primarily attributable to coal-fired electricity generation, fugitive methane, and flaring of methane during shale gas processing and transmission. Direct water consumption was estimated at 20–720 million metric tons. The largest sources of energy use and emissions for infrastructure development were the metals, mining, non-metal mineral products, and power sectors, which should be the focus of energy efficiency initiatives to reduce the impacts of shale gas infrastructure development moving forward.

August 23, 2014. [*Category:* General (Comment / Review)]

The competition situation analysis of shale gas industry in China: Applying Porter's five forces and scenario model.

- Yunna, Wu; Yisheng, Yang.
- In: *Renewable and Sustainable Energy Reviews*, Vol. 40, December 2014, pages 798-805.
- http://www.sciencedirect.com/science/article/pii/S1364032114006911

Abstract: With the increasing of energy demand and environmental pressure, China government has been exploring a way to diversify energy supply. Shale gas development is becoming an important energy strategy in China in recent years due to giant shale gas reserves. However, the shale gas market is preliminarily shaping in China, so that many factors have great influence on its competition. To find these factors and to control them rationally is good for the cultivating Chinese shale gas market. Five forces model for industry analysis puts an insight into the competitive landscape of shale gas market by showing the forces of supplier power, buyer power, threat of substitution, barriers to entry, and degree of rivalry. Illustrating the key factors that affect competitive landscape provides a view into the situation of shale gas industry. The variation tendency of shale gas industry is analyzed by setting various scenarios. Finally some suggestions are proposed in order to keep the development of shale gas industry positively.

August 21, 2014. [*Category:* Water Quality]

Leakage detection of Marcellus Shale natural gas at an Upper Devonian gas monitoring well: a 3-D numerical modeling approach.

- Zhang, Liwei; Anderson, Nicole; Dilmore, Robert; Soeder, Daniel J.; Bromhal, Grant.

- In: *Environmental Science & Technology*, Vol. 48, Issue 18, pages 10795-10803.
- http://dx.doi.org/10.1021/es501997p

Abstract: Potential natural gas leakage into shallow, overlying formations and aquifers from Marcellus Shale gas drilling operations is a public concern. However, before natural gas could reach underground sources of drinking water (USDW), it must pass through several geologic formations. Tracer and pressure monitoring in formations overlying the Marcellus could help detect natural gas leakage at hydraulic fracturing sites before it reaches USDW. In this study, a numerical simulation code (TOUGH 2) was used to investigate the potential for detecting leaking natural gas in such an overlying geologic formation. The modeled zone was based on a gas field in Greene County, Pennsylvania, undergoing production activities. The model assumed, hypothetically, that methane (CH4), the primary component of natural gas, with some tracer, was leaking around an existing well between the Marcellus Shale and the shallower and lower-pressure Bradford Formation. The leaky well was located 170 m away from a monitoring well, in the Bradford Formation. A simulation study was performed to determine how quickly the tracer monitoring could detect a leak of a known size. Using some typical parameters for the Bradford Formation, model results showed that a detectable tracer volume fraction of 2.0 x 10-15 would be noted at the monitoring well in 9.8 years. The most rapid detection of tracer for the leak rates simulated was 81 days, but this scenario required that the leakage release point was at the same depth as the perforation zone of the monitoring well and the zones above and below the perforation zone had low permeability, which created a preferred tracer migration pathway along the perforation zone. Sensitivity analysis indicated that the time needed to detect CH4 leakage at the monitoring well was very sensitive to changes in the thickness of the high-permeability zone, CH4 leaking rate and production rate of the monitoring well.

August 20, 2014. [*Category:* Seismicity]

Social impacts of earthquakes caused by gas extraction in the Province of Groningen, The Netherlands.

- Van der Voort, Nick; Vanclay, Frank.
- In: *Environmental Impact Assessment Review*, Vol. 50, January 2015, pages 1-15.
- http://www.sciencedirect.com/science/article/pii/S0195925514000766

Abstract: Gas extraction from the Groningen gasfield in the northern Netherlands has led to localised earthquakes which are projected to become more severe. The social impacts experienced by local residents include: damage to property; declining house prices; concerns about the chance of dykes breaking; feelings of anxiety and insecurity; health issues; and anger. These social and emotional impacts are exacerbated by the increasing distrust Groningen people have towards the national government and the gas company, NAM, a partnership between Shell and ExxonMobil. The earthquakes have reopened discussions about the distribution of benefits from gas production and the extent to which benefits are retained locally. Mitigation of the impacts is attempted, but the lack of trust decreases the effectiveness of the mitigation measures. The extent of this experience of previously-unforeseen, unanticipated impacts suggests that a new social and environmental impact assessment needs to be undertaken, and a new Social Impact Management Plan (SIMP) and Impacts and Benefits Agreement (IBA) developed, so that the project can regain its legitimacy and social licence to operate. In addition to conventional gas, this paper has wider relevance for unconventional gas developments, for example shale gas extraction by hydraulic fracturing methods (fracking).

August 20, 2014. [*Category:* General (Comment / Review)]

Stimulating shale gas development in China: A comparison with the US experience.

- Tian, Lei; Wang, Zhongmin; Krupnick, Alan; Liu, Xiaoli.
- In: *Energy Policy*, Vol. 75, December 2014, pages 109-116.
- http://www.sciencedirect.com/science/article/pii/S0301421514004534

Abstract: In this paper, we use the US shale gas experience to shed light on how China might overcome the innovation problem inherent in exploring and developing shale gas plays with complex geology. We separate shale gas development into two stages, an innovation stage and a scaling-up stage, with the first presenting a much bigger challenge than the latter. Our analysis suggests that China′s national oil companies offer the best hope for overcoming the innovation problem. China′s policy of opening shale gas development to new entrants is a market-oriented reform that can be justified on various grounds, but the new entrants will not play a major role in overcoming the innovation problem even though they may help scale up production later on.

August 18, 2014. [*Category:* General (Comment/Review)]

Environmental risks of shale gas development in China.

- Krupnick, Alan; Wang, Zhongmin; Wang, Yushuang.
- In: Energy Policy, Vol. 75, December 2014, pages 117-125.
- http://www.sciencedirect.com/science/article/pii/S0301421514004509

Abstract: Shale gas development in China can generate great potential economic benefits, but also poses serious environmental risks. In this paper, we offer a macro assessment of the environmental risks of shale gas development in China. We use the US experience to identify the nature of shale gas development activities and the types of potential burdens these activities may create. We then review the baseline environmental conditions and the effectiveness of environmental regulations in China and discuss the implications of these China-specific factors for risk assessment. We recommend China to conduct a strategic environmental assessment and to consider sector-specific environmental regulations.

August 13, 2014. [*Category:* Air Quality]

Measurement of atmospheric pollutants associated with oil and natural gas exploration and production activity in Pennsylvania's Allegheny National Forest.

- Pekney, Natalie J.; Veloski, Garret; Reeder, Matthew; Tamilia, Joseph; Rupp, Erik; Wetzel, Alan.

- In: *Journal of the Air & Waste Management Association*, Vol. 64, Issue 9, pages 1962-1072.
- http://dx.doi.org/10.1080/10962247.2014.897270

Abstract: Oil and natural gas exploration and production (E&P) activities generate emissions from diesel engines, compressor stations, condensate tanks, leaks and venting of natural gas, construction of well pads, and well access roads that can negatively impact air quality on both local and regional scales. A mobile, autonomous air quality monitoring laboratory was constructed to collect measurements of ambient concentrations of pollutants associated with oil and natural gas E&P activities. This air-monitoring laboratory was deployed to the Allegheny National Forest (ANF) in northwestern Pennsylvania for a campaign that resulted in the collection of approximately 7 months of data split between three monitoring locations between July 2010 and June 2011. The three monitoring locations were the Kane Experimental Forest (KEF) area in Elk County, which is downwind of the Sackett oilfield; the Bradford Ranger Station (BRS) in McKean County, which is downwind of a large area of historic oil and gas productivity; and the U.S. Forest Service Hearts Content campground (HC) in Warren County, which is in an area relatively unimpacted by oil and gas development and which therefore yielded background pollutant concentrations in the ANF. Concentrations of criteria pollutants ozone and NO2 did not vary significantly from site to site; averages were below National Ambient Air Quality Standards. Concentrations of volatile organic compounds (VOCs) associated with oil and natural gas (ethane, propane, butane, pentane) were highly correlated. Applying the conditional probability function (CPF) to the ethane data yielded most probable directions of the sources that were coincident with known location of existing wells and activity. Differences between the two impacted and one background site were difficult to discern, suggesting the that the monitoring laboratory was a great enough distance downwind of active areas to allow for sufficient dispersion with background air such that the localized plumes were not detected. ImplicationsMonitoring of pollutants associated with oil and natural gas exploration and production activity at three sites within the Allegheny National Forest (ANF) showed only slight site-to-site differences even with one site far removed from these activities. However, the impact was evident not in detection of localized plumes but in regional elevated ethane concentrations, as ethane can be considered a tracer species for oil and natural gas activity. The data presented serve as baseline conditions for evaluation of impacts from future development of Marcellus or Utica shale gas reserves.

August 13, 2014. [*Category:* Waste / Fluids]

Organic compounds in produced waters from shale gas wells.

- Maguire-Boyle, Samuel J.; Barron, Andrew R.
- In: *Environmental Science: Processes & Impacts*, Vol. 16, Issue 10, page 2237-2248.
- http://pubs.rsc.org/en/content/articlelanding/2014/em/c4em00376d

Abstract: A detailed analysis is reported of the organic composition of produced water samples from typical shale gas wells in the Marcellus (PA), Eagle Ford (TX), and Barnett (NM) formations. The quality of shale gas produced (and frac flowback) waters is a current environmental concern and disposal problem for producers. Re-use of produced water for hydraulic fracturing is being encouraged; however, knowledge of the organic impurities is important in determining the method of treatment. The metal content was determined by inductively coupled plasma optical emission spectrometry (ICP-OES). Mineral elements are expected depending on the reservoir geology and salts used in hydraulic fracturing; however, significant levels of other transition metals and heavier main group elements are observed. The presence of scaling elements (Ca and Ba) is related to the pH of the water rather than total dissolved solids (TDS). Using gas chromatography mass spectrometry (GC/MS) analysis of the chloroform extracts of the produced water samples, a plethora of organic compounds were identified. In each water sample, the majority of organics are saturated (aliphatic), and only a small fraction comes under aromatic, resin, and asphaltene categories. Unlike coalbed methane produced water it appears that shale oil/gas produced water does not contain significant quantities of polyaromatic hydrocarbons reducing the potential health hazard. Marcellus and Barnett produced waters contain predominantly C6–C16 hydrocarbons, while the Eagle Ford produced water shows the highest concentration in the C17–C30 range. The structures of the saturated hydrocarbons identified generally follows the trend of linear > branched > cyclic. Heterocyclic compounds are identified with the largest fraction being fatty alcohols, esters, and ethers. However, the presence of various fatty acid phthalate esters in the Barnett and Marcellus produced waters can be related to their use in drilling fluids and breaker additives rather than their presence in connate fluids. Halogen containing compounds are found in each of the water samples, and although the fluorocarbon compounds identified are used as tracers, the presence of chlorocarbons and organobromides formed as a consequence of using chlorine containing oxidants (to remove bacteria from source water), suggests that industry should concentrate on non-chemical treatments of frac and produced waters.

August 13, 2014. [*Category:* Waste / Fluids]

Bromide: A Pressing Issue to Address in China's Shale Gas Extraction.

- Shi, Mei; Huang, Dongyan; Zhao, Gaowen; Li, Ronghua; Zheng, Jianzhong.
- In: *Environmental Science & Technology*, Vol. 48, Issue 17, pages 9971-9972.
- http://dx.doi.org/10.1021/es502848p

Extract: "China is fighting to shift its coal-based energy system to a clean and sustainable one to alleviate its ever increasing environmental pressures. Backed by the largest proven shale gas reserve worldwide, China has set an ambitious goal to produce 60−100 billion cubic meters of shale gas annually by 2020 by hydraulic cracking. Large amounts of shale gas wastewater (SGW) are expected to be generated in association with an average 700 gallons of brine produced per million cubic feet of gas produced, according to a recent analysis of data from Marcellus. Shale gas wastewater consists of flowback and produced water, a mixture of injected fluids for hydraulic fracturing and pore water from shale formation. Because of this, SGW often contains heavy metals, radioactive metals, high levels of total dissolved solids (TDS), and in some cases, elevated concentrations of bromide. Compared with other ions in water (e.g., heavy metals and radioactive ions), bromide does not readily adsorb on soils and sediments, and hence can migrate a long distance downstream once entering surface waters. At the dawn of massive production of shale gas, China should pay particular attention to this contaminant. Poor management of bromide-containing wastewater would potentially cause contamination of China's already limited drinking water resources, and pose threats to the quality of the finished water from drinking water plants using the Br-contaminated source water due to the formation of carcinogenic brominated disinfection byproducts (DBPs)." ....

August 11, 2014. [*Category:* General (Comment / Review)]

The Environmental Costs and Benefits of Fracking.

- Jackson, Robert B.; Vengosh, Avner; Carey, J. William; Davies, Richard J.; Darrah, Thomas H.; O'Sullivan, Francis; Pétron, Gabrielle.
- In: *Annual Review of Environment and Resources*, Vol. 39, Issue 1, October 2014, pages 327-362.
- http://www.annualreviews.org/doi/abs/10.1146/annurev-environ-031113-144051

Abstract: Unconventional oil and natural gas extraction enabled by horizontal drilling and hydraulic fracturing (fracking) is driving an economic boom, with consequences described from "revolutionary" to "disastrous." Reality lies somewhere in between. Unconventional energy generates income and, done well, can reduce air pollution and even water use compared with other fossil fuels. Alternatively, it could slow the adoption of renewables and, done poorly, release toxic chemicals into water and air. Primary threats to water resources include surface spills, wastewater disposal, and drinking-water contamination through poor well integrity. An increase in volatile organic compounds and air toxics locally are potential health threats, but the switch from coal to natural gas for electricity generation will reduce sulfur, nitrogen, mercury, and particulate air pollution. Data gaps are particularly evident for human health studies, for the question of whether natural gas will displace coal compared with renewables, and for decadal-scale legacy issues of well leakage and plugging and abandonment practices. Critical topics for future research include data for (a) estimated ultimate recovery (EUR) of unconventional hydrocarbons, (b) the potential for further reductions of water requirements and chemical toxicity, (c) whether unconventional resource development alters the frequency of well integrity failures, (d) potential contamination of surface and ground waters from drilling and spills, (e) factors that could cause wastewater injection to generate large earthquakes, and (f) the consequences of greenhouse gases and air pollution on ecosystems and human health. Expected final online publication date for the Annual Review of Environment and Resources Volume 39 is October 17, 2014.

Please see http://www.annualreviews.org/catalog/pubdates.aspx for revised estimates.

August 10, 2014. [*Category:* Climate]

Life cycle greenhouse gas emissions from Barnett Shale gas used to generate electricity.

- Heath, G.; Meldrum, J.; Fisher, N.; Arent, D.; Bazilian, M.
- In: *Journal of Unconventional Oil and Gas Resources*, Vol. 8, December 2014, pages 46-55.
- http://www.sciencedirect.com/science/article/pii/S2213397614000366

Abstract: This paper presents research findings on life cycle greenhouse gas (GHG) emissions associated with natural gas production in the Barnett Shale play in Texas. The data sources and approach used in this study differ significantly from previous efforts. The authors used inventories from the year 2009 tracking emissions of regulated air pollutants by the natural gas industry in the Barnett Shale play. These inventories were collected and screened by the Texas Commission on Environmental Quality (TCEQ). These data cover the characteristics and volatile organic compound (VOC) emissions of more than 16,000 individual sources in shale gas production and processing. Translating estimated emissions of VOCs into estimates of methane and carbon dioxide emissions was accomplished through the novel compilation of spatially heterogeneous gas composition analyses. Life cycle greenhouse gas emissions associated with electricity generated from Barnett Shale gas extracted in 2009 were found to be very similar to conventional natural gas and less than half those of coal-fired electricity generation.

August 8, 2014. [*Category:* General (Comment / Review)]

How did the fracking controversy emerge in the period 2010-2012?

- Mazur, A.
- In: *Public Understanding of Science*.
- http://pus.sagepub.com/content/early/2014/08/07/0963662514545311.abstract

Abstract: In 2010-2012, the controversy over fracking grew rapidly, first in the United States, and then internationally. An important step was the anti-fracking documentary film *Gasland*. With help from celebrity sources, the film was produced and won a prize at the Sundance Film Festival by early 2010 and had an Oscar nomination by early 2011, in the meantime popularizing potent images of hazard including tainted aquifers and ignitable water running from kitchen faucets. During this period, major US news organizations paid little attention to the issue. The offshore *Deepwater Horizon* disaster of April 2010 spurred *The New York Times* to prolific reporting on potential risks of the new onshore technique for extracting shale gas. With flagship news coverage, the controversy had by 2012 gained wide media attention that evoked public concern and opposition, spreading from the United States to other nations.

August 8, 2014. [*Category:* Waste / Fluids]

In vitro cytotoxicity assessment of a hydraulic fracturing fluid.

- Payne, Madeleine E.; Chapman, Heather F.; Cumming, Janet; Leusch, Frederic D. L.
- In: *Environmental Chemistry*, Vol. 12, Issue 3, pages 286-292.
- http://www.publish.csiro.au/paper/EN14010.htm

Abstract: Hydraulic fracturing fluids are chemical mixtures used to enhance oil and gas extraction. There are concerns that fracturing fluids are hazardous and that their release into the environment – by direct injection to coal and shale formations or as residue in produced water – may have effects on ecosystems, water quality and public health. This study aimed to characterise the acute cytotoxicity of a hydraulic fracturing fluid using a human gastrointestinal cell line and, using this data, contribute to the understanding of potential human health risks posed by coal seam gas (CSG) extraction in Queensland, Australia. Previous published research on the health effects of hydraulic fracturing fluids has been limited to desktop studies of *individual* chemicals. As such, this study is one of the first attempts to characterise the toxicity of a hydraulic fracturing *mixture* using laboratory methods. The fracturing fluid was determined to be cytotoxic, with half maximal inhibitory concentrations (IC_{50}) values across mixture variations ranging between 25 and 51 mM. When used by industry, these fracturing fluids would be at concentrations of over 200 mM before injection into the coal seam. A 5-fold dilution would be sufficient to reduce the toxicity of the fluids to below the detection limit of the assay. It is unlikely that human exposure would occur at these high ('before use') concentrations and likely that the fluids would be diluted during use. Thus, it can be inferred that the level of acute risk to human health associated with the use of these fracturing fluids is low. However, a thorough exposure assessment and additional chronic and targeted toxicity assessments are required to conclusively determine human health risks.

August 8, 2014. [*Category:* Water Quality]

Assessing changes in gas migration pathways at a hydraulic fracturing site: Example from Greene County, Pennsylvania, USA.

- Sharma, Shikha; Bowman, Lindsey; Schroeder, Karl; Hammack, Richard.
- In: *Applied Geochemistry* (in press).
- http://www.sciencedirect.com/science/article/pii/S0883292714001814

Abstract: Natural gas produced from a zone of thin Upper Devonian/Lower Mississippian sands approximately 1200 m above the hydraulically fractured Middle Devonian Marcellus Shale interval was monitored for evidence of gas migration. Gas samples were collected from seven vertical Upper Devonian/Lower Mississippian gas wells and two vertical Marcellus Shale gas wells 2 months prior to-, during-, and 14 months after the hydraulic fracturing of six horizontal Marcellus Shale gas wells at the study site. The isotopic and molecular compositions of gas from the two producing zones were distinct and remained so during the entire monitoring period. Over the time of monitoring, the molecular/isotopic signatures of gas from the Upper Devonian/Lower Mississippian field did not show any evidence of contamination from deeper Marcellus Shale gas that might have migrated upward from the hydraulically fractured interval. Our results indicate no hydrologic connectivity between the fractured interval and formations 1200 m above, which means that contamination of even shallower drinking water aquifers (~2200 m above fractured interval) is unlikely at this study site. While localized consideration for geology and site development practices are extremely important, the monitoring methods used in this study are applicable when trying to understand and quantify natural gas mixing and migration trends.

August 5, 2014. [*Category:* General (Comment / Review)]

Special Issue: Understanding the Risks of Unconventional Shale Gas Development.

- Stern, Paul C.; Webler, Thomas; Small, Mitchell J.
- In: *Environmental Science & Technology*, Vol. 48, Issue 15, pages 8287-8288.
- http://dx.doi.org/10.1021/es502459b

Extract: Advances in methods for hydraulic fracturing, horizontal drilling, and related technologies that enable the recovery of natural gas and oil from deep shale formations have been ongoing for decades. However, it is primarily in the past few years that the evolution of this technology and its more widespread deployment in areas unaccustomed to recent oil and gas activity, such as in the eastern United States, has led to concern and controversy. Proponents argue that the shale gas revolution has enabled a new era of clean domestic energy, bringing significant economic benefits and jobs to those who need them and reducing U.S. greenhouse gas (GHG) emissions, while posing modest environmental risks similar to those of other natural gas and energy development technologies. Furthermore, they believe these risks to be well-managed by the current mix of drillers and operators utilizing ongoing improvements in technology and industry standards for best practice, together with the current set of governmental regulations.

August 2, 2014. [*Category:* General (Comment / Review)]

Distance: A critical aspect for environmental impact assessment of hydraulic fracking.

- Meng, Qingmin; Ashby, Steve.
- In: *The Extractive Industries and Society*, Vol. 1, Issue 2, pages 124-126.
- http://www.sciencedirect.com/science/article/pii/S2214790X14000513

Abstract: Public concerns about hydraulic fracking are growing and scientists continue to analyze and evaluate its associated environmental impacts. However, a rigorous spatial analysis of environmental impacts is necessary to provide a perspective on risk based on proximity to fracking wells. This comment describes the environmental impacts of fracking within a spatial context. It emphasizes five key points: (1) the closer to a hydraulic fracking well, the higher the risk of groundwater and drinking water well contamination; (2) residents living nearest to a fracking well experience a higher human health risk due to exposure to gas emissions during the fracking process; (3) huge and high density gas emissions are detected and recorded close to fracking wells; (4) fracking induces seismicity and small earthquakes are recorded close to fracking wells; and (5) hydraulic fracking directly changes local environment and landscape characteristics. Spatial impact assessments are critical for improving understanding of the impacts of hydraulic fracking on the environment and society.

August 2, 2014. [*Category:* Waste / Fluids]

Analysis of Hydraulic Fracturing Flowback and Produced Waters Using Accurate Mass: Identification of Ethoxylated Surfactants.

- Thurman, E. Michael; Ferrer, Imma; Blotevogel, Jens; Borch, Thomas.
- In: *Analytical Chemistry*, Vol. 86, Issue 19, pages 9653-9661.
- http://dx.doi.org/10.1021/ac502163k

Abstract: Two series of ethylene oxide (EO) surfactants, polyethylene glycols (PEGs from EO3 to EO33) and linear alkyl ethoxylates (LAEs C-9 to C-15 with EO3 to EO28), were identified in hydraulic fracturing flowback and produced water using a new application of the Kendrick mass defect and liquid chromatography/quadrupole-time-of-flight mass spectrometry. The Kendrick mass defect differentiates the proton, ammonium, and sodium adducts in both singly- and doubly-charged forms. A structural model of adduct formation is presented and binding constants are calculated, which is based on a spherical cage-like conformation, where the central cation (NH4+ or Na+) is coordinated with ether oxygens. A major purpose of the study was the identification of the ethylene oxide (EO) surfactants and the construction of a database with accurate masses and retention times in order to unravel the mass spectral complexity of surfactant mixtures used in hydraulic fracturing fluids. For example, over five hundred accurate mass assignments are made in a few seconds of computer time, which then is used as a fingerprint chromatogram of the water samples. This technique is applied to a series of flowback and produced water samples to illustrate the usefulness of ethoxylate "fingerprinting", in a first application to monitor water quality that results from fluids used in hydraulic fracturing.

August 1, 2014. [*Category:* Health]

Evaluation of Some Potential Chemical Exposure Risks During Flowback Operations in Unconventional Oil and Gas Extraction: Preliminary Results.

- Esswein, Eric J.; Snawder, John; King, Bradley; Breitenstein, Michael; Alexander-Scott, Marissa; Kiefer, Max.
- In: *Journal of Occupational and Environmental Hygiene*, Vol. 11, Issue 10, pages D174-D184.
- http://www.tandfonline.com/doi/abs/10.1080/15459624.2014.933960

Introduction: Approximately 562,000 workers were employed in the U.S. oil and gas extraction industry in 2012; nearly half those workers were employed by well servicing companies, which include companies that conduct hydraulic fracturing and flowback operations. To understand public risks for chemical exposures in modern oil and gas extraction operations, the National Institute for Occupational Safety and Health (NIOSH) initiated the Field Effort to Assess Chemical Exposures in Oil and Gas Workers. Initial research identified exposure risks for repsirable crystalline silica during hydraulic fracturing as an occupational health hazard. This report describes industrial hygiene sampling during flowback operations at six unconventional oil and gas extraction sites in Colorado and Wyoming during spring and summer 2013. The results are considered preliminary; additional exposure assessments are needed to better understand the range of possible exposures, risk factors, and controls during flowback operations.

August 1, 2014. [*Categories:* Ecology, General (Comment / Review)]

Biotic impacts of energy development from shale: research priorities and knowledge gaps.

- Souther, Sara; Tingley, Morgan W.; Popescu, Viorel D.; Hayman, David T.S.; Ryan, Maureen E.; Graves, Tabitha A.; Hartl, Brett; Terrell, Kimberly.
- In: *Frontiers in Ecology and the Environment*, Vol. 12, Issue 6, pages 330-338.
- http://www.esajournals.org/doi/abs/10.1890/130324

Abstract: Although shale drilling operations for oil and natural gas have increased greatly in the past decade, few studies directly quantify the impacts of shale development on plants and wildlife. We evaluate knowledge gaps related to shale development and prioritize research needs using a quantitative framework that includes spatial and temporal extent, mitigation difficulty, and current level of understanding. Identified threats to biota from shale development include: surface and groundwater contamination; diminished stream flow; stream siltation; habitat loss and fragmentation; localized air, noise, and light pollution; climate change; and cumulative impacts. We find the highest research priorities to be probabilistic threats (underground chemical migration; contaminant release during storage, during disposal, or from accidents; and cumulative impacts), the study of which will require major scientific coordination among researchers, industry, and government decision makers. Taken together, our research prioritization outlines a way forward to better understand how energy development affects the natural world.

August, 2014. [*Categories:* General (Comment / Review), Water Quality]

Hydraulic "Fracking": Are surface water impacts an ecological concern?

- Burton, G. Allen; Basu, Niladri; Ellis, Brian R.; Kapo, Katherine E.; Entrekin, Sally; Nadelhoffer, Knute.
- In: *Environmental Toxicology and chemistry / SETAC*, Vol. 33, Issue 8, pages 1679-1689.
- http://www.ncbi.nlm.nih.gov/pubmed/25044053

Abstract: Use of high-volume hydraulic fracturing (HVHF) in unconventional reservoirs to recover previously inaccessible oil and natural gas is rapidly expanding in North America and elsewhere. Although hydraulic fracturing has been practiced for decades, the advent of more technologically advanced horizontal drilling coupled with improved slickwater chemical formulations has allowed extensive natural gas and oil deposits to be recovered from shale formations. Millions of liters of local groundwaters are utilized to generate extensive fracture networks within these low-permeability reservoirs, allowing extraction of the trapped hydrocarbons. Although the technology is relatively standardized, the geographies and related policies and regulations guiding these operations vary markedly. Some ecosystems are more at risk from these operations than others because of either their sensitivities or the manner in which the HVHF operations are conducted. Generally, the closer geographical proximity of the susceptible ecosystem to a drilling site or a location of related industrial processes, the higher the risk of that ecosystem being impacted by the operation. The associated construction of roads, power grids, pipelines, well pads, and water-extraction systems along with increased truck traffic are common to virtually all HVHF operations. These operations may result in increased erosion and sedimentation, increased risk to aquatic ecosystems from chemical spills or runoff, habitat fragmentation, loss of stream riparian zones, altered biogeochemical cycling, and reduction of available surface and hyporheic water volumes because of withdrawal-induced lowering of local groundwater levels. The potential risks to surface waters from HVHF operations are similar in many ways to those resulting from agriculture, silviculture, mining, and urban development. Indeed, groundwater extraction associated with agriculture is perhaps a larger concern in the long term in some regions. Understanding the ecological impacts of these anthropogenic activities provides useful information for evaluations of potential HVHF hazards. Geographic information system-based modeling combined with strategic site monitoring has provided insights into the relative importance of these and other ecoregion and land-use factors in discerning potential HVHF impacts. Recent findings suggest that proper siting and operational controls along with strategic monitoring can reduce the potential for risks to aquatic ecosystems. Nevertheless, inadequate data exist to predict ecological risk at this time. The authors suggest considering the plausibility of surface water hazards associated with the various HVHF operations in terms of the ecological context and in the context of relevant anthropogenic activities.

July 31, 2014. [*Category:* Ecology]

Effects of Livestock Grazing and Well Construction on Prairie Vegetation Structure Surrounding Shallow Natural Gas Wells.

- Koper, N.; Molloy, K.; Leston, L.; Yoo, J.
- In: *Environmental Management*, Vol. 54, Issue 5, pages 1131-1138.
- http://link.springer.com/article/10.1007/s00267-014-0344-5

Abstract: Short and sparse vegetation near shallow gas wells has generally been attributed to residual effects from well construction, but other mechanisms might also explain these trends. We evaluated effects of distance to shallow gas wells on vegetation and bare ground in mixed-grass prairies in southern Alberta, Canada, from 2010 to 2011. We then tested three hypotheses to explain why we found shorter vegetation and more bare ground near wells, using cattle fecal pat transects from 2012, and our vegetation quadrats. We evaluated whether empirical evidence suggested that observed patterns were driven by (1) higher abundance of crested wheatgrass (Agropyron cristatum) near wells, (2) residual effects of well construction, or (3) attraction of livestock to wells. Crested wheatgrass occurrence was higher near wells, but this did not explain effects of wells on vegetation structure. Correlations between distance to wells and litter depth were the highest near newer wells, providing support for the construction hypothesis. However, effects of distance to wells on other vegetation metrics did not decline as time since well construction increased, suggesting that other mechanisms explained observed edge effects. Cattle abundance was substantially higher near wells, and this effect corresponded with changes in habitat structure. Our results suggest that both residual effects of well construction and cattle behavior may explain effects of shallow gas wells on habitat structure in mixed-grass prairies, and thus, to be effective, mitigation strategies must address both mechanisms.

July 29, 2014. [*Category:* General (Comment / Review)]

The Shale Gas Revolution from the Viewpoint of a Former Industry Insider.

- Bamberger, Michelle; Oswald, Robert.
- In: *NEW SOLUTIONS: A Journal of Environmental and Occupational Health Policy*, Vol. 29, July 2014, pages 1-16.
- http://baywood.metapress.com/link.asp?id=k322627843616205

Abstract: This is an interview conducted with an oil and gas worker who was employed in the industry from 1993 to 2012. He requested that his name not be used. From 2008 to 2012, he drilled wells for a major operator in Bradford County, Pennsylvania. Bradford County is the center of the Marcellus shale gas boom in Northeastern Pennsylvania. In 2012, he formed a consulting business to assist clients who need information on the details of gas and oil drilling operations. In this interview, the worker describes the benefits and difficulties of the hard work involved in drilling unconventional gas wells in Pennsylvania. In particular, he outlines the safety procedures that were in place and how they sometimes failed, leading to workplace injuries. He provides a compelling view of the trade-offs between the economic opportunities of working on a rig and the dangers and stresses of working long hours under hazardous conditions.

July 25, 2014. [*Category:* Water Quality]

Using Discriminant Analysis to Determine Sources of Salinity in Shallow Groundwater Prior to Hydraulic Fracturing.

- Lautz, Laura K.; Hoke, Gregory D.; Lu, Zunli; Siegel, Donald I.; Christian, Kayla; Kessler, John Daniel; Teale, Natalie G.

- In: *Environmental Science & Technology*, Vol. 48, Issue 16, Pages 9061-9069.
- http://pubs.acs.org/doi/abs/10.1021/es502244v

Abstract: High-volume hydraulic fracturing (HVHF) gas-drilling operations in the Marcellus Play have raised environmental concerns, including the risk of groundwater contamination. Fingerprinting water impacted by gas-drilling operations is not trivial given other potential sources of contamination. We present a multivariate statistical modeling framework for developing a quantitative, geochemical fingerprinting tool to distinguish sources of high salinity in shallow groundwater. The model was developed using new geochemical data for 204 wells in New York State (NYS), which has a HVHF moratorium and published data for additional wells in NYS and several salinity sources (Appalachian Basin brines, road salt, septic effluent, and animal waste). The model incorporates a stochastic simulation to predict the geochemistry of high salinity (>20 mg/L Cl) groundwater impacted by different salinity sources and then employs linear discriminant analysis to classify samples from different populations. Model results indicate Appalachian Basin brines are the primary source of salinity in 35% of sampled NYS groundwater wells with >20 mg/L Cl. The model provides an effective means for differentiating groundwater impacted by basin brines versus other contaminants. Using this framework, similar discriminatory tools can be derived for other regions from background water quality data.

July 22, 2014. [*Category:* Climate]

Methane Destruction Efficiency of Natural Gas Flares Associated with Shale Formation Wells.

- Caulton, Dana R.; Shepson, Paul B.; Cambaliza, Maria; McCabe, David; Baum, Ellen; Stirm, Brian.
- In: *Environmental Science & Technology*, Vol. 48, Issue 16, pages 9548-9554.
- http://dx.doi.org/10.1021/es500511w

Abstract: Flaring to dispose of natural gas has increased in the United States and is typically assumed to be 98% efficient, accounting for both incomplete combustion and venting during unintentional flame termination. However, no in-situ measurements of flare emissions have been reported. We used an aircraft platform to sample 10 flares in North Dakota and 1 flare in Pennsylvania, measuring CO2, CH4 and meteorological data. Destruction Removal Efficiency (DRE) was calculated by assuming a flare natural gas input composition of 60-100% CH4. In all cases flares were greater than 99.80% efficient at the 25% quartile. Crosswinds up to 15 m/s were observed, but did not significantly adversely affect efficiency. During analysis unidentified peaks of CH4, most likely from unknown venting practices, appeared much larger in magnitude than emissions from flaring practices. Our analysis suggests 98% efficiency for non-sputtering flares is a conservative estimate for incomplete combustion and that the unidentified venting is a greater contributor to CH4 emissions.

July 22, 2014. [*Category:* General (Comment / Review)]

Nuclear Waste Disposal: A Cautionary Tale for Shale Gas Development.

- Alley, William M.; Cherry, John A.; Parker, Beth L.; Ryan, M. Cathryn.
- In: *EOS, Transactions America Geophysical Union*, Vol. 95, Issue 29, page 264.
- http://onlinelibrary.wiley.com/doi/10.1002/2014EO290005/abstract

Abstract: Nuclear energy and shale gas development each began with the promise of cheap, abundant energy and prospects for national energy independence. Nuclear energy was touted as “too cheap to meter,” and shale gas promised jobs and other economic benefits during a recession.

July 21, 2014. [*Category:* Climate]

Harmonization of initial estimates of shale gas life cycle greenhouse gas emissions for electric power generation.

- Heath, Garvin A.; O'Donoughue, Patrick; Arent, Douglas J.; Bazilian, Morgan.
- In: *Proceedings of the National Academy of Sciences*, Vol. 111, Issue 31, pages E3167-E3176.
- http://www.pnas.org/content/111/31/E3167

Abstract: Recent technological advances in the recovery of unconventional natural gas, particularly shale gas, have served to dramatically increase domestic production and reserve estimates for the United States and internationally. This trend has led to lowered prices and increased scrutiny on production practices. Questions have been raised as to how greenhouse gas (GHG) emissions from the life cycle of shale gas production and use compares with that of conventionally produced natural gas or other fuel sources such as coal. Recent literature has come to different conclusions on this point, largely due to differing assumptions, comparison baselines, and system boundaries. Through a meta-analytical procedure we call harmonization, we develop robust, analytically consistent, and updated comparisons of estimates of life cycle GHG emissions for electricity produced from shale gas, conventionally produced natural gas, and coal. On a per-unit electrical output basis, harmonization reveals that median estimates of GHG emissions from shale gas-generated electricity are similar to those for conventional natural gas, with both approximately half that of the central tendency of coal. Sensitivity analysis on the harmonized estimates indicates that assumptions regarding liquids unloading and estimated ultimate recovery (EUR) of wells have the greatest influence on life cycle GHG emissions, whereby shale gas life cycle GHG emissions could approach the range of best-performing coal-fired generation under certain scenarios. Despite clarification of published estimates through harmonization, these initial assessments should be confirmed through methane emissions measurements at components and in the atmosphere and through better characterization of EUR and practices.

July 18, 2014. [*Category:* Health]

Environmental Health Research Recommendations from the Inter-Environmental Health Sciences Core Center Working Group on Unconventional Natural Gas Drilling Operations.

- Penning, Trevor M.; Breysse, Patrick N.; Gray, Kathleen; Howarth, Marilyn; Yan, Beizhan.
- In: *Environmental Health Perspectives*, Vol. 122, Issue 11, November 2014.
- http://ehp.niehs.nih.gov/1408207/

Abstract:

Background: Unconventional natural gas drilling operations (UNGDO) (which include hydraulic fracturing and horizontal drilling) supply an energy source that is potentially cleaner than liquid or solid fossil fuels and may provide a route to energy independence. However, significant concerns have arisen due to the lack of research on the public health impact of UNGDO.

Objectives: Environmental Health Sciences Core Centers (EHSCCs), funded by the National Institute of Environmental Health Sciences (NIEHS), formed a working group to review the literature on the potential public health impact of UNGDO and to make recommendations for needed research.

Discussion: The Inter-EHSCC Working Group concluded that a potential for water and air pollution exists that might endanger public health, and that the social fabric of communities could be impacted by the rapid emergence of drilling operations. The working group recommends research to inform how potential risks could be mitigated.

Conclusions: Research on exposure and health outcomes related to UNGDO is urgently needed, and community engagement is essential in the design of such studies.

July 16, 2014. [*Categories:* General (Comment / Review), Regulation]

Risks and Risk Governance in Unconventional Shale Gas Development.

- Small, Mitchell J.; Stern, Paul C.; Bomberg, Elizabeth; Christopherson, Susan M.; Goldstein, Bernard; Israel, Andrei L.; Jackson, Robert B.; Krupnick, Alan; Mauter, Meagan S.; Nash, Jennifer; North, D. Warner; Olmstead, Sheila; Prakash, Aseem; Rabe, Barry G.; Richardson, Nathan; Tierney, Susan; Webler, Thomas; Wong-Parodi, Gabrielle; Zielinska, Barbara.
- In: *Environmental Science & Technology*, Vol. 48, Issue 15, pages 8289-8297.
- http://www.ncbi.nlm.nih.gov/pubmed/24983403

Abstract: A broad assessment is provided of the current state of knowledge regarding the risks associated with shale gas development and their governance. For the principal domains of risk, we identify observed and potential hazards and promising mitigation options to address them, characterizing current knowledge and research needs. Important unresolved research questions are identified for each area of risk, however, certain domains exhibit especially acute deficits of knowledge and attention, including integrated studies of public health, ecosystems, air quality, socioeconomic impacts on communities, and climate change. For these, current research and analysis are insufficient to either confirm or preclude important impacts. The rapidly evolving landscape of shale gas governance in the U.S. is also assessed, noting challenges and opportunities associated with the current decentralized (state-focused) system of regulation. We briefly review emerging approaches to shale gas governance in other nations, and consider new governance initiatives and options in the U.S. involving voluntary industry certification, comprehensive development plans, financial instruments, and possible future federal roles. In order to address the multiple disciplines and complexities of the evolving shale gas system and reduce the many key uncertainties needed for improved management, a coordinated multiagency federal research effort will need to be implemented.

July 16, 2014. [*Category:* Waste / Fluids]

Characterization of Marcellus Shale Flowback Water.

- Abualfaraj, Noura; Gurian, Patrick L.; Olson, Mira S.
- In: *Environmental Engineering Science,* Vol. 31, Issue 9, pages 514-524.
- http://online.liebertpub.com/doi/full/10.1089/ees.2014.0001

Abstract: Flowback water is the solution that returns to the surface following completion of the hydraulic fracturing process during natural gas extraction. This study examines and analyzes the constituents that make up flowback waters collected from various drilling sites in Marcellus shale formation in the states of Pennsylvania, New York, and West Virginia. Flowback sampling data were collected from four different sources (the Environmental Protection Agency, Gas Technology Institute; Pennsylvania Department of Environmental Protection; Bureau of Oil and Gas Management; and the New York Department of Environmental Conservation) and compiled into one database with a total of 35,000 entries. Descriptive statistical analysis revealed high concentrations of chlorinated solvents, disinfectants, dissolved metals, organic compounds, radionuclides, and total dissolved solids. A one-way ANOVA test revealed that over 60% of the constituents tested displayed significant differences (significance level=0.05) in mean concentrations among the four data sources. Relative prioritization scores were developed for 58 constituents by dividing observed mean concentrations by the maximum contamination level (MCL) guidelines for drinking water. The following constituents were found to have mean concentrations over 10 times greater than the MCL: 1,2-dichloroethane, antimony, barium, benzene, benzo(a)pyrene, chloride, dibromochloromethane, gross alpha, iron, manganese, pentachlorophenol, radium, thallium, and vinyl chloride. Concentrations of anthropogenic chemicals are tightly correlated with each other, but not with chloride concentrations, and not with naturally occurring inorganics and radionuclides.

July 15, 2014. [*Category:* Waste / Fluids]

Strontium Isotopes Test Long-Term Zonal Isolation of Injected and Marcellus Formation Water after Hydraulic Fracturing.

- Kolesar Kohl, Courtney A.; Capo, Rosemary C.; Stewart, Brian W.; Wall, Andrew J.; Schroeder, Karl T.; Hammack, Richard Warren; Guthrie, George Drake.
- In: *Environmental Science & Technology*, Vol. 48, Issue 16, pages 9867-9873.
- http://pubs.acs.org/doi/abs/10.1021/es501099k

Abstract: One concern regarding unconventional hydrocarbon production from organic-rich shale is that hydraulic fracture stimulation could create pathways that allow injected fluids and deep brines from the target formation or adjacent units to migrate upward into shallow drinking water aquifers. This study presents Sr isotope and geochemical data from a well-constrained site in Greene County, Pennsylvania, in which samples were collected before and after hydraulic fracturing of the Middle Devonian Marcellus Shale. Results spanning a 15-month period indicated no significant migration of Marcellus-derived fluids into Upper Devonian/Lower Mississippian units located 900-1200 m above the lateral Marcellus boreholes or into groundwater sampled at a spring near the site. Monitoring the Sr isotope ratio of water from legacy oil and gas wells or drinking water wells can provide a sensitive early warning of upward brine migration for many years after well stimulation.

July 11, 2014. [*Category:* General (Comment / Review)]

What's the 'fracking' problem? One word can't say it all.

- Evensen, Darrick; Jacquet, Jeffrey B.; Clarke, Christopher E.; Stedman, Richard C.
- In: *The Extractive Industries and Society*, Vol. 1, Issue 2, pages 130-136.
- http://www.sciencedirect.com/science/article/pii/S2214790X14000471

Abstract: "Fracking" has received substantial attention in scientific, mass media, and public discourse. This word originally referred to the process of hydraulic fracturing, but recently it has taken on a wider range of meanings in many fora. It now denotes one or more of several processes and impacts related to gas/oil exploration, extraction, and development; confusion can arise when it is unclear which processes or impacts are included in a particular use of this term. "Fracking" also carries negative and lewd connotations that shape public representations of the processes and impacts associated with it. By causing confusion and evoking bias, the word "fracking" can constrain meaningful policy conversation about the underlying issues and concerns. We offer recommendations for how to discuss this controversial topic while at best avoiding, or at least supplementing, the term "fracking".

July 9, 2014. [*Categories:* General (Comment / Review), Water Quality]

The integrity of oil and gas wells.

- Jackson, Robert B.
- In: *PNAS*, Vol. 111, Issue 30, pages 10902-10903.
- http://www.pnas.org/content/111/30/10902.extract

Extract: Public concerns about oil and natural gas extraction these days inevitably turn to hydraulic fracturing, where millions of gallons of water, sand, and chemicals are pumped underground at high pressures to crack open rocks. Hydraulic fracturing often occurs a mile or more down, far from the water we drink or the air we breathe. The focus for safety and environmental stewardship should often be somewhere else—nearer the surface—emphasizing risks from spills, wastewater disposal, and the integrity of oil and natural gas wells passing through drinking-water aquifers (1⇓⇓–4). In PNAS, Ingraffea et al. examine one of these factors, well integrity, across the Marcellus region of Pennsylvania, using inspection records from the state Department of Environmental Protection (DEP).

In a technical sense, "well integrity" refers to the zonal isolation of liquids and gases from the target formation or from intermediate layers through which the well passes. In a practical sense, it means that a well doesn't leak. Drilling companies emphasize well integrity because a faulty well is expensive to repair and, in the rarest of cases, costs lives, as in the Deepwater Horizon disaster in the Gulf of Mexico. Drillers use steel casing (pipes), cement between nested casings and between the outside casing and rock wall, and mechanical devices to keep fluids inside the well.

Faulty casing and cementing cause most well integrity problems. Steel casing can leak at the connections or corrode from acids. Cement can deteriorate with time too, but leaks also happen when cement shrinks, develops cracks or channels, or is lost into the surrounding rock when applied. If integrity fails, gases and liquids can leak out of the casing or, just as importantly, move into, up, and out of the well through faulty cement between the casing and the rock wall.

July 3, 2014. [*Category:* Seismicity]

Sharp increase in central Oklahoma seismicity since 2008 induced by massive wastewater injection.

- Keranen, K. M.; Weingarten, M.; Abers, G. A.; Bekins, B. A.; Ge, S.
- In: *Science*, Vol. 345, Issue 6195, pages 448-451.
- http://www.sciencemag.org/content/345/6195/448.abstract

Abstract: Unconventional oil and gas production provides a rapidly growing energy source; however, high-production states in the United States, such as Oklahoma, face sharply rising numbers of earthquakes. Subsurface pressure data required to unequivocally link earthquakes to injection are rarely accessible. Here we use seismicity and hydrogeological models to show that fluid migration from high-rate disposal wells in Oklahoma is potentially responsible for the largest swarm. Earthquake hypocenters occur within disposal formations and upper-basement, between 2-5 km depth. The modeled fluid pressure perturbation propagates throughout the same depth range and tracks earthquakes to distances of 35 km, with a triggering threshold of ~0.07 MPa. Although thousands of disposal wells operate aseismically, four of the highest-rate wells are capable of inducing 20% of 2008-2013 central US seismicity.

July, 2014. [*Category:* Health]

Hydraulic Fracturing and the Risk of Silicosis.

- Rosenman, Kenneth D.
- In: *Clinical Pulmonary Medicine*, Vol. 21, Issue 4, pages 167-172.
- http://journals.lww.com/clinpulm/Abstract/2014/07000/Hydraulic_Fracturing_and_the_Risk_of_Silicosis.2.aspx

Abstract: "Fracking," the common name for hydraulic fracturing is widely used to extract oil and gas, particularly from deep shale formations. A single well requires the use of millions of gallons of water and tons of sand. Air sampling results show that the majority of silica levels at hydraulic fracturing sites were above the Occupational Safety and Health Administration allowable standard and 84% were above Occupational Safety and Health Administration's new proposed standard. These exposure levels put workers, particularly sand mover operators and T-belt operators who had the highest levels, at risk of silicosis and the other silica-related conditions of lung cancer, end-stage renal disease, chronic obstructive pulmonary disease, tuberculosis, and connective tissue disease. Because of the fracking industry's demand for silica, sand mining has markedly increased, which has also increased the number of workers at risk of developing silicosis and other silica-related conditions in the mining industry. This paper reviews the parts of the country where health care providers should be most concerned about possible patients in their practice who are at risk from this newly recognized source of silica exposure and the appropriate medical testing to perform. However, given the long latency, 20 or more years, of most silica-related health conditions and the fact that fracking did not become widely used until the 2000s, it may be years before health care providers see clinical-related disease in their practices.

July, 2014. [*Categories:* Waste / Fluids, Water Quality]

Development of Rapid Radiochemical Method for Gross Alpha and Gross Beta Activity Concentration in Flowback and Produced Waters from Hydraulic Fracturing Operations.

- Schumacher, Brian; Griggs, John; Askren, Dan; Litman, Bob; Shannon, Bob; Mehrhoff, Marinea; Nelson, Andrew; Schultz, Michael K.
- By: *U.S. Environmental Protection Agency*, contract EP-W-07-037, 90 pages. (Prepared for the National Analytical Radiation Laboratory of the Office of Radiation and Indoor Air and the National Exposure Research Center of the Office of Research and Development.)
- http://www2.epa.gov/sites/production/files/2014-08/documents/epa-600-r-14-107_-_gross_alpha_-_gross_beta_508_km_08-08-2014.pdf

Extract: This report summarizes the development and testing of an improved method for the Determination of Gross Alpha and Gross Beta Activity in Flowback and Produced Waters from Hydraulic Fracturing Operations (FPWHFO). Flowback and produced waters are characterized by high concentrations and complex mixtures of inorganic salts, organic compounds and other materials. They may commonly contain concentrations of naturally-occurring radionuclides from the uranium and thorium decay chains as high as 10^3–10^4 times the level of activity routinely observed in environmental water samples. The complex nature and high concentration of matrix constituents in these water samples present significant technical challenges especially for gross alpha and gross beta determinations in such samples.

June 30, 2013. [*Category:* General (Comment / Review)]

Observations of the Release of Non-Methane Hydrocarbons from Fractured Shale.

- Sommariva, Roberto; Blake, Robert S.; Cuss, Robert J.; Cordell, Rebecca; Harrington, Jon F.; White, Iain R.; Monks, Paul S.
- In: *Environmental Science & Technology*, Vol. 48, Issue 15, pages 8891-8896.
- http://dx.doi.org/10.1021/es502508w

Abstract: The organic content of shale has become of commercial interest as a source of hydrocarbons, owing to the development of hydraulic fracturing ("fracking"). While the main focus is on the extraction of methane, shale also contains significant amounts of non-methane hydrocarbons (NMHCs). We describe the first real-time observations of the release of NMHCs from a fractured shale. Samples from the Bowland-Hodder formation (England) were analyzed under different conditions using mass spectrometry, with the objective of understanding the dynamic process of gas release upon fracturing of the shale. A wide range of NMHCs (alkanes, cycloalkanes, aromatics, and bicyclic hydrocarbons) are released at parts per million or parts per billion level with temperature- and humidity-dependent release rates, which can be rationalized in terms of the physicochemical characteristics of different hydrocarbon classes. Our results indicate that higher energy inputs (i.e., temperatures) significantly increase the amount of NMHCs released from shale, while humidity tends to suppress it; additionally, a large fraction of the gas is released within the first hour after the shale has been fractured. These findings suggest that other hydrocarbons of commercial interest may be extracted from shale and open the possibility to optimize the "fracking" process, improving gas yields and reducing environmental impacts.

June 30, 2014. [*Category:* Water Quality]

Assessment and risk analysis of casing and cement impairment in oil and gas wells in Pennsylvania, 2000–2012.

- Ingraffea, Anthony R.; Wells, Martin T.; Santoro, Renee L.; Shonkoff, Seth B. C.
- In: *Proceedings of the National Academy of Sciences*, Vol. 111, Issue No. 30, pages 10955-10960.
- http://www.pnas.org/content/early/2014/06/25/1323422111

Abstract: Casing and cement impairment in oil and gas wells can lead to methane migration into the atmosphere and/or into underground sources of drinking water. An analysis of 75,505 compliance reports for 41,381 conventional and unconventional oil and gas wells in Pennsylvania drilled from January 1, 2000–December 31, 2012, was performed with the objective of determining complete and accurate statistics of casing and cement impairment. Statewide data show a sixfold higher incidence of cement and/or casing issues for shale gas wells relative to conventional wells. The Cox proportional hazards model was used to estimate risk of impairment based on existing data. The model identified both temporal and geographic differences in risk. For post-2009 drilled wells, risk of a cement/casing impairment is 1.57-fold [95% confidence interval (CI) (1.45, 1.67); $P < 0.0001$] higher in an unconventional gas well relative to a conventional well drilled within the same time period. Temporal differences between well types were also observed and may reflect more thorough inspections and greater emphasis on finding well leaks, more detailed note taking in the available inspection reports, or real changes in rates of structural integrity loss due to rushed development or other unknown factors. Unconventional gas wells in northeastern (NE) Pennsylvania are at a 2.7-fold higher risk relative to the conventional wells in the same area. The predicted cumulative risk for all wells (unconventional and conventional) in the NE region is 8.5-fold [95% CI (7.16, 10.18); $P < 0.0001$] greater than that of wells drilled in the rest of the state.

June 28, 2014. [*Categories:* General (Comment / Review), Health]

Shale gas regulation in the UK and health implications of fracking.

- Hill, Michael.
- In: *The Lancet*, Vol. 383, Issue 9936, pages 2211-2212.
- http://www.thelancet.com/journals/lancet/article/PIIS0140-6736%2814%2960888-6/fulltext

Summary: I have some serious concerns with Sari Kovats and colleagues' Comment (March 1, p 757), as I feel it is misleading (albeit unintentionally). Although the UK Government has indeed stated that it accepts the Royal Society and Royal Academy of Engineering Working Group's recommendations on shale gas extraction, the reality is that only one of these recommendations has been implemented in full; one out of ten in 2 years. Other recommendations have been ignored or the opposite has been put in place.

June 20, 2014. [*Category:* Health]

Field Survey of Health Perception and Complaints of Pennsylvania Residents in the Marcellus Shale Region.

- Saberi, Pouné; Propert, Kathleen Joy; Powers, Martha; Emmett, Edward; Green-McKenzie, Judith.
- In: *International Journal of Environmental Research and Public Health*, Vol. 11, Issue 6, pages 6517-6527.
- http://www.mdpi.com/1660-4601/11/6/6517

Abstract: Pennsylvania Marcellus Shale region residents have reported medical symptoms they believe are related to nearby Unconventional Natural Gas Development (UNGD). Associations between medical symptoms and UNGD have been minimally explored. The objective of this descriptive study is to explore whether shale region Pennsylvania residents perceive UNGD as a health concern and whether they attribute health symptoms to UNGD exposures. A questionnaire was administered to adult volunteers with medical complaints in a primary-care medical office in a county where UNGD was present. Participants were asked whether they were concerned about health effects from UNGD, and whether they attributed current symptoms to UNGD or to some other environmental exposure. There were 72 respondents; 22% perceived UNGD as a health concern and 13% attributed medical symptoms to UNGD exposures. Overall, 42% attributed one or more of their medical symptoms to environmental causes, of which UNGD was the most frequent. A medical record review conducted on six participants who attributed their medical symptoms to UNGD revealed that only one of these records documented both the symptoms in question and the attribution to UNGD. The results of this pilot study suggest that there is substantial concern about adverse health effects of UNGD among Pennsylvania Marcellus Shale residents, and that these concerns may not be adequately represented in medical records. Further efforts to determine the relationship between UNGD and health are recommended in order to address community concerns.

June 19, 2014. [*Category:* Climate]

Natural gas fugitive emissions rates constrained by global atmospheric methane and ethane.

- Schwietzke, Stefan; Griffin, W. Michael; Matthews, H. Scott; Bruhwiler, Lori M. P.
- In: *Environmental Science & Technology*, Vol. 48, Issue 14, pages 7714-7722.
- http://pubs.acs.org/doi/abs/10.1021/es501204c

Abstract: The amount of methane emissions released by the natural gas (NG) industry is a critical and uncertain value for various industry and policy decisions, such as for determining the climate implications of using NG over coal. Previous studies have estimated fugitive emissions rates (FER) – the fraction of produced NG (mainly methane and ethane) escaped to the atmosphere – between 1-9%. Most of these studies rely on few and outdated measurements, and some may represent only temporal/regional NG industry snapshots. This study estimates NG industry representative FER using global atmospheric methane and ethane measurements over three decades, and literature ranges of (i) tracer gas atmospheric lifetimes, (ii) non-NG source estimates, and (iii) fossil fuel fugitive gas hydrocarbon compositions. The modeling suggests an upper bound global average FER of 5% during 2006-2011, and a most likely FER of 2-4% since 2000, trending downward. These results do not account for highly uncertain natural hydrocarbon seepage, which could lower the FER. Further emissions reductions by the NG industry may be needed to ensure climate benefits over coal during the next few decades.

June 18, 2014. [*Category:* General (Comment / Review)]

Shale gas policy in the United Kingdom: An argumentative discourse analysis.

- Cotton, Matthew; Rattle, Imogen; Van Alstine, James.
- In: *Energy Policy*, Vol. 73, October 2014, pages 427-438.
- http://www.sciencedirect.com/science/article/pii/S0301421514003309

Abstract: Shale gas has become an energy policy priority in the United Kingdom in light of profitable extraction activities in the United States. Since 2012 the Coalition Government has created key economic drivers to encourage shale exploration, whilst growing activism in affected site communities has stirred significant media and academic commentary. This study examines the growing national debate as a matter of discourse, adopting an argumentative discourse analytic approach to assess data collected from stakeholder interviews (n=21) and key policy actor statements quoted in broadsheet newspapers. We explore three dominant "storylines" emerging in relation to shale gas policy: (1) "cleanliness and dirt" concerns the relative framing of the environmental benefits and harms of shale gas; (2) "energy transitions – pathways and diversions" concerns geographic metaphors of transitions to carbon intensive and low-carbon energy systems; and (3) "geographies of environmental justice" concerns divisions of economic benefit distribution, environmental impact and procedural fairness. We find that central government policy rhetoric emphasises economic development, regulatory oversight and distribution of benefits to site communities, whilst minimising discussion of the implications of shale gas for anthropogenic climate change. The role of these discourses in influencing shale gas policy is discussed.

June 18, 2014. [*Category:* Waste / Fluids]

The flux of radionuclides in flowback fluid from shale gas exploitation.

- Almond, S.; Clancy, S. A.; Davies, R. J.; Worrall, F.
- In: *Environmental Science and Pollution Research International*, Vol. 21, Issue 21, November 2014, pages 12316-12324.
- http://www.ncbi.nlm.nih.gov/pubmed/24938807

Abstract: This study considers the flux of radioactivity in flowback fluid from shale gas development in three areas: the Carboniferous, Bowland Shale, UK; the Silurian Shale, Poland; and the Carboniferous Barnett Shale, USA. The radioactive flux from these basins was estimated, given estimates of the number of wells developed or to be developed, the flowback volume per well and the concentration of K (potassium) and Ra (radium) in the flowback water. For comparative purposes, the range of concentration was itself considered within four scenarios for the concentration range of radioactive measured in each shale gas basin, the groundwater of the each shale gas basin, global groundwater and local surface water. The study found that (i) for the Barnett Shale and the Silurian Shale, Poland, the 1 % exceedance flux in flowback water was between seven and eight times that would be expected from local groundwater. However, for the Bowland Shale, UK, the 1 % exceedance flux (the flux that would only be expected to be exceeded 1 % of the time, i.e. a reasonable worst case scenario) in flowback water was 500 times that expected from local groundwater. (ii) In no scenario was the 1 % exceedance exposure greater than 1 mSv-the allowable annual exposure allowed for in the UK. (iii) The radioactive flux of per energy produced was lower for shale gas than for conventional oil and gas production, nuclear power production and electricity generated through burning coal.

June 17, 2014. [*Category:* General (Comment / Review)]

The Karoo Fracking Debate: A Christian Contribution to the World Communities of Faith.

- Tucker, A. Roger; Tonder, Gerrit van.
- In: *Science and Engineering Ethics*, June 2014, pages 1-23.
- http://link.springer.com/article/10.1007/s11948-014-9563-7

Abstract: The fracking debate is a product of the tension between the environmental degradation it may cause, on the one hand, and on the other the greater energy demands of a rapidly increasing South African population with expectations of an ever-increasing standard of living. Shale gas fracking in the Karoo of South Africa promises to make vast reserves of oil and gas available to help meet a significant percentage of the country’s energy needs for many years to come. This will aid development and contribute to raising the standard of living of many. This article seeks to apprise the South African faith communities of the technology and risks involved. Christian theological guidelines are presented by which its benefits and dangers may be interrogated so that the community may be able come to an informed decision as to whether or not to support fracking.

June 15, 2014. [*Category:* Water Quality]

Hydraulic Fracture Extending into Network in Shale: Reviewing Influence Factors and Their Mechanism.

- Ren, Lan; Zhao, Jinzhou; Hu, Yongquan.
- In: *The Scientific World Journal*, Vol. 2014, 9 pages.
- http://www.hindawi.com/journals/tswj/2014/847107/abs/

Abstract: Hydraulic fracture in shale reservoir presents complex network propagation, which has essential difference with traditional plane biwing fracture at forming mechanism. Based on the research results of experiments, field fracturing practice, theory analysis, and numerical simulation, the influence factors and their mechanism of hydraulic fracture extending into network in shale have been systematically analyzed and discussed. Research results show that the fracture propagation in shale reservoir is influenced by the geological and the engineering factors, which includes rock mineral composition, rock mechanical properties, horizontal stress field, natural fractures, treating net pressure, fracturing fluid viscosity, and fracturing scale. This study has important theoretical value and practical significance to understand fracture network propagation mechanism in shale reservoir and contributes to improving the science and efficiency of shale reservoir fracturing design.

June 11, 2014. [*Category:* Water Usage]

Quantifying the potential effects of high-volume water extractions on water resources during natural gas development: Marcellus Shale, NY.

- Best, Laura C.; Lowry, Christopher S.
- In: *Journal of Hydrology: Regional Studies*, Vol. 1, July 2014, pages 1-16.
- http://www.sciencedirect.com/science/article/pii/S2214581814000020

Abstract:

Study region

The Marcellus Shale, New York State, USA.

Study focus

Development of natural gas resources within the Marcellus Shale will require large volumes of water if high-volume hydraulic fracturing expands into New York State. Although this region has ample fresh water resources, it is necessary to explore the response of hydraulically connected groundwater and surface water systems to large withdrawals. Because such effects would not be apparent from a typical water budget approach, this study applied groundwater flow modelling under scenarios of high-volume water withdrawals. Emphasis on water quantity, in contrast with other lines of research concerning water quality, introduced an important perspective to this controversial topic.

New hydrological insights for the region

The potential effects of the withdrawal scenarios on both the water table and stream discharge were quantified. Based on these impact results, locations in the aquifer and stream networks were identified, which demonstrate particular vulnerability to increased withdrawals and their distribution. These are the locations of importance for planners and regulators who oversee water permitting, to reach a sustainable management of the water resources under changing conditions of energy and corresponding water demand.

June 6, 2014. [*Category:* Water Quality]

Effect of Hydrofracking Fluid on Colloid Transport in the Unsaturated Zone.

- Sang, Wenjing; Stoof, Cathelijne R.; Zhang, Wei.; Morales, Veronica L.; Gao, Bin; Kay, Robert W.; Liu, Lin; Zhang, Yalei; Steenhuis, Tammo S.

- In: *Environmental Science & Technology*, Vol. 48, Issue 14, pages 8266-8274.
- http://dx.doi.org/10.1021/es501441e

Abstract: Hydraulic fracturing is expanding rapidly in the US to meet increasing energy demand and requires high volumes of hydrofracking fluid to displace natural gas from shale. Accidental spills and deliberate land application of hydrofracking fluids, which return to the surface during hydrofracking, are common causes of environmental contamination. Since the chemistry of hydrofracking fluids favors transport of colloids and mineral particles through rock cracks, it may also facilitate transport of in-situ colloids and associated pollutants in unsaturated soils. We investigated this by subsequently injecting deionized water and flowback fluid at increasing flow rates into unsaturated sand columns containing colloids. Colloid retention and mobilization was measured in the column effluent and visualized in-situ with bright field microscopy. While <5% of initial colloids were released by flushing with deionized water, 32-36% were released by flushing with flowback fluid in two distinct breakthrough peaks. These peaks resulted from 1) surface tension reduction and steric repulsion, and 2) slow kinetic disaggregation of colloid flocs. Increasing the flow rate of the flowback fluid mobilized an additional 36% of colloids, due to the expansion of water filled pore space. This study suggests that hydrofracking fluid may also indirectly contaminate groundwater by remobilizing existing colloidal pollutants.

June 6, 2014. [*Category:* Waste / Fluids]

Biodegradation of Novel Hydrocarbon Ring Structures Found in Hydraulic Fracturing Waters Using Silica-Encapsulated Pseudomonas sp. NCIB 9816-4.

- Aukema, Kelly G.; Kasinkas, Lisa; Aksan, Alptekin; Wackett, Lawrence P.
- In: *Applied and Environmental Microbiology*, Vol. 80, Issue 16, pages 4968-4876 (August 2014).
- http://aem.asm.org/content/early/2014/06/03/AEM.01100-14

Abstract: The most problematic hydrocarbons in hydraulic fracturing waste waters consist of fused, isolated, bridged, and spiro ring systems, the latter of which have been poorly studied with respect to biodegradation, prompting the testing here of six major ring structural sub-classes using a well-characterized bacterium and a silica encapsulation system previously shown to enhance biodegradation. The direct biological oxygenation of spiro ring compounds was demonstrated here for the first time. These and other hydrocarbon ring compounds have previously been shown to be present in flowback and produced waters from hydraulic fracturing operations. Pseudomonas sp. strain NCIB 9816-4 containing naphthalene dioxygenase was selected for its broad substrate specificity and it was demonstrated here to oxidize fundamental ring structures that are common in shale-derived waters but not previously investigated with this or related enzymes. Pseudomonas sp. NCIB 9816-4 was tested here in the presence of a silica encasement, a protocol that has been shown previously to protect bacteria against the extremes of salinity present in fracking waste waters. These studies demonstrate degradation of highly hydrophobic compounds by a silica-encapsulated model bacterium, demonstrate what it may not degrade, and contribute to a knowledge of the full range of hydrocarbon ring compounds that can be oxidized using Pseudomonas sp. NCIB 9816-4.

June 4, 2014. [*Category:* Water Quality]

Use of stable isotopes to identify sources of methane in Appalachian Basin shallow groundwaters: a review.

- Hakala, J. Alexandra.
- In: *Environmental Science: Processes & Impacts*, Vol. 16, pages 2080-2086.
- http://pubs.rsc.org/en/content/articlelanding/2014/em/c4em00140k#!divAbstract

Abstract: Development of unconventional shale gas reservoirs in the Appalachian Basin has raised questions regarding the potential for these activities to affect shallow groundwater resources. Geochemical indicators, such as stable carbon and hydrogen isotopes of methane, stable carbon isotopes of ethane, and hydrocarbon ratios, have been used to evaluate methane sources however their utility is complicated by influences from multiple physical (e.g., mixing) and geochemical (e.g., redox) processes. Baseline sampling of shallow aquifers prior to development, and measurement of additional geochemical indicators within samples from across the Appalachian Basin, may aid in identifying natural causes for dissolved methane in shallow groundwater versus development-induced pathways.

June 3, 2014. [*Category:* Economics]

Shale gas: Analysis of its role in the global energy market.

- Melikoglu, Mehmet.
- In: *Renewable and Sustainable Energy Reviews*, Vol. 37, September 2014, pages 460-468.
- http://www.sciencedirect.com/science/article/pii/S1364032114003189

Abstract: Shale gas revolution that took place in the United States at the beginning of the 21st century has still been shaping our global fossil fuel market. In 2012, the U.S. has surpassed Russia in natural gas production for the first time since 1982. At the same year, annual average U.S. Henry hub natural gas spot price decreased to $2.75 per million BTU, which was $8.69 per million BTU in 2005. In 2013, proved shale gas reserves of the world is estimated at nearly 2.7 trillion cubic metres (tcm) and unproved resources at staggering 203.9 tcm. As a result, there is a global rush to develop most of this resource as possible. However, shale gas is no miracle fuel. It has been suggested that its effects on the environment could be worse than conventional natural gas. Fugitive methane emissions, groundwater pollution, and increased seismicity are amongst the most important potential environmental side effects. There is also concern about the accuracy of resource potential estimations due to lack of data and specifically designed shale gas reservoir models. Nonetheless, the analysis in this study clearly showed that without developing global shale gas resources we have to consume 66% of our proved natural gas reserves to supply the demand till 2040. This would make most of the world natural gas importers, and rules of economy dictate that limited supply and increasing demand would skyrocket natural gas prices. Therefore, shale gas resource development is not an option but a must for the continuance of our global energy market and economy.

June 3, 2014. [*Categories:* Air Quality, Climate]

A new look at methane and non-methane hydrocarbon emissions from oil and natural gas operations in the Colorado Denver-Julesburg Basin.

- Pétron, Gabrielle; Karion, Anna; Sweeney, Colm; Miller, Benjamin Rd.; Montzka, Stephen A.; Frost, Gregory; Trainer, Michael; Tans, Pieter; Andrews, Arlyn; Kofler, Jonathan; Helmig, Detlev; Guenther, Douglas; Dlugokencky, Ed; Lang, Patricia; Newberger, Tim; Wolter, Sonja; Hall, Bradley; Novelli, Paul; Brewer, Alan; Conley, Stephen; Hardesty, Mike; Banta, Robert; White, Allen; Noone, David; Wolfe, Dan; Schnell, Russ.
- In: *Journal of Geophysical Research: Atmospheres*, Vol. 119, Issue 11, pages 6836-6852 (June 16, 2014).
- http://onlinelibrary.wiley.com/doi/10.1002/2013JD021272/abstract

Abstract: Emissions of methane (CH4) from oil and natural (O&G) gas operations in the most densely drilled area of the Denver-Julesburg (D-J) Basin in Weld County located in northeastern Colorado are estimated for two days in May 2012 using aircraft-based CH4 observations and planetary boundary layer height and ground-based wind profile measurements. Total top-down CH4 emission estimates are 25.8 ± 8.4 and 26.2 ± 10.7 tonnes CH4/hr for the May 29 and May 31 flights, respectively. Using inventory data, we estimate the total emissions of CH4 from non-O&G gas related sources at 7.1 ± 1.7 and 6.3 ± 1.0 tonnes CH4/hr for these two days. The difference in emissions is attributed to O&G sources in the study region and their total emission is on average 19.3 ± 6.9 tonnes/hr, close to three times higher than an hourly emission estimate based on EPA's Greenhouse Gas Reporting Program data for 2012. We derive top-down emissions estimates for propane, n-butane, i-pentane, n-pentane, and benzene from our total top-down CH4 emission estimate and the relative hydrocarbon abundances in aircraft-based discrete air samples. Emissions for these five non-methane hydrocarbons alone total 25.4 ± 8.2 tonnes/hr. Assuming these emissions are solely originating from O&G related activities in the study region, our results show that the state inventory for total VOC emitted by O&G activities is at least a factor of two too low for May 2012. Our top-down emission estimate of benzene emissions from O&G operations is 173 ± 64 kg/hr, or seven times larger than in the state inventory.

June 1, 2014. [*Category:* General (Comment / Review)]

Belief superiority in the environmental domain: Attitude extremity and reactions to fracking.

- Raimi, Kaitlin Toner; Leary, Mark R.
- In: *Journal of Environmental Psychology*, Vol. 40, December 2014, pages 76-85.
- http://www.sciencedirect.com/science/article/pii/S0272494414000474

Abstract: This study examined belief superiority—the belief that one's own beliefs are more correct than other viewpoints—in the domain of environmental and energy issues. Replicating research in other domains, attitude extremity on seven energy issues was associated with belief superiority about those viewpoints. Consequences of belief superiority were also tested: participants read an article that either confirmed or contradicted their position on hydraulic fracturing ("fracking"). People high in belief superiority rated the article's author more harshly when he disagreed with them. However, these participants were also more willing than those low in belief superiority to discuss and work on fracking topics. Those high in belief superiority thought they were better educated about energy than others, and their certainty about their beliefs tended to increase after reading the article, even when the article contradicted those beliefs. Implications of belief superiority for energy education and environmental campaigns are discussed.

May 29, 2014. [*Category:* General (Comment / Review)]

Cornucopia or curse? Reviewing the costs and benefits of shale gas hydraulic fracturing (fracking).

- Sovacool, Benjamin K.
- In: *Renewable and Sustainable Energy Reviews*, Vol. 37, September 2014, pages 249-264.
- http://www.sciencedirect.com/science/article/pii/S1364032114003062

Abstract: This study assesses the overall technical, economic, environmental, and social costs and benefits of the hydraulic fracturing ("fracking") of natural gas. Drawn from a review of more than 100 studies looking at shale gas in the past 10 years, most of them peer-reviewed, this article begins by briefly explaining the process of hydrofracking and summarizing recent market trends up until late 2013. Then, the study discusses a series of advantages and disadvantages to hydrofracking. It notes that done properly, shale gas development can enhance energy security and the availability of energy fuels, lower natural gas prices, offer a cleaner environmental footprint than some other fossil fuels, and enable local economic development. However, done poorly production can be prone to accidents and leakage, contribute to environmental degradation, induce earthquakes, and, when externalities are accounted for, produce more net economic losses than profits. The study concludes that the pursuit and utilization of shale gas thus presents policymakers, planners, and investors with a series of pernicious tradeoffs and tough choices.

May 21, 2014. [*Category:* Climate]

Emissions of organic carbon and methane from petroleum and dairy operations in California's San Joaquin Valley.

- Gentner, D. R.; Ford, T. B.; Guha, A.; Boulanger, K.; Brioude, J.; Angevine, W. M.; de Gouw, J. A.; Warneke, C.; Gilman, J. B.; Ryerson, T. B.; Peischl, J.; Meinardi, S.; Blake, D. R.; Atlas, E.; Lonneman, W. A.; Kleindienst, T. E.; Beaver, M. R.; Clair, J. M. St.; Wennberg, P. O.; VandenBoer, T. C.; Markovic, M. Z.; Murphy, J. G.; Harley, R. A.; Goldstein, A. H.
- In: *Atmospheric Chemistry and Physics*, Vol. 14, Issue 10, pages 4955-4978.
- http://www.atmos-chem-phys.net/14/4955/2014/

Abstract: Petroleum and dairy operations are prominent sources of gas-phase organic compounds in California's San Joaquin Valley. It is essential to understand the emissions and air quality impacts of these relatively understudied sources, especially for oil/gas operations in light of increasing US production. Ground site measurements in Bakersfield and regional aircraft measurements of reactive gas-phase organic compounds and methane were part of the CalNex (California Research at the Nexus of Air Quality and Climate Change) project to determine the sources contributing to regional gas-phase organic carbon emissions. Using a combination of near-source and downwind data, we assess the composition and magnitude of emissions, and provide average source profiles. To examine the spatial distribution of emissions in the San Joaquin Valley, we developed a statistical modeling method using ground-based data and the FLEXPART-WRF transport and meteorological model. We present evidence for large sources of paraffinic hydrocarbons from petroleum operations and oxygenated compounds from dairy (and other cattle) operations. In addition to the small straight-chain alkanes typically associated with petroleum operations, we observed a wide range of branched and cyclic alkanes, most of which have limited previous in situ measurements or characterization in petroleum operation emissions. Observed dairy emissions were dominated by ethanol, methanol, acetic acid, and methane. Dairy operations were responsible for the vast majority of methane emissions in the San Joaquin Valley; observations of methane were well correlated with non-vehicular ethanol, and multiple assessments of the spatial distribution of emissions in the San Joaquin Valley highlight the dominance of dairy operations for methane emissions. The petroleum operations source profile was developed using the composition of non-methane hydrocarbons in unrefined natural gas associated with crude oil. The observed source profile is consistent with fugitive emissions of condensate during storage or processing of associated gas following extraction and methane separation. Aircraft observations of concentration hotspots near oil wells and dairies are consistent with the statistical source footprint determined via our FLEXPART-WRF-based modeling method and ground-based data. We quantitatively compared our observations at Bakersfield to the California Air Resources Board emission inventory and find consistency for relative emission rates of reactive organic gases between the aforementioned sources and motor vehicles in the region. We estimate that petroleum and dairy operations each comprised 22% of anthropogenic non-methane organic carbon at Bakersfield and were each responsible for 8–13% of potential precursors to ozone. Yet, their direct impacts as potential secondary organic aerosol (SOA) precursors were estimated to be minor for the source profiles observed in the San Joaquin Valley.

May 20, 2014. [*Category:* Air Quality]

Strong wintertime ozone events in the Upper Green River basin, Wyoming.

- Rappenglück, B.; Ackermann, L.; Alvarez, S.; Golovko, J.; Buhr, M.; Field, R. A.; Soltis, J.; Montague, D. C.; Hauze, B.; Adamson, S.; Risch, D.; Wilkerson, G.; Bush, D.; Stoeckenius, T.; Keslar, C.

- In: *Atmospheric Chemistry and Physics*, Vol. 14, 2014, pages 4909-4934.
- http://www.atmos-chem-phys.net/14/4909/2014/acp-14-4909-2014.html

Abstract. During recent years, elevated ozone (O_3) values have been observed repeatedly in the Upper Green River basin (UGRB), Wyoming, during wintertime. This paper presents an analysis of high ozone days in late winter 2011 (1 h average up to 166 ppbv – parts per billion by volume). Intensive operational periods (IOPs) of ambient monitoring were performed, which included comprehensive surface and boundary layer measurements. On IOP days, maximum O_3 values are restricted to a very shallow surface layer. Low wind speeds in combination with low mixing layer heights (~ 50 m above ground level around noontime) are essential for accumulation of pollutants within the UGRB. Air masses contain substantial amounts of reactive nitrogen (NO_x) and non-methane hydrocarbons (NMHC) emitted from fossil fuel exploration activities in the Pinedale Anticline. On IOP days particularly in the morning hours, reactive nitrogen (up to 69%), aromatics and alkanes (~ 10–15%; mostly ethane and propane) are major contributors to the hydroxyl (OH) reactivity. Measurements at the Boulder monitoring site during these time periods under SW wind flow conditions show the lowest NMHC / NO_x ratios (~ 50), reflecting a relatively low reactive NMHC mixture, and a change from a NO_x-limited regime towards a NMHC-limited regime as indicated by photochemical indicators, e.g., O_3 /NO_y, O_3 /NO_z, and O_3 / HNO_3 and the EOR (extent of reaction). OH production on IOP days is mainly due to nitrous acid (HONO). On a 24 h basis and as determined for a measurement height of 1.80 m above the surface HONO photolysis on IOP days can contribute ~ 83% to OH production on average, followed by alkene ozonolysis (~ 9%). Photolysis by ozone and HCHO photolysis contribute about 4% each to hydroxyl formation. High HONO levels (maximum hourly median on IOP days: 1096 pptv – parts per trillion by volume) are favored by a combination of shallow boundary layer conditions and enhanced photolysis rates due to the high albedo of the snow surface. HONO is most likely formed through (i) abundant nitric acid (HNO_3) produced in atmospheric oxidation of NO_x, deposited onto the snow surface and undergoing photo-enhanced heterogeneous conversion to HONO (estimated HONO production: 10.2 ± 40% ppbv h^{-1}) and (ii) combustion-related emission of HONO (estimated HONO production: ~ 0.1 ± 30% ppbv h^{-1}). HONO production is confined to the lowermost 10 m of the boundary layer. HONO, serves as the most important precursor for OH, strongly enhanced due to the high albedo of the snow cover (HONO photolysis rate 10.7 ± 30% ppbv h^{-1}). OH radicals will oxidize NMHCs, mostly aromatics (toluene, xylenes) and alkanes (ethane, propane), eventually leading to an increase in ozone.

May 20, 2014. [*Category:* Water Quality]

The fate of residual treatment water in gas shale.

- Engelder, Terry; Cathles, Lawrence M.; Bryndzia, L. Taras.
- In: *Journal of Unconventional Oil and Gas Resources*, Vol. 7, September 2014, pages 33-48.
- http://www.sciencedirect.com/science/article/pii/S2213397614000202

Abstract: More than $2 \times 10^4 m^3$ of water containing additives is commonly injected into a typical horizontal well in gas shale to open fractures and allow gas recovery. Less than half of this treatment water is recovered as flowback or later production brine, and in many cases recovery is <30%. While recovered treatment water is safely managed at the surface, the water left in place, called residual treatment water (RTW), slips beyond the control of engineers. Some have suggested that this RTW poses a long term and serious risk to shallow aquifers by virtue of being free water that can flow upward along natural pathways, mainly fractures and faults. These concerns are based on single phase Darcy Law physics which is not appropriate when gas and water are both present. In addition, the combined volume of the RTW and the initial brine in gas shale is too small to impact near surface aquifers even if it could escape. When capillary and osmotic forces are considered, there are no forces propelling the RTW upward from gas shale along natural pathways. The physics dominating these processes ensure that capillary and osmotic forces both propel the RTW into the matrix of the shale, thus permanently sequestering it. Furthermore, contrary to the suggestion that hydraulic fracturing could accelerate brine escape and make near surface aquifer contamination more likely, hydraulic fracturing and gas recovery will actually reduce this risk. We demonstrate this in a series of STP counter-current imbibition experiments on cuttings recovered from the Union Springs Member of the Marcellus gas shale in Pennsylvania and on core plugs of Haynesville gas shale from NW Louisiana.

May 13, 2014. [*Category:* Air Quality]

Volatile organic compound emissions from the oil and natural gas industry in the Uinta Basin, Utah: point sources compared to ambient air composition.

- Warneke, C.; Geiger, F.; Edwards, P. M.; Dube, W.; Pétron, G.; Kofler, J.; Zahn, A.; Brown, S. S.; Graus, M.; Gilman, J.; Lerner, B.; Peischl, J.; Ryerson, T. B.; de Gouw, J. A.; Roberts, J. M.
- In: *Atmospheric Chemistry and Physics*, Vol. 14, Issue 8, pages 11895-11927.
- http://www.atmos-chem-phys-discuss.net/14/11895/2014/

Abstract: The emissions of volatile organic compounds (VOCs) associated with oil and natural gas production in the Uinta Basin, Utah were measured at a ground site in Horse Pool and from a NOAA mobile laboratory with PTR-MS instruments. The VOC compositions in the vicinity of individual gas and oil wells and other point sources such as evaporation ponds, compressor stations and injection wells are compared to the measurements at Horse Pool. High mixing ratios of aromatics, alkanes, cycloalkanes and methanol were observed for extended periods of time and short-term spikes caused by local point sources. The mixing ratios during the time the mobile laboratory spent on the well pads were averaged. High mixing ratios were found close to all point sources, but gas wells using dry-gas collection, which means dehydration happens at the well, were clearly associated with higher mixing ratios than other wells. Another large source was the flowback pond near a recently hydraulically re-fractured gas well. The comparison of the VOC composition of the emissions from the oil and natural gas wells showed that wet gas collection wells compared well with the majority of the data at Horse Pool and that oil wells compared well with the rest of the ground site data. Oil wells on average emit heavier compounds than gas wells. The mobile laboratory measurements confirm the results from an emissions inventory: the main VOC source categories from individual point sources are dehydrators, oil and condensate tank flashing and pneumatic devices and pumps. Raw natural gas is emitted from the pneumatic devices and pumps and heavier VOC mixes from the tank flashings.

May 10, 2014. [*Category:* General (Comment / Review)]

Barriers to the development of China's shale gas industry.

- Wan, Zheng; Huang, Tao; Craig, Brian.
- In: *Journal of Cleaner Production*, Vol. 84, pages 818-823 (December 1, 2014).
- http://www.sciencedirect.com/science/article/pii/S0959652614004363

Abstract: Shale gas has become a promising onshore energy prospect in China. As much as the country aspires for greater energy independence through the use of its shale gas reserves, this process is slowed down by the combined weight of relative inexperience, lack of technology, geographical complexity, a hostile economic environment, a disincentive pipeline regime, and a complex land ownership system. To foster a better understanding of the current circumstances of the country's shale gas sector, a panel of scholars and experts shared their perspectives and insider knowledge on China's shale gas industry. It was found that some of the country's man-made institutional barriers are factors that have been hindering shale gas development in China, in addition to natural conditions such as water concerns and the complex geography of shale fields. Resolving this situation necessitates breaking the monopoly that major state-owned oil companies have over high-quality shale gas resources, opening pipeline network access, providing geological data, developing the domestic oil service market, creating conditions for fair competition between service providers, and improving the water management system.

May 8, 2014. [*Category:* Waste / Fluids]

Evolution of multi-well pad development and influence of well pads on environmental violations and wastewater volumes in the Marcellus shale (USA).

- Manda, Alex K.; Heath, Jamie L.; Klein, Wendy A.; Griffin, Michael T.; Montz, Burrell E.
- In: *Journal of Environmental Management*, Vol. 142, September 1, pages 36-45.
- http://www.ncbi.nlm.nih.gov/pubmed/24814546

Abstract: A majority of well pads for unconventional gas wells that are drilled into the Marcellus shale (northeastern USA) consist of multiple wells (in some cases as many as 12 wells per pad), yet the influence of the evolution of well pad development on the extent of environmental violations and wastewater production is unknown. Although the development of multi-well pads (MWP) at the expense of single well pads (SWP) has been mostly driven by economic factors, the concentrated nature of drilling activities from hydraulic fracturing and horizontal drilling operations on MWP suggests that MWP may create less surface disturbance, produce more volumes of wastewater, and generate more environmental violations than SWP. To explore these hypotheses, we use geospatial techniques and statistical analyses (i.e., regression and Mann-Whitney tests) to assess development of unconventional shale gas wells, and quantify environmental violations and wastewater volumes on SWP and MWP in Pennsylvania. The analyses include assessments of the influence of different types of well pads on potential, minor and major environmental events. Results reveal that (a) in recent years, a majority of pads on which new wells for unconventional gas were drilled are MWP, (b) on average, MWP have about five wells located on each pad and thus, had the transition to MWP not occurred, between two and four times as much land surface disturbance would have occurred per year if drilling was relegated to SWP, (c) there were more environmental violations on MWP than SWP, but when the number of wells were taken into account, fewer environmental violations per well were observed on MWP than on SWP, (d) there were more wastewater and recycled wastewater volumes per pad and per well produced on MWP than on SWP, and (e) the proportion of wastewater that was recycled was higher on MWP than SWP. This study sheds light on how the evolution from SWP to MWP has influenced environmental violations and wastewater production in a field that has undergone rapid development in recent years.

May 6. 2014. [*Category:* Waste / Fluids]

T*emporal Changes in Microbial Ecology and Geochemistry in Produced Water from Hydraulically Fractured Marcellus Shale Gas Wells.*

- Cluff, Maryam; Hartsock, Angela; MacRae, Jean; Carter, Kimberly; Mouser, Paula J.

- In: *Environmental Science & Technology*, Vol. 48, Issue 11, pages 6508-6517.
- http://pubs.acs.org/doi/abs/10.1021/es501173p

Abstract: Microorganisms play several important roles in unconventional gas recovery, from biodegradation of hydrocarbons to souring of wells and corrosion of equipment. During and after the hydraulic fracturing process, microorganisms are subjected to harsh physicochemical conditions within the kilometer-deep hydrocarbon-bearing shale, including high pressures, elevated temperatures, exposure to chemical additives and biocides, and brine-level salinities. A portion of the injected fluid returns to the surface and may be reused in other fracturing operations, a process that can enrich for certain taxa. This study tracked microbial community dynamics using pyrotag sequencing of 16S rRNA genes in water samples from three hydraulically fractured Marcellus Shale wells in Pennsylvania, USA over a 328-day period. There was a reduction in microbial richness and diversity after fracturing, with the lowest diversity at 49 days. Thirty-one taxa dominated injected, flowback, and produced water communities, which took on distinct signatures as injected carbon and electron acceptors were attenuated within the shale. The majority (>90%) of the community in flowback and produced fluids were related to halotolerant bacteria associated with fermentation, hydrocarbon oxidation, and sulfur-cycling metabolisms, including heterotrophic genera Halolactibacillus, Vibrio, Marinobacter, Halanaerobium, and Halomonas, and autotrophs belonging to Arcobacter. Sequences related to halotolerant methanogenic genera Methanohalophilus and Methanolobus were detected at low abundance (<2%) in produced waters several months after hydraulic fracturing. Five taxa were strong indicators of later produced fluids. These results provide insight into the temporal trajectory of subsurface microbial communities after "fracking", and have important implications for the enrichment of microbes potentially detrimental to well infrastructure and natural gas fouling during this process.

May 1, 2014. [*Category:* Ecology]

A Framework to Predict the Impacts of Shale Gas Infrastructures on the Forest Fragmentation of an Agroforest Region.

- Racicot, Alexandre; Babin-Roussel, Véronique; Dauphinais, Jean-François; Joly, Jean-Sébastien; Noël, Pascal; Lavoie, Claude.

- In: *Environmental Management*, Vol. 53, Issue 5, pages 1023-1033.
- http://link.springer.com/article/10.1007/s00267-014-0250-x

Abstract: We propose a framework to facilitate the evaluation of the impacts of shale gas infrastructures (well pads, roads, and pipelines) on land cover features, especially with regards to forest fragmentation. We used a geographic information system and realistic development scenarios largely inspired by the PA (United States) experience, but adapted to a region of QC (Canada) with an already fragmented forest cover and a high gas potential. The scenario with the greatest impact results from development limited by regulatory constraints only, with no access to private roads for connecting well pads to the public road network. The scenario with the lowest impact additionally integrates ecological constraints (deer yards, maple woodlots, and wetlands). Overall the differences between these two scenarios are relatively minor, with <1 % of the forest cover lost in each case. However, large areas of core forests would be lost in both scenarios and the number of forest patches would increase by 13–21 % due to fragmentation. The pipeline network would have a much greater footprint on the land cover than access roads. Using data acquired since the beginning of the shale gas industry, we show that it is possible, within a reasonable time frame, to produce a robust assessment of the impacts of shale gas extraction. The framework we propose could easily be applied to other contexts or jurisdictions.

April 29, 2014. [*Categories:* Community, General (Comment / Review)]

Public and Stakeholder Participation for Managing and Reducing the Risks of Shale Gas Development.

- North, D. Warner; Stern, Paul C.; Webler, Thomas; Field, Patrick.
- In: *Environmental Science & Technology*, Vol. 48, Issue 15, pages 8388-8396.
- http://dx.doi.org/10.1021/es405170k

Abstract: Emerging technologies pose particularly strong challenges for risk governance when they have multidimensional and inequitable impacts, when there is scientific uncertainty about the technology and its risks, when there are strong value conflicts over the perceived benefits and risks, when decisions must be made urgently, and when the decision making environment is rife with mistrust. Shale gas development is one such emerging technology. Drawing on previous U.S. National Research Council committee reports that examined risk decision making for complex issues like these, we point to the benefits and challenges of applying the analytic-deliberative process recommened in those reports for stakeholder and public engagement in risk decision making about shale gas development in the United States. We discuss the different phases of such a process and conclude by noting the dangers of allowing controversy to ossify and the benefits of sound dialogue and learning among publics, stakeholders, industry, and regulatory decision makers.

April 29, 2014. [*Category:* Health]

Unconventional oil and gas extraction and animal health.

- Bamberger, M.; Oswald, R. E.
- In: *Environmental Science: Processes & Impacts*
- http://pubs.rsc.org/en/content/articlelanding/2014/em/c4em00150h#!divAbstract

Abstract: The extraction of hydrocarbons from shale formations using horizontal drilling with high volume hydraulic fracturing (unconventional shale gas and tight oil extraction), while derived from methods that have been used for decades, is a relatively new innovation that was introduced first in the United States and has more recently spread worldwide. Although this has led to the availability of new sources of fossil fuels for domestic consumption and export, important issues have been raised concerning the safety of the process relative to public health, animal health, and our food supply. Because of the multiple toxicants used and generated, and because of the complexity of the drilling, hydraulic fracturing, and completion processes including associated infrastructure such as pipelines, compressor stations and processing plants, impacts on the health of humans and animals are difficult to assess definitively. We discuss here findings concerning the safety of unconventional oil and gas extraction from the perspectives of public health, veterinary medicine, and food safety.

April 25, 2014. [*Category:* Waste / Fluids]

Physical, Chemical, and Biological Characteristics of Compounds Used in Hydraulic Fracturing.

- Stringfellow, William T.; Camarillo, Mary Kay; Domen, Jeremy K.; Sandelin, Whitney L.; Borglin, Sharon.
- In: *Journal of Hazardous Materials*, Vol. 275, June 2014, pages 37-54.
- http://www.sciencedirect.com/science/article/pii/S0304389414003021

Abstract: Hydraulic fracturing (HF), a method to enhance oil and gas production, has become increasingly common throughout the U.S. As such, it is important to characterize the chemicals found in HF fluids to evaluate potential environmental fate, including fate in treatment systems, and human health impacts. Eighty-one common HF chemical additives were identified and categorized according to their functions. Physical and chemical characteristics of these additives were determined using publicly available chemical information databases. Fifty-four of the compounds are organic and twenty-seven of these are considered readily biodegradable. Twenty-one chemicals have high theoretical chemical oxygen demand and are used in concentrations that present potential treatment challenges. Most of the HF chemicals evaluated were non-toxic or of low toxicity and only three were classified as Category 2 oral toxins according to standards in the Globally Harmonized System of Classification and Labeling of Chemicals; however, toxicity information was not located for thirty of the HF chemicals evaluated. Volatilization is not expected to be a significant exposure pathway for most HF chemicals. Gaps in toxicity and other chemical properties suggest deficiencies in the current state of knowledge, highlighting the need for further assessment to understand potential issues associated with HF chemicals in the environment.

April 23, 2014. [*Category:* Climate]

Spatially Explicit Methane Emissions from Petroleum Production and the Natural Gas System in California.

- Jeong, Seongeun; Millstein, Dev; Fischer, Marc L.
- In: *Environmental Science & Technology*, Vol. 48, Issue 10, pages 5982-5990.
- http://pubs.acs.org/doi/abs/10.1021/es4046692

Abstract: We present a new, spatially resolved inventory of methane (CH4) emissions based on US-EPA emission factors and publically available activity data for 2010 California petroleum production and natural gas production, processing, transmission, and distribution. Compared to official California bottom-up inventories, our initial estimates are 3 to 7 times higher for the petroleum and natural gas production sectors but similar for the natural gas transmission and distribution sectors. Evidence from published “top-down” atmospheric measurement campaigns within southern California supports our initial emission estimates from production and processing, but indicates emission estimates from transmission and distribution are low by a factor of approximately 2. To provide emission maps with more accurate total emissions we scale the spatially resolved inventory by sector-specific results from a Southern California aircraft measurement campaign to all of California. Assuming uncertainties are determined by the uncertainties estimated in the top-down study, our estimated state total CH4 emissions are 541±144 Gg yr-1, (as compared with 210.7 Gg yr-1 in California’s current official inventory), where the majority of our reported uncertainty is derived from transmission and distribution. We note uncertainties relative to the mean for a given region are likely larger than that for the State total, emphasizing the need for additional measurements in under sampled regions.

April 22, 2014. [*Category:* Climate]

Implications of Shale Gas Development for Climate Change.

- Newell, Richard G.; Raimi, Daniel.
- In: *Environmental Science & Technology*, Vol. 48, Issue 15, pages 8360-8368.
- http://pubs.acs.org/doi/abs/10.1021/es4046154

Abstract: Advances in technologies for extracting oil and gas from shale formations have dramatically increased U.S. production of natural gas. As production expands domestically and abroad, natural gas prices will be lower than without shale gas. Lower prices have two main effects: increasing overall energy consumption, and encouraging substitution away from sources such as coal, nuclear, renewables, and electricity. We examine the evidence and analyze modeling projections to understand how these two dynamics affect greenhouse gas emissions. Most evidence indicates that natural gas as a substitute for coal in electricity production, gasoline in transport, and electricity in buildings decreases greenhouse gases, although as an electricity substitute this depends on the electricity mix displaced. Modeling suggests that absent substantial policy changes, increased natural gas production slightly increases overall energy use, more substantially encourages fuel-switching, and that the combined effect slightly alters economy wide GHG emissions; whether the net effect is a slight decrease or increase depends on modeling assumptions including upstream methane emissions. Our main conclusions are that natural gas can help reduce GHG emissions, but in the absence of targeted climate policy measures, it will not substantially change the course of global GHG concentrations. Abundant natural gas can, however, help reduce the costs of achieving GHG reduction goals.

April 21, 2014. [*Category:* Water Usage]

Water Intensity Assessment of Shale Gas Resources in the Wattenberg Field in Northeastern Colorado.

- Goodwin, Stephen; Carlson, Kenneth H.; Knox, Ken; Douglas, Caleb; Rein, Luke.
- In: *Environmental Science & Technology*, Vol. 48, Issue 10, pages 5991-5995.
- http://pubs.acs.org/doi/abs/10.1021/es404675h

Abstract: Efficient use of water, particularly in the western U.S., is an increasingly important aspect of many activities including agriculture, urban and industry. As the population increases and agriculture and energy needs continue to rise, the pressure on water and other natural resources is expected to intensify. Recent advances in technology have stimulated growth in oil and gas development as well as increasing the industry's need for water resources. This study provides an analysis of how efficiently water resources are used for unconventional shale development in Northeastern Colorado. The study is focused on the Wattenberg Field in the Denver-Julesberg Basin. The 2,000 square mile field located in a semi-arid climate with competing agriculture, municipal, and industrial water demands was one of the first fields where widespread use of hydraulic fracturing was implemented. The consumptive water intensity is measured using a ratio of the net water consumption and the net energy recovery and is used to measure how efficiently water is used for energy extraction. The water and energy use as well as energy recovery data were collected from 200 Noble Energy Inc. wells to estimate the consumptive water intensity. The consumptive water intensity of unconventional shale in the Wattenberg is compared with the consumptive water intensity for extraction of other fuels for other energy sources including coal, natural gas, oil, nuclear, and renewables. 1.4 to 7.5 million gallons is required to drill and hydraulically fracture horizontal wells before energy is extracted in the Wattenberg Field. However, when the large acute water demand is normalized to the amount of energy produced over the lifespan of a well, the consumptive water intensity is estimated to be between 1.8 and 2.7 gal/MMBtu and is similar to surface coal mining.

April 19, 2014. [*Category:* Seismicity]

An investigation of seismicity clustered near the Cordel Field, west central Alberta, and its relation to a nearby disposal well.

- Schultz, Ryan; Stern, Virginia; Gu, Yu Jeffrey.
- In: *Journal of Geophysical Research-Solid Earth*, Vol. 119, Issue 4, pages 3410-3423.
- http://onlinelibrary.wiley.com/doi/10.1002/2013JB010836/abstract\

Abstract: Historically, seismicity documented in the Western Canada Sedimentary Basin has been relatively quiescent and earthquakes are usually restricted to the foreland belt of the Rocky Mountains. However, exceptional clusters of events, which have remained active for decades, are recognized in Alberta. In this study we investigate the seismicity in this region using data obtained from recently established regional arrays, emphasizing the relationship between a disposal well in the Cordel Field and a nearby cluster of previously reported earthquakes. We explore temporal correlations of wastewater pumping rates and local seismic activity dating back to 1960. We find that the first statistically significant increase in seismicity lags the onset of wastewater injection (October 1991) by ~3.33 years. In particular, the waveform similarity of 32 events are analyzed from continuous data recorded at NOR, a nearby (~30 km) station operated by the University of Alberta starting in September of 2006. Results from this analysis suggest that many events are well correlated in the characteristics of the waveforms and thus are likely to share a similar origin and source mechanism. The most prolific of these multiplets repeats more than 10 times sporadically throughout the entire duration of recorded data from October 2006 to March 2012. Despite the limited availability of nearby stations, which adversely affects the resolution of our analysis, hypocenter depths could be relatively accurately determined from waveform synthesis and double difference methods. The results of our analysis provide first-order evidence that the seismicity is consistent with fluid injection-induced events.

April 17, 2014. [*Categories:* General (Comment / Review), Health]

Public Health England's draft report on shale gas extraction.

- Law, A.; Hays, J.; Shonkoff, S. B.; Finkel, M. L.
- In: *BMJ*, Vol. 348, Issue Apr 17 – 6, page g2728.
- http://www.bmj.com/content/348/bmj.g2728?view=long&pmid=24747542

Abstract: Global interest in developing unconventional natural gas reserves continues to increase, despite the paucity of empirical evidence on risks to the environment and human health. The operations required to produce natural gas from hydrocarbon reservoirs such as shale are spatially intense and sometimes occur close to human populations. Although research has been conducted to understand the potential impacts of gas development on public health, for the most part these efforts fall short. In addition, efforts to summarise the existing public health science tend to focus on regulations and engineering solutions, rather than on health outcome data and pathways of exposure. A focus on mostly hypothetical regulatory and engineering solutions may mistake best practices for actual practices, and supplants the empirical with the theoretical.

April 17, 2014. [*Category:* General (Comment / Review)]

Practical measures for reducing the risk of environmental contamination in shale energy production.

- Ziemkiewicz, Paul; Quaranta, John D.; McCawley, Michael.
- In: *Environmental Science: Processes & Impacts*, Vol. 16, Issue 7, pages 1692-1699.
- http://www.ncbi.nlm.nih.gov/pubmed/24745034

Abstract: Gas recovery from shale formations has been made possible by advances in horizontal drilling and hydraulic fracturing technology. Rapid adoption of these methods has created a surge in natural gas production in the United States and increased public concern about its environmental and human health effects. We surveyed the environmental literature relevant to shale gas development and studied over fifteen well sites and impoundments in West Virginia to evaluate pollution caused by air emissions, light and noise during drilling. Our study also characterized liquid and solid waste streams generated by drilling and hydraulic fracturing and evaluated the integrity of impoundments used to store fluids produced by hydraulic fracturing. While most shale gas wells are completed with little or no environmental contamination, we found that many of the problems associated with shale gas development resulted from inattention to accepted engineering practices such as impoundment construction, improper liner installation and a lack of institutional controls. Recommendations are provided based on the literature and our field studies. They will address not all but a great many of the deficiencies that result in environmental release of contaminants from shale gas development. We also identified areas where new technologies are needed to fully address contaminant releases to air and water.

April 16, 2014. [*Category:* Health]

Environmental Public Health Dimensions of Shale and Tight Gas Development.

- Shonkoff, Seth B.; Hays, Jake; Finkel, Madelon L.
- In: *Environmental Health Perspectives*, Vol. 122, Issue 8, August 2014.
- http://ehp.niehs.nih.gov/1307866

Abstract:

Background: The United States has experienced a boom in natural gas production due to recent technological innovations that have enabled this resource to be produced from shale formations.

Objectives: We reviewed the body of evidence related to exposure pathways in order to evaluate the potential environmental public health impacts of shale gas development. We highlight what is currently known and identify data gaps and research limitations by addressing matters of toxicity, exposure pathways, air quality, and water quality.

Discussion: There is evidence of potential environmental public health risks associated with shale gas development. Several studies suggest that shale gas development contributes to ambient air concentrations of pollutants known to be associated with increased risk of morbidity and mortality. Similarly, an increasing body of studies suggest that water contamination risks exist through a variety of environmental pathways, most notably during wastewater transport and disposal, and via poor zonal isolation of gases and fluids due to structural integrity impairment of cement in gas wells.

Conclusion: Despite a growing body of evidence, data gaps persist. Most important, there is a need for more epidemiological studies to assess associations between risk factors, such as air and water pollution, and health outcomes among populations living in close proximity to shale gas operations.

April 15, 2014. [*Category:* Waste / Fluids]

Co-precipitation of Radium with Barium and Strontium Sulfate and Its Impact on the Fate of Radium during Treatment of Produced Water from Unconventional Gas Extraction.

- Zhang, Tieyuan; Gregory, Kelvin; Hammack, Richard W.; Vidic, Radisav D.
- In: *Environmental Science & Technology*, Vol. 48, Issue 8, pages 4596-4603.
- http://dx.doi.org/10.1021/es405168b

Abstract: Radium occurs in flowback and produced waters from hydraulic fracturing for unconventional gas extraction along with high concentrations of barium and strontium and elevated salinity. Radium is often removed from this wastewater by co-precipitation with barium or other alkaline earth metals. The distribution equation for Ra in the precipitate is derived from the equilibrium of the lattice replacement reaction (inclusion) between the Ra^{2+} ion and the carrier ions (e.g., Ba^{2+} and Sr^{2+}) in aqueous and solid phases and is often applied to describe the fate of radium in these systems. Although the theoretical distribution coefficient for Ra–$SrSO_4$ (K_d = 237) is much larger than that for Ra–$BaSO_4$ (K_d = 1.54), previous studies have focused on Ra–$BaSO_4$ equilibrium. This study evaluates the equilibria and kinetics of co-precipitation reactions in Ra–Ba–SO_4 and Ra–Sr–SO_4 binary systems and the Ra–Ba–Sr–SO_4 ternary system under varying ionic strength (IS) conditions that are representative of brines generated during unconventional gas extraction. Results show that radium removal generally follows the theoretical distribution law in binary systems and is enhanced in the Ra–Ba–SO_4 system and restrained in the Ra–Sr–SO_4 system by high IS. However, the experimental distribution coefficient (K_d') varies widely and cannot be accurately described by the distribution equation, which depends on IS, kinetics of carrier precipitation and does not account for radium removal by adsorption. Radium removal in the ternary system is controlled by the co-precipitation of Ra–Ba–SO_4, which is attributed to the rapid $BaSO_4$ nucleation rate and closer ionic radii of Ra^{2+} with Ba^{2+} than with Sr^{2+}. Carrier (i.e., barite) recycling during water treatment was shown to be effective in enhancing radium removal even after co-precipitation was completed. Calculations based on experimental results show that Ra levels in the precipitate generated in centralized waste treatment facilities far exceed regulatory limits for disposal in municipal sanitary landfills and require careful monitoring of allowed source term loading (ASTL) for technically enhanced naturally occurring materials (TENORM) in these landfills. Several alternatives for sustainable management of TENORM are discussed.

April 14, 2014. [*Category:* Climate]

Toward a better understanding and quantification of methane emissions from shale gas development.

- Caulton, Dana R.; Shepson, Paul B.; Santoro, Renee L.; Sparks, Jed P.; Howarth, Robert W.; Ingraffea, Anthony R.; Cambaliza, Maria O. L.; Sweeney, Colm; Karion, Anna; Davis, Kenneth J.; Stirm, Brian H.; Montzka, Stephen A.; Miller, Ben R.
- In: *Proceedings of the National Academy of Sciences*, Vol. 111, Issue 17, pages 6237-6242.
- http://www.pnas.org/content/111/17/6237.abstract

Abstract: The identification and quantification of methane emissions from natural gas production has become increasingly important owing to the increase in the natural gas component of the energy sector. An instrumented aircraft platform was used to identify large sources of methane and quantify emission rates in southwestern PA in June 2012. A large regional flux, 2.0–14 g CH_4 s^{-1} km^{-2}, was quantified for a ∼2,800-km^2 area, which did not differ statistically from a bottom-up inventory, 2.3–4.6 g CH_4 s^{-1} km^{-2}. Large emissions averaging 34 g CH_4/s per well were observed from seven well pads determined to be in the drilling phase, 2 to 3 orders of magnitude greater than US Environmental Protection Agency estimates for this operational phase. The emissions from these well pads, representing ∼1% of the total number of wells, account for 4–30% of the observed regional flux. More work is needed to determine all of the sources of methane emissions from natural gas production, to ascertain why these emissions occur and to evaluate their climate and atmospheric chemistry impacts.

April 11, 2014. [*Category:* Climate]

Life cycle greenhouse gas footprint of shale gas: a probabilistic approach.

- Shahriar, Anjuman; Sadiq, Rehan; Tesfamariam, Solomon.
- In: *Stochastic Environmental Research and Risk Assessment*, Vol. 28, Issue 8, pages 2185-2204.
- http://link.springer.com/article/10.1007%2Fs00477-014-0874-7

Abstract: With the increase in natural gas (NG) production in recent years, primarily from shale gas, some sources, including the US Environmental Protection Agency (EPA), have suggested that upstream methane emissions are increasing. Much of the recent controversy has centered on emissions during well drilling, testing, and completion even though emissions downstream of the wellhead are also of concern. The study critically assessed the current state of knowledge about the life cycle GHG footprint of NG, analyzed the assumptions, data and analysis methodologies used in the existing literature. This study comprehensively analyzed the emission of methane from different stage of the life of well for conventional and unconventional NG using the EPA's revised 2011 estimates as well as other existing literature and publicly available government data. The study proposed a probabilistic model to estimate the range of total GHG footprint of NG with varying probabilities. Through the bottom up approach starting from the well construction to the delivery of NG to the small user and using Monte Carlo simulation, the study identified the critical sources of fugitive emissions from the NG. As expected, emissions from well completion and periodic emissions (e.g. liquid unloading in the case of onshore conventional wells and workovers in the case of unconventional wells) are significant contributors to the overall GHG footprint of NG, and possess large opportunity for reduction. Finally the application of probabilistic model is demonstrated through a case study using the data from the Montney and Horn River shale gas basins in the Northern British Columbia to estimate the range of total GHG footprint of shale gas with varying probabilities. The study found that the GHG footprint of Montney and Horn River wells are much smaller than that of Barnett shale (which is representative of US shale gas) due to strict flaring regulations followed in BC. The study also undercuts the outcome of Howarth et al. (Clim Chang Lett 106:679-690, 2011), which states that the GHG footprint of shale gas is at least 20 % greater than coal.

April 7, 2014. [*Category:* Waste / Fluids]

A review of fracturing fluid systems used for hydraulic fracturing of oil and gas wells.

- Barati, Reza; Liang, Jenn-Tai.
- In: *Journal of Applied Polymer Science*, Vol. 131, Issue 16.
- http://onlinelibrary.wiley.com/doi/10.1002/app.40735/abstract

Abstract: Hydraulic fracturing has been used by the oil and gas industry as a way to boost hydrocarbon production since 1947. Recent advances in fracturing technologies, such as multistage fracturing in horizontal wells, are responsible for the latest hydrocarbon production boom in the US. Linear or crosslinked guars are the most commonly used fluids in traditional fracturing operations. The main functions of these fluids are to open/propagate the fractures and transport proppants into the fractures. Proppants are usually applied to form a thin layer between fracture faces to prop the fractures open at the end of the fracturing process. Chemical breakers are used to break the polymers at the end of the fracturing process so as to provide highly conductive fractures. Concerns over fracture conductivity damage by viscous fluids in ultra-tight formations found in unconventional reservoirs prompted the industry to develop an alternative fracturing fluid called “slickwater”. It consists mainly of water with a very low concentration of linear polymer. The low concentration polymer serves primarily to reduce the friction loss along the flow lines. Proppant-carrying capability of this type of fluids is still a subject of debate among industry experts. Constraints on local water availability and the potential for damage to formations have led the industry to develop other types of fracturing fluids such as viscoelastic surfactants and energized fluids. This article reviews both the traditional viscous fluids used in conventional hydraulic fracturing operations as well as the new family of fluids being developed for both traditional and unconventional reservoirs.

April 4, 2014. [*Categories:* General (Comment / Review), Waste / Fluids]

The Role of Toxicological Science in Meeting the Challenges and Opportunities of Hydraulic Fracturing.

- Goldstein, Bernard D.; Brooks, Bryan W.; Cohen, Steven D.; Gates, Alexander E.; Honeycutt, Michael E.; Morris, John B.; Penning, Trevor M.; Orme-Zavaleta, Jennifer; Snawder, John.

- In: *Toxicological Sciences*, Vol. 139, Issue 2, June 2014, pages 271-283.
- http://toxsci.oxfordjournals.org/content/early/2014/04/04/toxsci.kfu061.long

Abstract: We briefly describe how toxicology can inform the discussion and debate of the merits of hydraulic fracturing by providing information on the potential toxicity of the chemical and physical agents associated with this process, individually and in combination. We consider upstream activities related to bringing chemical and physical agents to the site; on-site activities including drilling of wells and containment of agents injected into or produced from the well; and downstream activities including the flow/removal of hydrocarbon products and of produced water from the site. A broad variety of chemical and physical agents are involved. As the industry expands this has raised concern about the potential for toxicological effects on ecosystems, workers and the general public. Response to these concerns requires a concerted and collaborative toxicological assessment. This assessment should take into account the different geology in areas newly subjected to hydraulic fracturing as well as evolving industrial practices that can alter the chemical and physical agents of toxicological interest. The potential for ecosystem or human exposure to mixtures of these agents presents a particular toxicological and public health challenge. These data are essential for developing a reliable assessment of the potential risks to the environment and to human health of the rapidly increasing use of hydraulic fracturing and deep underground horizontal drilling techniques for tightly bound shale gas and other fossil fuels. Input from toxicologists will be most effective when employed early in the process, before there are unwanted consequences to the environment and human health, or economic losses due to the need to abandon or rework costly initiatives.

April 2, 2014. [*Category:* Economics]

US shale gas production outlook based on well roll-out rate scenarios.

- Weijermars, Ruud.
- In: *Applied Energy*, Vol. 124, pages 283-297.
- http://www.sciencedirect.com/science/article/pii/S0306261914002025

Abstract: This study models the uncertainty range in the future gas production output from US shale plays up to 2025. The future spread in gas output in our models follows from variations in the number of wells that will be drilled according to three distinct scenarios. Each scenario assumes a well development plan for the six major shale plays over the studied period and then quantifies the cumulative US production output from the combined shale plays. We compare the bottom-up model results with other model projections for future US shale gas output, including the top-down shale gas production forecasts by the US National Energy Modeling System (NEMS). The remarkable growth of North American gas output from unconventional resources has been highlighted in numerous industry reports and government publications, but what has remained relatively underexposed is the deterioration of economic margins due to the failure to predict the gas price decline in the North American market. The past development record of North America's shale gas resources suggests that security of future gas supplies seems ensured, but here we develop a contrarian view. Our scenario models take into account the effect of recent declines in gas rig counts and decline in gas well completions due to the depressed gas prices. A scenario with declining shale gas output – one of three scenarios considered – cannot be excluded as being unlikely to occur, which means the future security of US gas supply that assumes a steady growth of shale gas supply cannot be ascertained at present.

April 1, 2014. [*Categories:* Air Quality, Climate]

Mobile measurement of methane and hydrogen sulfide at natural gas production site fence lines in the Texas Barnett Shale.

- Eapi, Gautam R.; Sabnis, Madhu S.; Sattler, Melanie L.
- In: *Journal of the Air & Waste Management Association*, Vol. 64, Issue 8, pages 927-944.
- http://dx.doi.org/10.1080/10962247.2014.907098

Abstract: Production of natural gas from shale formations is bringing drilling and production operations to regions of the United States that have seen little or no similar activity in the past, which has generated considerable interest in potential environmental impacts. This study focused on the Barnett Shale Fort Worth Basin in Texas, which saw the number of gas-producing wells grow from 726 in 2001 to 15,870 in 2011. This study aimed to measure fence line concentrations of methane and hydrogen sulfide at natural gas production sites (wells, liquid storage tanks, and associated equipment) in the four core counties of the Barnett Shale (Denton, Johnson, Tarrant, and Wise). A mobile measurement survey was conducted in the vicinity of 4788 wells near 401 lease sites, representing 35% of gas production volume, 31% of wells, and 38% of condensate production volume in the four-county core area. Methane and hydrogen sulfide concentrations were measured using a Picarro G2204 cavity ring-down spectrometer (CRDS). Since the research team did not have access to lease site interiors, measurements were made by driving on roads on the exterior of the lease sites. Over 150 hr of data were collected from March to July 2012. During two sets of drive-by measurements, it was found that 66 sites (16.5%) had methane concentrations >3 parts per million (ppm) just beyond the fence line. Thirty-two lease sites (8.0%) had hydrogen sulfide concentrations >4.7 parts per billion (ppb) (odor recognition threshold) just beyond the fence line. Measured concentrations generally did not correlate well with site characteristics (natural gas production volume, number of wells, or condensate production). t tests showed that for two counties, methane concentrations for dry sites were higher than those for wet sites. Follow-up study is recommended to provide more information at sites identified with high levels of methane and hydrogen sulfide. Implications:Information regarding air emissions from shale gas production is important given the recent increase in number of wells in various regions in the United States. Methane, the primary natural gas constituent, is a greenhouse gas; hydrogen sulfide, which can be present in gas condensate, is an odor-causing compound. This study surveyed wells representing one-third of the natural gas production volume in the Texas Barnett Shale and identified the percent of sites that warrant further study due to their fence line methane and hydrogen sulfide concentrations.

April 1, 2014. [*Category:* Health]

Birth Outcomes and Maternal Residential Proximity to Natural Gas Development in Rural Colorado.

- McKenzie, Lisa M.; Guo, Ruixin; Witter, Roxana Zulauf; Savitz, David A.; Newman, Lee S.; Adgate, John L.

- In: *Environmental Health Perspectives*, Vol. 122, Issue 4, pages 412-417.
- http://ehp.niehs.nih.gov/1306722/

Introduction

Approximately 3.3% of U.S. live-born children have a major birth defect (Centers for Disease Control and Prevention 2013; Parker et al. 2010); these defects account for 20% of infant deaths as well as 2.3% of premature death and disability (McKenna et al. 2005). Oral clefts, neural tube defects (NTDs), and congenital heart defects (CHD) are the most common classes of birth defects (Parker et al. 2010). These defects are thought to originate in the first trimester as a result of polygenic inherited disease or gene–environment interactions (Brent 2004). Suspected nongenetic risk factors for these birth defects include folate deficiency (Wald and Sneddon 1991), maternal smoking (Honein et al. 2006), alcohol abuse and solvent use (Romitti et al. 2007), and exposure to benzene (Lupo et al. 2010b; Wennborg et al. 2005), toluene (Bowen et al. 2009), polycyclic aromatic hydrocarbons (PAHs) (Ren et al. 2011), and petroleum-based solvents, including aromatic hydrocarbons (Chevrier et al. 1996). Associations between air pollution [volatile organic compounds (VOCs), particulate matter (PM), and nitrogen dioxide (NO_2)] and low birth weight and preterm birth have been reported (Ballester et al. 2010; Brauer et al. 2008; Dadvand et al. 2013; Ghosh et al. 2012; Llop et al. 2010). Many of these air pollutants are emitted during development and production of natural gas (referred to herein as NGD), and concerns have been raised that they may increase risk of adverse birth outcomes and other health effects (Colborn et al. 2011; McKenzie et al. 2012). Increased prevalence of low birth weight and small for gestational age and reduced APGAR scores were reported in infants born to mothers living near NGD in Pennylvania (Hill 2013).

Technological advances in directional drilling and hydraulic fracturing have resulted in a global boom of drilling and production of natural gas reserves [U.S. Energy Information Administration (EIA) 2011a, 2011b; Vidas and Hugman 2008]. NGD is an industrial process resulting in potential worker and community exposure to multiple environmental stressors (Esswein et al. 2013; King 2012; Witter et al. 2013). Diesel-powered heavy equipment is used for worksite development as well as transporting large volumes of water, sand, and chemicals to sites and for waste removal (Witter et al. 2013). It is increasingly common for NGD to encroach on populated areas, potentially exposing more people to air and water emissions as well as to noise and community-level changes that may arise from industrialization [Colorado Oil and Gas Conservation Commission (COGCC) 2009]. Studies in Colorado, Texas, Wyoming, and Oklahoma have demonstrated that NGD results in emission of VOCs, NO_2, sulfur dioxide (SO_2), PM, and PAHs from either the well itself or from associated drilling processes or related infrastructure (i.e., drilling muds, hydraulic fracturing fluids, tanks containing waste water and liquid hydrocarbons, diesel engines, compressor stations, dehydrators, and pipelines) (CDPHE 2007; Frazier 2009; Kemball-Cook et al. 2010; Olaguer 2012; Walther 2011; Zielinska et al. 2011). Some of these pollutants, such as toluene, xylenes, and benzene, are suspected teratogens (Lupo et al. 2010b; Shepard 1995) or mutagens (Agency for Toxic Substances and Disease Registry 2007) and are known to cross the placenta (Bukowski 2001), raising the possibility of fetal exposure to these and other pollutants resulting from NGD. Currently, there are few studies on the effects of air pollution or NGD on birth outcomes.

In this analysis, we explored the association between maternal exposure to NGD and birth outcomes, using a data set with individual-level birth data and geocoded natural gas well locations. We conducted a retrospective cohort study to investigate the association between density and proximity of natural gas wells within a 10-mile radius of maternal residences in rural Colorado and three classes of birth defects, preterm birth, and fetal growth.

Conclusion

This study suggests a positive association between greater density and proximity of natural gas wells within a 10-mile radius of maternal residence and greater prevalence of CHDs and possibly NTDs, but not oral clefts, preterm birth, or reduced fetal growth. Further studies incorporating information on specific activities and production levels near homes over the course of pregnancy would improve exposure assessments and provide more refined effect estimates. Recent data indicate that exposure to NGD activities is increasingly common. The COGCC estimates that 26% of the > 47,000 oil and gas wells in Colorado are located within 150–1,000 feet of a home or other type of building intended for human occupancy (COGCC 2012). Taken together, our results and current trends in NGD underscore the importance of conducting more comprehensive and rigorous research on the potential health effects of NGD.

March 31, 2014. [*Category:* Water Quality]

Regional Variation in Water Related Impacts of Shale Gas Development and Implications for Emerging International Plays.

- Mauter, Meagan S.; Alvarez, Pedro J. J.; Burton, G. Allen; Cafaro, Diego Carlos; Chen, Wei; Gregory, Kelvin B.; Jiang, Guibin; Li, Qilin; Pittock, Jamie; Reible, Danny; Schnoor, Jerald L.
- In: *Environmental Science & Technology*, Vol. 48, Issue 15, page 8298-8306.
- http://pubs.acs.org/doi/abs/10.1021/es405432k

Abstract: The unconventional fossil fuel industry is expected to expand dramatically in coming decades as conventional reserves wane. Minimizing the environmental impacts of this energy transition requires a contextualized understanding of the unique regional issues that shale gas development poses. This manuscript highlights the variation in regional water issues associated with shale gas development in the US and the approaches of various states in mitigating these impacts. The manuscript also explores opportunities for emerging international shale plays to leverage the diverse experiences of US states in formulating development strategies that minimize water related impacts within their environmental, cultural, and political ecosystem.

March 29, 2014. [*Category:* Air Quality]

Understanding exposure from natural gas drilling puts current air standards to the test.

- Brown, David; Weinberger, Beth; Lewis, Celia; Bonaparte, Heather.
- In: *Reviews on Environmental Health*, Vol. 29, Issue 4, pages 277-292.
- http://www.environmentalhealthproject.org/wp-content/uploads/2014/04/reveh-2014-0002-Brown-et-al.pdf

Abstract: Case study descriptions of acute onset of respiratory, neurologic, dermal, vascular, abdominal, and gastrointestinal sequelae near natural gas facilities contrast with a subset of emissions research, which suggests that there is limited risk posed by unconventional natural gas development (UNGD). An inspection of the pathophysiological effects of acute toxic actions reveals that current environmental monitoring protocols are incompatible with the goal of protecting the health of those living and working near UNGD activities. The intensity, frequency, and duration of exposures to toxic materials in air and water determine the health risks to individuals within a population. Currently, human health risks near UNGD sites are derived from average population risks without adequate attention to the processes of toxicity to the body. The objective of this paper is to illustrate that current methods of collecting emissions data, as well as the analyses of these data, are not sufficient for accurately assessing risks to individuals or protecting the health of those near UNGD sites. Focusing on air pollution impacts, we examined data from public sources and from the published literature. We compared the methods commonly used to evaluate health safety near UNGD sites with the information that would be reasonably needed to determine plausible outcomes of actual exposures. Such outcomes must be based on the pathophysiological effects of the agents present and the susceptibility of residents near these sites. Our study has several findings. First, current protocols used for assessing compliance with ambient air standards do not adequately determine the intensity, frequency or durations of the actual human exposures to the mixtures of toxic materials released regularly at UNGD sites. Second, the typically used periodic 24-h average measures can underestimate actual exposures by an order of magnitude. Third, reference standards are set in a form that inaccurately determines health risk because they do not fully consider the potential synergistic combinations of toxic air emissions. Finally, air dispersion modeling shows that local weather conditions are strong determinates of individual exposures. Appropriate estimation of safety requires nested protocols that measure real time exposures. New protocols are needed to provide 1) continuous measures of a surrogate compound to show periods of extreme exposure; 2) a continuous screening model based on local weather conditions to warn of periodic high exposures; and 3) comprehensive detection of chemical mixtures using canisters or other devices that capture the major components of the mixtures.

March 25, 2014. [*Category:* Water Quality]

Oil and gas wells and their integrity: Implications for shale and unconventional resource exploitation.

- Davies, Richard J.; Almond, Sam; Ward, Robert S.; Jackson, Robert B.; Adams, Charlotte; Worrall, Fred; Herringshaw, Liam G.; Gluyas, Jon G.; Whitehead, Mark A.
- In: *Marine and Petroleum Geology*, Vol. 56, September 2014, pages 239-254.
- http://www.sciencedirect.com/science/article/pii/S0264817214000609

Abstract: Data from around the world (Australia, Austria, Bahrain, Brazil, Canada, the Netherlands, Poland, the UK and the USA) show that more than four million onshore hydrocarbon wells have been drilled globally. Here we assess all the reliable datasets (25) on well barrier and integrity failure in the published literature and online. These datasets include production, injection, idle and abandoned wells, both onshore and offshore, exploiting both conventional and unconventional reservoirs. The datasets vary considerably in terms of the number of wells examined, their age and their designs. Therefore the percentage of wells that have had some form of well barrier or integrity failure is highly variable (1.9%–75%). Of the 8030 wells targeting the Marcellus shale inspected in Pennsylvania between 2005 and 2013, 6.3% of these have been reported to the authorities for infringements related to well barrier or integrity failure. In a separate study of 3533 Pennsylvanian wells monitored between 2008 and 2011, there were 85 examples of cement or casing failures, 4 blowouts and 2 examples of gas venting. In the UK, 2152 hydrocarbon wells were drilled onshore between 1902 and 2013 mainly targeting conventional reservoirs. UK regulations, like those of other jurisdictions, include reclamation of the well site after well abandonment. As such, there is no visible evidence of 65.2% of these well sites on the land surface today and monitoring is not carried out. The ownership of up to 53% of wells in the UK is unclear; we estimate that between 50 and 100 are orphaned. Of 143 active UK wells that were producing at the end of 2000, one has evidence of a well integrity failure.

March 25, 2014. [*Category:* General (Comment / Review)]

Hydraulic Fracturing: Paving the Way for a Sustainable Future?

- Chen, Jiangang; Al-Wadei, Mohammed H.; Kennedy, Rebekah C. M.;Terry, Paul D.
- In: *Journal of Environmental and Public Health*, Vol. 2014, page 656824.
- http://www.ncbi.nlm.nih.gov/pmc/articles/PMC3984842/ & http://www.ncbi.nlm.nih.gov/pmc/articles/PMC3984842/pdf/JEPH2014-656824.pdf

Abstract: With the introduction of hydraulic fracturing technology, the United States has become the largest natural gas producer in the world with a substantial portion of the production coming from shale plays. In this review, we examined current hydraulic fracturing literature including associated wastewater management on quantity and quality of groundwater. We conclude that proper documentation/reporting systems for wastewater discharge and spills need to be enforced at the federal, state, and industrial level. Furthermore, Underground Injection Control (UIC) requirements under SDWA should be extended to hydraulic fracturing operations regardless if diesel fuel is used as a fracturing fluid or not. One of the biggest barriers that hinder the advancement of our knowledge on the hydraulic fracturing process is the lack of transparency of chemicals used in the practice. Federal laws mandating hydraulic companies to disclose fracturing fluid composition and concentration not only to federal and state regulatory agencies but also to health care professionals would encourage this practice. The full disclosure of fracturing chemicals will allow future research to fill knowledge gaps for a better understanding of the impacts of hydraulic fracturing on human health and the environment.

March 24, 2014. [*Category:* Air Quality]

Atmospheric Hydrocarbon Emissions and Concentrations in the Barnett Shale Natural Gas Production Region.

- Zavala-Araiza, Daniel; Sullivan, David W.; Allen, David T.

- In: *Environmental Science & Technology*, Vol. 48, Issue 9, pages 5314-5321.
- http://dx.doi.org/10.1021/es405770h

Abstract: Hourly ambient hydrocarbon concentration data were collected, in the Barnett Shale Natural Gas Production Region, using automated gas chromatography (auto-GC), for the period from April 2010 to December 2011. Data for three sites were compared: a site in the geographical center of the natural gas production region (Eagle Mountain Lake (EML)); a rural/suburban site at the periphery of the production region (Flower Mound Shiloh), and an urban site (Hinton). The dominant hydrocarbon species observed in the Barnett Shale region were light alkanes. Analyses of daily, monthly, and hourly patterns showed little variation in relative composition. Observed concentrations were compared to concentrations predicted using a dispersion model (AERMOD) and a spatially resolved inventory of volatile organic compounds (VOC) emissions from natural gas production (Barnett Shale Special Emissions Inventory) prepared by the Texas Commission on Environmental Quality (TCEQ), and other emissions information. The predicted concentrations of VOC due to natural gas production were 0-40% lower than background corrected measurements, after accounting for potential under-estimation of certain emission categories. Hourly and daily variations in observed, background corrected concentrations were primarily explained by variability in meteorology, suggesting that episodic emission events had little impact on hourly averaged concentrations. Total emissions for VOC from natural gas production sources are estimated to be approximately 25,300 tons/yr, when accounting for potential under-estimation of certain emission categories. This region produced, in 2011, approximately 5 bcf/d of natural gas (100 Gg/d) for a VOC to natural gas production ratio (mass basis) of 0.0006.

March 24, 2014. [*Category:* Air Quality]

Air quality concerns of unconventional oil and natural gas production.

- Field, R. A.; Soltis, J.; Murphy, S.
- In: *Environmental Science: Process & Impacts*, Issue 5.
- http://pubs.rsc.org/en/content/articlelanding/2014/em/c4em00081a

Abstract: Increased use of hydraulic fracturing ("fracking") in unconventional oil and natural gas (O & NG) development from coal, sandstone, and shale deposits in the United States (US) has created environmental concerns over water and air quality impacts. In this perspective we focus on how the production of unconventional O & NG affects air quality. We pay particular attention to shale gas as this type of development has transformed natural gas production in the US and is set to become important in the rest of the world. A variety of potential emission sources can be spread over tens of thousands of acres of a production area and this complicates assessment of local and regional air quality impacts. We outline upstream activities including drilling, completion and production. After contrasting the context for development activities in the US and Europe we explore the use of inventories for determining air emissions. Location and scale of analysis is important, as O & NG production emissions in some US basins account for nearly 100% of the pollution burden, whereas in other basins these activities make up less than 10% of total air emissions. While emission inventories are beneficial to quantifying air emissions from a particular source category, they do have limitations when determining air quality impacts from a large area. Air monitoring is essential, not only to validate inventories, but also to measure impacts. We describe the use of measurements, including ground-based mobile monitoring, network stations, airborne, and satellite platforms for measuring air quality impacts. We identify nitrogen oxides, volatile organic compounds (VOC), ozone, hazardous air pollutants (HAP), and methane as pollutants of concern related to O & NG activities. These pollutants can contribute to air quality concerns and they may be regulated in ambient air, due to human health or climate forcing concerns. Close to well pads, emissions are concentrated and exposure to a wide range of pollutants is possible. Public health protection is improved when emissions are controlled and facilities are located away from where people live. Based on lessons learned in the US we outline an approach for future unconventional O & NG development that includes regulation, assessment and monitoring.

March 21, 2014. [*Category:* Water Quality]

Evidence and mechanisms for Appalachian Basin brine migration into shallow aquifers in NE Pennsylvania, USA.

- Llewellyn, Garth T.
- In: *Hydrogeology Journal*, Vol. 22, Issue 5, pages 1055-1066.
- http://link.springer.com/article/10.1007/s10040-014-1125-1

Abstract: Multiple geographic information system (GIS) datasets, including joint orientations from nine bedrock outcrops, inferred faults, topographic lineaments, geophysical data (e.g. regional gravity, magnetic and stress field), 290 pre-gas-drilling groundwater samples (Cl–Br data) and Appalachian Basin brine (ABB) Cl–Br data, have been integrated to assess pre-gas-drilling salinization sources throughout Susquehanna County, Pennsylvania (USA), a focus area of Marcellus Shale gas development. ABB has migrated naturally and preferentially to shallow aquifers along an inferred normal fault and certain topographic lineaments generally trending NNE–SSW, sub-parallel with the maximum regional horizontal compressive stress field (orientated NE–SW). Gravity and magnetic data provide supporting evidence for the inferred faults and for structural control of the topographic lineaments with dominant ABB shallow groundwater signatures. Significant permeability at depth, imparted by the geologic structures and their orientation to the regional stress field, likely facilitates vertical migration of ABB fluids from depth. ABB is known to currently exist within Ordovician through Devonian stratigraphic units, but likely originates from Upper Silurian strata, suggesting significant migration through geologic time, both vertically and laterally. The natural presence of ABB-impacted shallow groundwater has important implications for differentiating gas-drilling-derived brine contamination, in addition to exposing potential vertical migration pathways for gas-drilling impacts.

March 19, 2014. [*Category:* Seismicity]

Maximum magnitude earthquakes induced by fluid injection.

- McGarr, A.
- In: *Journal of Geophysical Research – Solid Earth,* Vol. 119, Issue 2, pages 1008-1019.
- http://onlinelibrary.wiley.com/doi/10.1002/2013JB010597/abstract

Abstract: Analysis of numerous case histories of earthquake sequences induced by fluid injection at depth reveals that the maximum magnitude appears to be limited according to the total volume of fluid injected. Similarly, the maximum seismic moment seems to have an upper bound proportional to the total volume of injected fluid. Activities involving fluid injection include (1) hydraulic fracturing of shale formations or coal seams to extract gas and oil, (2) disposal of wastewater from these gas and oil activities by injection into deep aquifers, and (3) the development of enhanced geothermal systems by injecting water into hot, low-permeability rock. Of these three operations, wastewater disposal is observed to be associated with the largest earthquakes, with maximum magnitudes sometimes exceeding 5. To estimate the maximum earthquake that could be induced by a given fluid injection project, the rock mass is assumed to be fully saturated, brittle, to respond to injection with a sequence of earthquakes localized to the region weakened by the pore pressure increase of the injection operation and to have a Gutenberg-Richter magnitude distribution with a *b* value of 1. If these assumptions correctly describe the circumstances of the largest earthquake, then the maximum seismic moment is limited to the volume of injected liquid times the modulus of rigidity. Observations from the available case histories of earthquakes induced by fluid injection are consistent with this bound on seismic moment. In view of the uncertainties in this analysis, however, this should not be regarded as an absolute physical limit.

March 19, 2014. [*Category:* Regulation]

Understanding a Period of Policy Change: The Case of Hydraulic Fracturing Disclosure Policy in Colorado.

- Heikkila, Tanya; Pierce, Jonathan J.; Gallaher, Samuel; Kagan, Jennifer; Crow, Deserai A.; Weible, Christopher M.
- In: *Review of Policy Research*, Vol. 31, Issue 2, pages 65-87.
- http://onlinelibrary.wiley.com/doi/10.1111/ropr.12058/abstract

Abstract: This paper investigates the beliefs and framing strategies of interest groups during a period of policy change and the factors explaining policy change. We develop propositions to explore questions concerning policy change primarily from the advocacy coalition framework as well as from other theorie. The propositions are tested by examining the promulgation of a Colorado regulation requiring the disclosure of chemicals used in hydraulic fracturing. Using coded data of documents published by organizations involved in the rulemaking process, we find divergence between industry and environmental groups on their beliefs concerning hydraulic fracturing, as well as their portraying themselves and each other as heroes, victims, and villains, but some convergence on their more specific beliefs concerning disclosure of chemicals. Interviews point to the importance of policy entrepreneurs, timing, a negotiated agreement, and learning for explaining policy change. The findings provide both theoretical and methodological insights into how and why policy changes.

March 17, 2014. [*Category:* Water Quality]

Evolving shale gas management: water resource risks, impacts, and lessons learned.

- Rahm, Brian G.; Riha, Susan J.
- In: *Environmental Science: Processes & Impacts*, Vol. 16, Issue 6, pages 1400-1412.
- http://pubs.rsc.org/en/content/articlelanding/2014/em/c4em00018h

Abstract: Unconventional shale gas development promises to significantly alter energy portfolios and economies around the world. It also poses a variety of environmental risks, particularly with respect to the management of water resources. We review current scientific understanding of risks associated with the following: water withdrawals for hydraulic fracturing; wastewater treatment, discharge and disposal; methane and fluid migration in the subsurface; and spills and erosion at the surface. Some of these risks are relatively unique to shale gas development, while others are variations of risks that we already face from a variety of industries and activities. All of these risks depend largely on the pace and scale of development that occurs within a particular region. We focus on the United States, where the shale gas boom has been on-going for several years, paying particular attention to the Marcellus Shale, where a majority of peer-reviewed study has taken place. Governments, regulatory agencies, industry, and other stakeholders are challenged with responding to these risks, and we discuss policies and practices that have been adopted or considered by these various groups. Adaptive Management, a structured framework for addressing complex environmental issues, is discussed as a way to reduce polarization of important discussions on risk, and to more formally engage science in policy-making, along with other economic, social and value considerations. Data suggests that some risks can be substantially reduced through policy and best practice, but also that significant uncertainty persists regarding other risks. We suggest that monitoring and data collection related to water resource risks be established as part of planning for shale gas development before activity begins, and that resources are allocated to provide for appropriate oversight at various levels of governance.

March 14, 2014. [*Category:* General (Comment / Review)]

Is China really ready for shale gas revolution—Re-evaluating shale gas challenges.

- Wang, Changjian; Wang, Fei; Du, Hongru; Zhang, Xiaolei.
- In: *Environmental Science & Policy*, Vol. 39, May 2014, pages 49-55.
- http://www.sciencedirect.com/science/article/pii/S1462901114000549

Abstract: Tackling climate change and reducing reliance on energy imports justify the exploitation of unconventional energy around the word. Influenced by the U.S. shale gas massive development, Chinese government set an ambitious plan to produce 6.5 billion m3 of shale gas by 2015, 60–100 billion m3 by 2020, and then 13 provinces were given priorities for exploitation. China's shale gas production will go ahead. Local government's ambitious targets combined with technical bottlenecks, lack of drilling experience, poor extraction operations, lagging infrastructure construction, imperfect price mechanism, water shortages, water contamination, and other undesired environmental effects with significant levels of uncertainty, are major impediments for shale gas revolution in China. Exploitation of shale gas reserves offers opportunities for China to meet its growing energy demands and reduce the reliance on energy imports. But China's ongoing shale gas plans should be seriously re-evaluated with reference to eco-environmental and social impacts. This is a unique and great opportunity for China to be a demonstration model, especially for other countries wanting of shale gas.

March 14, 2014. [*Category:* Health]

Occupational exposures in the oil and gas extraction industry: State of the science and research recommendations.

- Witter, Roxana Z.; Tenney, Liliana; Clark, Suzanne; Newman, Lee S.
- In: *American Journal of Industrial Medicine*, Vol. 57, Issue 7, July 2014, pages 847-856.
- http://onlinelibrary.wiley.com/doi/10.1002/ajim.22316/abstract

Abstract: The oil and gas extraction industry is rapidly growing due to horizontal drilling and high volume hydraulic fracturing (HVHF). This growth has provided new jobs and economic stimulus. The industry occupational fatality rate is 2.5 times higher than the construction industry and 7 times higher than general industry; however injury rates are lower than the construction industry, suggesting injuries are not being reported. Some workers are exposed to crystalline silica at hazardous levels, above occupational health standards. Other hazards (particulate, benzene, noise, radiation) exist. In this article, we review occupational fatality and injury rate data; discuss research looking at root causes of fatal injuries and hazardous exposures; review interventions aimed at improving occupational health and safety; and discuss information gaps and areas of needed research. We also describe Wyoming efforts to improve occupational safety in this industry, as a case example. Am. J. Ind. Med. © 2014 Wiley Periodicals, Inc.

March 13, 2014. [*Category:* Air Quality]

Highly Elevated Atmospheric Levels of Volatile Organic Compounds in the Uintah Basin, Utah.

- Helmig, D.; Thompson, C. R.; Evans, J.; Boylan, P.; Hueber, J.; Park, J.-H.
- In: *Environmental Science & Technology*, Vol. 48, Issue 9, pages 4707-4715.
- http://dx.doi.org/10.1021/es405046r

Abstract: Oil and natural gas production in the Western United States has grown rapidly in recent years, and with this industrial expansion, growing environmental concerns have arisen regarding impacts on water supplies and air quality. Recent studies have revealed highly enhanced atmospheric levels of volatile organic compounds (VOCs) from primary emissions in regions of heavy oil and gas development and associated rapid photochemical production of ozone during winter. Here, we present surface and vertical profile observations of VOC from the Uintah Basin Winter Ozone Studies conducted in January–February of 2012 and 2013. These measurements identify highly elevated levels of atmospheric alkane hydrocarbons with enhanced rates of C_2–C_5 nonmethane hydrocarbon (NMHC) mean mole fractions during temperature inversion events in 2013 at 200–300 times above the regional and seasonal background. Elevated atmospheric NMHC mole fractions coincided with build-up of ambient 1-h ozone to levels exceeding 150 ppbv (parts per billion by volume). The total annual mass flux of C_2–C_7 VOC was estimated at $194 \pm 56 \times 10^6$ kg yr^{-1}, equivalent to the annual VOC emissions of a fleet of ∼100 million automobiles. Total annual fugitive emission of the aromatic compounds benzene and toluene, considered air toxics, were estimated at $1.6 \pm 0.4 \times 10^6$ and $2.0 \pm 0.5 \times 10^6$ kg yr^{-1}, respectively. These observations reveal a strong causal link between oil and gas emissions, accumulation of air toxics, and significant production of ozone in the atmospheric surface layer.

March 13, 2014. [*Category:* Community]

Review of Risks to Communities from Shale Energy Development.

- Jacquet, Jeffrey B.
- In: *Environmental Science & Technology*, Vol. 48, Issue 15, pages 8321-8333.
- http://dx.doi.org/10.1021/es404647x

Abstract: Although shale energy development can bring infusions of money and jobs to local communities, an array of risks to community-level assets and institutions is also possible. Sociological research dating back to the 1970s links rapid oil and gas development with overburdened municipal services, upended social and cultural patterns, and volatile economic growth. Research on technological risk has demonstrated communities can come to be associated with pollution and contamination, resulting in out-migration, declining amenity-led development, and decreased financial investment. Emerging shale energy case studies in Wyoming, Pennsylvania, North Dakota, and Texas show a similar, although nuanced, picture of these concerns. Yet, little data exists on the prevalence or magnitude of these risks in the current context of shale gas development. The existing research has largely remained case-based in nature, has not been synthesized across various disciplines, and has not been updated to account for various social and technological trends that have occurred since its publication. This paper offers a critical review of major research endeavors that inform our knowledge of risk to communities from shale energy development, while identifying gaps in our understanding of these risks and areas of research need.

March 11, 2014. [*Category:* General (Comment / Review)]

Link between endowments, economics and environment in conventional and unconventional gas reservoirs.

- Aguilera, Roberto F.; Ripple, Ronald D.; Aguilera, Roberto.
- In: *Fuel*, Vol. 126, June 15, 2014, pages 224-238.
- http://www.sciencedirect.com/science/article/pii/S0016236114002117

Abstract: This paper presents a methodology for connecting endowments, economics and the environment in conventional, tight, shale and Coalbed Methane (CBM) reservoirs. The volumetric estimates are generated by a Variable Shape Distribution model (VSD). The VSD has been shown in the past to be useful for the evaluation of conventional and tight gas reservoirs. However, this is the first paper in which the method is used to also include shale gas and CBM formations. Results indicate a total gas endowment of 70,000 tcf, split between 15,000 tcf in conventional reservoirs, 15,000 tcf in tight gas, 30,000 tcf in shale gas and 10,000 tcf in CBM reservoirs. Thus, natural gas formations have potential to provide a significant contribution to global energy demand estimated at approximately 790 quads by 2035. A common thread between unconventional formations is that nearly all of them must be hydraulically fractured to attain commercial production. A significant volume of data indicates that the probabilities of hydraulic fracturing (fracking) fluids and/or methane contaminating ground water through the hydraulically-created fractures are very low. Since fracking has also raised questions about the economic viability of producing unconventional gas in some parts of the world, supply curves are estimated in this paper for the global gas portfolio. The curves show that, in some cases, the costs of producing gas from unconventional reservoirs are comparable to those of conventional gas. The conclusion is that there is enough natural gas to supply the energy market for nearly 400 years at current rates of consumption and 110 years with a growth rate in production of 2% per year. With appropriate regulation, this may be done safely, commercially, and in a manner that is more benign to the environment as compared with other fossil fuels.

March 10, 2014. [*Category:* Regulation]

The Capacity of State Institutions to Govern Shale Gas Development Risks.

- Wiseman, Hannah.
- In: *Environmental Science & Technology*, Vol. 48, Issue 15, pages 8376-8387.
- http://pubs.acs.org/doi/abs/10.1021/es4052582

Abstract: The development of natural gas and oil from unconventional formations in the United States has grown substantially in recent years and has created governance challenges. The successes and failures of governance efforts in this country serve as important lessons for other nations that have their own unconventional petroleum resources and are beginning to move forward with development, thus calling for a more in-depth examination of the laws governing shale gas development and their implementation. Governance includes both the substance of laws and the activities of institutions that implement and influence laws, and in the case of oil and gas, states are primarily responsible for addressing risks. Nongovernmental actors and industry also work with states to shape and implement regulations and standards. This Policy Analysis introduces the role of various actors in U.S. shale gas governance, explaining why the states are primarily responsible for risk governance, and explores the capacity of states to conduct governance, examining the content of their laws and the strength of their institutions. The Analysis concludes that states are, to a degree, addressing the changing risks of development. Substantial gaps remain in the substance of regulations, however, and many states appear to lack adequate support or policies for training industry in compliance matters, monitoring activity at well sites, issuing violations, and ensuring that the public is aware of inspections and enforcement.

March 10, 2014. [*Category:* Waste / Fluids]

Pennsylvania's Technologically Enhanced, Naturally Occurring Radioactive Material Experiences and Studies of the Oil and Gas Industry.

(Presented at the March 10-11, 2014 annual meeting of the National Council on Radiation Protection and Measurements, at the Hyatt Regency Bethesda, Bethesda MD.)

- Allard, David J.
- In: *Health Physics*, Vol. 108, Issue 2, February 2015.
- http://www.ncbi.nlm.nih.gov/pubmed/25551500

Abstract: This presentation will provide an overview of the Commonwealth of Pennsylvania's experiences and ongoing studies related to technologically-enhanced naturally occurring radioactive material (TENORM) in the oil and gas industry. It has been known for many years that Pennsylvania's geology is unique, with several areas having relatively high levels of natural uranium and thorium. In the 1950s a few areas of the state were evaluated for commercial uranium production. In the late 1970s scoping studies of radon in homes prompted the Pennsylvania Department of Environmental Protection (DEP) Bureau of Radiation Protection (BRP) to begin planning for a larger state-wide radon study. The BRP and Oil and Gas Bureau also performed a TENORM study of produced water in the early 1990s for a number of conventional oil and gas wells. More recently BRP and the Bureau of Solid Waste developed radiation monitoring regulations for all Pennsylvania solid waste disposal facilities. These were implemented in 2001 prompting another evaluation of oil and gas operations and sludges generated from the treatment of conventional produced water and brine, but mainly focused on the disposal of TENORM solid waste in the state's Resource Conservation and Recovery Act Subtitle D landfills. However since 2008, the increase in volumes of gas well wastewater, and levels of 226Ra observed in the unconventional shale gas well flow-back frac water, has compelled DEP to fully re-examine these oil and gas operations. Specifically, with BRP in the lead, a new TENORM study of oil and gas operations and related wastewater treatment operations has been initiated. This study began in early 2013, and will examine the potential public and worker radiation exposure and environmental impact, as well as re-evaluate TENORM waste disposal. This presentation will summarize conventional and unconventional oil and gas well operations, geology and respective uranium/thorium content, radium content in oil and gas wastewater, treatment solids, radon in natural gas, the scope of other TENORM issues in the state, regulatory framework, national regulations and guidance, as well as, provide an overview of past and status of ongoing TENORM studies in the Commonwealth.

March 7, 2014. [*Category:* Seismicity]

Observations of static Coulomb stress triggering of the November 2011 M5.7 Oklahoma earthquake sequence.

- Sumy, Danielle F.; Cochran, Elizabeth S.; Keranen, Katie M.; Wei, Maya.; Abers, Geoffrey A.

- In: *Journal of Geophysical Research: Solid Earth*, Vol. 119, Issue 3, pages 1904-1923.
- http://onlinelibrary.wiley.com/doi/10.1002/2013JB010612/abstract

Abstract: In November 2011, a *M*5.0 earthquake occurred less than a day before a *M*5.7 earthquake near Prague, Oklahoma, which may have promoted failure of the mainshock and thousands of aftershocks along the Wilzetta fault, including a *M*5.0 aftershock. The *M*5.0 foreshock occurred in close proximity to active fluid injection wells; fluid injection can cause a buildup of pore fluid pressure, decrease the fault strength, and may induce earthquakes. *Keranen et al*. [2013] links the *M*5.0 foreshock with fluid injection, but the relationship between the foreshock and successive events has not been investigated. Here we examine the role of coseismic Coulomb stress transfer on earthquakes that follow the *M*5.0 foreshock, including the *M*5.7 mainshock. We resolve the static Coulomb stress change onto the focal mechanism nodal plane that is most consistent with the rupture geometry of the three $M \geq 5.0$ earthquakes, as well as specified receiver fault planes that reflect the regional stress orientation. We find that Coulomb stress is increased, e.g., fault failure is promoted, on the nodal planes of ~60% of the events that have focal mechanism solutions, and more specifically, that the *M*5.0 foreshock promoted failure on the rupture plane of the *M*5.7 mainshock. We test our results over a range of effective coefficient of friction values. Hence, we argue that the *M*5.0 foreshock, induced by fluid injection, potentially triggered a cascading failure of earthquakes along the complex Wilzetta fault system.

March 7, 2014. [*Category:* Water Quality]

A Critical Review of the Risks to Water Resources from Unconventional Shale Gas Development and Hydraulic Fracturing in the United States.

- Vengosh, Avner; Jackson, Robert B.; Warner, Nathaniel; Darrah, Thomas H.; and Kondash, Andrew.

- In: *Environmental Science & Technology*, Vol. 48, Issue 15, pages 8334-8348.
- http://dx.doi.org/10.1021/es405118y

Abstract: The rapid rise of shale gas development through horizontal drilling and high volume hydraulic fracturing has expanded the extraction of hydrocarbon resources in the U.S. The rise of shale gas development has triggered an intense public debate regarding the potential environmental and human health effects from hydraulic fracturing. This paper provides a critical review of the potential risks that shale gas operations pose to water resources, with an emphasis on case studies mostly from the U.S. Four potential risks for water resources are identified: (1) the contamination of shallow aquifers with fugitive hydrocarbon gases (i.e., stray gas contamination), which can also potentially lead to the salinization of shallow groundwater through leaking natural gas wells and subsurface flow; (2) the contamination of surface water and shallow groundwater from spills, leaks, and/or the disposal of inadequately treated shale gas wastewater; (3) the accumulation of toxic and radioactive elements in soil or stream sediments near disposal or spill sites; and (4) the overextraction of water resources for high-volume hydraulic fracturing that could induce water shortages or conflicts with other water users, particularly in water-scarce areas. Analysis of published data (through January 2014) reveals evidence for stray gas contamination, surface water impacts in areas of intensive shale gas development, and the accumulation of radium isotopes in some disposal and spill sites. The direct contamination of shallow groundwater from hydraulic fracturing fluids and deep formation waters by hydraulic fracturing itself, however, remains controversial.

March 4, 2014. [*Category:* Air Quality]

Anatomy of wintertime ozone associated with oil and natural gas extraction activity in Wyoming and Utah.

- Oltmans, Samuel; Schnell, Russell; Johnson, Bryan; Pétron, Gabrielle; Mefford, Thomas; Neely, Ryan.
- In: *Elementa: Science of the Anthropocene*, Vol. 2, 15 pages.
- http://elementascience.org/article/info:doi/10.12952/journal.elementa.000024

Abstract: Winter maximum daily 8-hour average (MDA8) ozone concentrations in the Upper Green River Basin, Wyoming (UGRBWY) and the Uintah Basin, Utah (UBUT) have frequently exceeded 100 ppb in January, February and March, in the past few years. Such levels are well above the U.S. air quality standard of 75 ppb. In these two remote basins in the Rockies, local ozone precursor emissions result from intense oil and gas extraction activities that release methane, volatile organic compounds (VOCs), and nitrogen oxides (NOx) to the atmosphere. These emissions become trapped beneath a stable and shallow (~50–200 m) boundary layer maintained in low wind conditions. Wintertime surface ozone formation conditions are more likely in the UBUT than in the UGRBWY as the topography of the UBUT is an enclosed basin whereas the UGRBWY is open on its southern perimeter thus allowing for more air turnover. With snow-covered ground, high ozone events regularly begin in mid-December and last into early March in the UBUT whereas they usually do not begin in earnest until about a month later in the UGRBWY and may persist until mid-March. Winters without snow cover and the accompanying cold pool meteorological conditions do not experience high ozone events in either basin. For nine years with ozone observations in the UGRBWY (2005–2013) and four in the UBUT (2010–2013), all years with adequate (≥6 inches) and persistent snow cover, experienced days with ozone values ≥75 ppb except in 2012 in the UGRBWY when persistent high wind (>5 m/s) conditions were prevalent. Year to year differences in the occurrences of high ozone episodes appear to be driven primarily by differing meteorological conditions rather than by variations in ozone precursor levels.

March 3, 2014. [*Category:* General (Comment / Review)]

Comment on "An Evaluation of Water Quality in Private Drinking Water Wells Near Natural Gas Extraction Sites in the Barnett Shale Formation."

- McHugh, Thomas; Molofsky, Lisa; Daus, Anthony; Connor, John.
- In: *Environmental Science & Technology*, Vol. 48, Issue 6, pages 3595-3596.
- http://dx.doi.org/10.1021/es405772d

Extract: The authors suggest that, within the active area, differences in arsenic, selenium, strontium, and TDS concentrations between the current data set and an historical data set may indicate recent impacts by gas development. However, the authors observe statistically significant increases in arsenic and strontium concentrations and statistically significant decreases in TDS and barium concentrations compared to the historical data set, a pattern that is inconsistent with impacts associated with natural gas development. For selenium, the authors' statistical analysis is inappropriate because the comparison is based only on **detected** results and the detection limit for selenium was much higher for the current data set (i.e., 10 μg/L) thereby creating a false indications of higher concentrations in the current data set. In addition, the current data set presents total (unfiltered) metal concentrations, while the historical data set presents undissolved metal concentrations, a difference that limits the significance of any comparisons.

March 3, 2014. [*Category:* Regulation]

Substate Federalism and Fracking Policies: Does State Regulatory Authority Trump Local Land Use Autonomy?

- Davis, Charles.
- In: *Environmental Science & Technology*, Vol. 48, Issue 15, pages 8397-8403.
- http://dx.doi.org/10.1021/es405095y

Abstract: State officials responsible for the regulation of hydraulic fracturing (fracking) operations used in the production of oil and gas resources will inevitably confront a key policy issue; that is, to what extent can statewide regulations be developed without reducing land use autonomy typically exercised by local officials? Most state regulators have historically recognized the economic importance of industry jobs and favor the adoption of uniform regulatory requirements even if these rules preempt local policymaking authority. Conversely, many local officials seek to preserve land use autonomy to provide a greater measure of protection for public health and environmental quality goals. This paper examines how public officials in three states - Colorado, Pennsylvania, and Texas - address the question of state control versus local autonomy through their efforts to shape fracking policy decisions. While local officials within Texas have succeeded in developing fracking ordinances with relatively little interference from state regulators, Colorado and Pennsylvania have adopted a tougher policy stance favoring the retention of preemptive oil and gas statutes. Key factors that account for between state differences in fracking policy decisions include the strength of home rule provisions, gubernatorial involvement, and the degree of local experience with industrial economic activities.

March 3, 2014. [*Category:* Air Quality]

Air Impacts of Increased Natural Gas Acquisition, Processing, and Use: A Critical Review.

- Moore, Christopher W.; Zielinska, Barbara; Petron, Gabrielle; Jackson, Robert B.
- In: *Environmental Science & Technology*, Vol. 48, Issue 15, pages 8349-8359.
- http://pubs.acs.org/doi/abs/10.1021/es4053472

Abstract: During the past decade, technological advancements in the United States and Canada have led to rapid and intensive development of many unconventional natural gas plays (e.g., shale gas, tight sand gas, coal-bed methane), raising concerns about environmental impacts. Here, we summarize the current understanding of local and regional air quality impacts of natural gas extraction, production, and use. Air emissions from the natural gas life cycle include greenhouse gases, ozone precursors (volatile organic compounds and nitrogen oxides), air toxics, and particulates. National and state regulators primarily use generic emission inventories to assess the climate, air quality, and health impacts of natural gas systems. These inventories rely on limited, incomplete, and sometimes outdated emission factors and activity data, based on few measurements. We discuss case studies for specific air impacts grouped by natural gas life cycle segment, summarize the potential benefits of using natural gas over other fossil fuels, and examine national and state emission regulations pertaining to natural gas systems. Finally, we highlight specific gaps in scientific knowledge and suggest that substantial additional measurements of air emissions from the natural gas life cycle are essential to understanding the impacts and benefits of this resource.

March 3, 2014. [*Category:* General (Comment / Review)]

Response to Comment on "An Evaluation of Water Quality in Private Drinking Water Wells Near Natural Gas Extraction Sites in the Barnett Shale Formation".

- Fontenot, Brian E.; Hildenbrand, Zacariah L.; Carlton, Doug D.; Walton, Jayme L.; Schug, Kevin A.
- In: *Environmental Science & Technology*, Vol. 48, Issue 6, pages 3597-3599.
- http://pubs.acs.org/doi/abs/10.1021/es500425j

Extract: McHugh et al. question our study of groundwater quality near natural gas extraction sites in the Barnett Shale. Here, we respond to their comments and provide additional clarification.

February 27, 2014. [*Category:* Health]

The health implications of fracking.

- Kovats, Sari; Depledge, Michael; Haines, Andy; Fleming, Lora E.; Wilkinson, Paul; Shonkoff, Seth B .; Scovronick, Noah.
- In: *The Lancet*, Vol. 383, Issue 9919, pages 757-758.
- http://psehealthyenergy.org/site/view/1183

Extract: What is known about the health effects of gas extraction by induced hydraulic fracturing of gas-bearing rock - ie, fracking? A workshop held on Nov 15, 2013, at the London School of Hygiene and Tropical Medicine and attended by scientists, public health professionals, and decision makers addressed this question.

Fracking is at a very early stage in the UK, with only one shale gas well tested so far. This situation provides an important opportunity to gather information and to conduct studies of health and environmental effects before any large-scale development. Scientific study of the health effects of fracking is in its infancy, but findings suggest that this form of extraction might increase health risks compared with conventional oil and gas wells because of the larger surface footprints of fracking sites; their close proximity to locations where people live, work, and play; and the need to transport and store large volumes of materials. In the USA, where more than 52,000 shale gas wells have been drilled, data suggest that risks of environmental contamination occur at all stages in the development of shale gas extraction. Failure of the structural integrity of the well cement and casing, surface spills and leakage from above-ground storage, emissions from gas-processing equipment, and the large numbers of heavy transport vehicles involved are the most important factors that contribute to environmental contamination and exposures in the USA.

February 26, 2014. [*Categories:* General (Comment / Review), Health]

Health and fracking: Should the medical profession be concerned?

- Mash, Rachel; Minnaar, Jolynn; Mash, Bob.
- In: *South African Medical Journal*, Vol. 104, Issue 5, pages 332-335.
- http://www.ncbi.nlm.nih.gov/pubmed/25212197

Abstract: The use of natural gas that is obtained from high-volume hydraulic fracturing (fracking) may reduce carbon emissions relative to the use of coal and have substantial economic benefits for South Africa. However, concerns have been raised regarding the health and environmental impacts. The drilling and fracking processes use hundreds of chemicals as well as silica sand. Additional elements are either released from or formed in the shale during drilling. These substances can enter the environment in various ways: through failures in the well casing; via alternative underground pathways; as wastewater, spills and leaks on the wellpad; through transportation accidents; and as air pollution. Although many of these chemicals and elements have known adverse health effects, there is little evidence available on the health impacts of fracking. These health concerns have not yet been fully addressed in policy making, and the authors recommend that the voice of health professionals should be part of the public debate on fracking and that a full health impact assessment be required before companies are given the go-ahead to drill.

February 24, 2014. [*Category:* Health]

Potential Public Health Hazards, Exposures and Health Effects from Unconventional Natural Gas Development.

- Adgate, John L.; Goldstein, Bernard D.; McKenzie, Lisa M.
- In: *Environmental Science & Technology*, Vol. 48, Issue 15, pages 8307-8320.
- http://dx.doi.org/10.1021/es404621d

Abstract: The rapid increase in unconventional natural gas (UNG) development in the United States during the past decade has brought wells and related infrastructure closer to population centers. This review evaluates risks to public health from chemical and nonchemical stressors associated with UNG, describes likely exposure pathways and potential health effects, and identifies major uncertainties to address with future research. The most important occupational stressors include mortality, exposure to hazardous materials and increased risk of industrial accidents. For communities near development and production sites the major stressors are air pollutants, ground and surface water contamination, truck traffic and noise pollution, accidents and malfunctions, and psychosocial stress associated with community change. Despite broad public concern, no comprehensive population-based studies of the public health effects of UNG operations exist. Major uncertainties are the unknown frequency and duration of human exposure, future extent of development, potential emission control and mitigation strategies, and a paucity of baseline data to enable substantive before and after comparisons for affected populations and environmental media. Overall, the current literature suggests that research needs to address these uncertainties before we can reasonably quantify the likelihood of occurrence or magnitude of adverse health effects associated with UNG production in workers and communities.

February 24, 2014. [*Category:* Regulation]

Shale Gas Development: A Smart Regulation Framework for Governing Forward.

- Konschnik, Katherine E.; Boling, Mark K.
- In: *Environmental Science & Technology*, Vol. 48, Issue 15, pages 8404-8416.
- http://pubs.acs.org/doi/abs/10.1021/es405377u

Abstract: Advances in directional drilling and hydraulic fracturing have sparked a natural gas boom from shale formations in the United States. Regulators face a rapidly changing industry comprised of hundreds of players, operating tens of thousands of wells across 30 states. They are often constrained in their efforts to respond by budget cuts, a brain drain to industry, regulations designed for conventional gas developments, insufficient information, and deeply polarized debates about hydraulic fracturing and its regulation. As a result, shale gas governance remains a halting patchwork of rules, undermining opportunities to effectively characterize and mitigate development risk. The situation is dynamic, with research and incremental regulatory advances underway. Into this mix, we offer the CO/RE framework - characterization of risk, optimization of mitigation strategies, regulation, and enforcement - to design tailored governance strategies. We then apply CO/RE to three types of shale gas risks, to illustrate its potential utility to regulators.

February 19, 2014. [*Categories:* Ecology, General (Comment / Review)]

Shale Gas, Wind and Water: Assessing the Potential Cumulative Impacts of Energy Development on Ecosystem Services within the Marcellus Play.

- Evans, Jeffrey S.; Kiesecker, Joseph M.
- In: *PLOS ONE*, Vol. 9, Issue 2, page e89210.
- http://dx.doi.org/10.1371/journal.pone.0089210

Abstract: Global demand for energy has increased by more than 50 percent in the last half-century, and a similar increase is projected by 2030. This demand will increasingly be met with alternative and unconventional energy sources. Development of these resources causes disturbances that strongly impact terrestrial and freshwater ecosystems. The Marcellus Shale gas play covers more than 160,934 km^2 in an area that provides drinking water for over 22 million people in several of the largest metropolitan areas in the United States (e.g. New York City, Washington DC, Philadelphia & Pittsburgh). Here we created probability surfaces representing development potential of wind and shale gas for portions of six states in the Central Appalachians. We used these predictions and published projections to model future energy build-out scenarios to quantify future potential impacts on surface drinking water. Our analysis predicts up to 106,004 new wells and 10,798 new wind turbines resulting up to 535,023 ha of impervious surface (3% of the study area) and upwards of 447,134 ha of impacted forest (2% of the study area). In light of this new energy future, mitigating the impacts of energy development will be one of the major challenges in the coming decades.

February 18, 2014. [*Category:* Water Quality]

Loopless nontrapping invasion-percolation model for fracking.

- Norris, J. Quinn; Turcotte, Donald L.; Rundle, John B.
- In: *Physical Review. E, Statistical, Nonlinear, and Soft Matter Physics*, Vol. 89, Issue 2-1.
- http://journals.aps.org/pre/abstract/10.1103/PhysRevE.89.022119

Abstract: Recent developments in hydraulic fracturing (fracking) have enabled the recovery of large quantities of natural gas and oil from old, low-permeability shales. These developments include a change from low-volume, high-viscosity fluid injection to high-volume, low-viscosity injection. The injected fluid introduces distributed damage that provides fracture permeability for the extraction of the gas and oil. In order to model this process, we utilize a loopless nontrapping invasion percolation previously introduced to model optimal polymers in a strongly disordered medium and for determining minimum energy spanning trees on a lattice. We performed numerical simulations on a two-dimensional square lattice and find significant differences from other percolation models. Additionally, we find that the growing fracture network satisfies both Horton-Strahler and Tokunaga network statistics. As with other invasion percolation models, our model displays burst dynamics, in which the cluster extends rapidly into a connected region. We introduce an alternative definition of bursts to be a consecutive series of opened bonds whose strengths are all below a specified value. Using this definition of bursts, we find good agreement with a power-law frequency-area distribution. These results are generally consistent with the observed distribution of microseismicity observed during a high-volume frack.

February 18, 2014. [*Category:* General (Comment / Review)]

Environmental Concerns of Shale Gas Production in China.

- Lu, P.; Yuan, T.; Feng, Q.; Sun, Y.
- In: *Energy Sources, Part A: Recovery, Utilization, and Environmental Effects*, Vol. 36, Issue 6, pages 638-642.
- http://dx.doi.org/10.1080/15567036.2013.835366

Abstract: China's energy consumption is highly relying on coal, which results in serious environmental and safety problems. The government sets a target to raise unconventional energy exploitation as a part of its new 12th-Five-Year Plan. This study reviews the challenge of shale gas production and discusses the possible impacts of shale gas exploitation on the local environment. Additionally, recommendations for further work are given in concern of local environment associated with shale gas production.

February 14, 2014. [*Category:* General (Comment / Review)]

Ensuring benefits from North American shale gas development: Towards a research agenda.

- Bazilian, M.; Brandt, A. R.; Billman, L.; Heath, G.; Logan, J.; Mann, M.; Melaina, M.; Statwick, P.; Arent, D.; Benson, S. M.
- In: *Journal of Unconventional Oil and Gas Resources*, Vol. 7, September 2014, pages 71-74.
- http://www.sciencedirect.com/science/article/pii/S2213397614000123

Abstract: The North American shale gas "revolution" provides tremendous opportunities, but our scientific understanding of this transition and its potential near- and long-term social, economic, and environmental impacts lags behind the rapid pace of change. Investors, policy makers, and other stakeholders need greater clarity to make robust decisions in today's dynamic natural gas sector. A comprehensive, interdisciplinary research agenda can help inform these decisions.

February 14, 2014. [*Category:* Climate]

Methane Leaks from North American Natural Gas Systems.

- Brandt, A. R.; Heath, G. A.; Kort, E. A.; O'Sullivan, F.; Pétron, G.; Jordaan, S. M.; Tans, P.; Wilcox, J.; Gopstein, A. M.; Arent, D.; Wofsy, S.; Brown, N. J.; Bradley, R.; Stucky, G. D.; Eardley, D.; Harriss, R.
- In: *Science*, Vol. 343, Issue 6172, pages 733-735.
- http://www.sciencemag.org/content/343/6172/733

Abstract: Natural gas (NG) is a potential "bridge fuel" during transition to a decarbonized energy system: It emits less carbon dioxide during combustion than other fossil fuels and can be used in many industries. However, because of the high global warming potential of methane (CH4, the major component of NG), climate benefits from NG use depend on system leakage rates. Some recent estimates of leakage have challenged the benefits of switching from coal to NG, a large near-term greenhouse gas (GHG) reduction opportunity. Also, global atmospheric CH4 concentrations are on the rise, with the causes still poorly understood.

February 10, 2014. [*Category:* Regulation]

Shale Play Politics: The Intergovernmental Odyssey of American Shale Governance.

- Rabe, Barry G.
- In: *Environmental Science & Technology*, Vol. 48, Issue 15, pages 8369-8375.
- http://pubs.acs.org/doi/abs/10.1021/es4051132

Abstract: Intergovernmental responsibility for policy development for shale gas is concentrated primarily at the state level, given multiple statutory and political constraints on potential federal engagement. This opens the question of how a large subset of American states might craft shale policies, amid competing scholarly views on the commitment of states to environmental protection when energy development opportunities arise in the absence of applicable federal authority. The article examines recent trends in state political economy that may shape policy development and capacity, considers the heterogeneous pattern of policy emerging thus far, and draws preliminary lessons from the very small set of states that have enacted far-reaching new state legislation. It also offers early discussion of cross-border issues that may trigger multistate, regional, or ultimately federal engagement as well as growing signs of volatility in policy development in some states.

February 10, 2014. [*Category:* Waste / Fluids]

Matrix Complications in the Determination of Radium Levels in Hydraulic Fracturing Flowback Water from Marcellus Shale.

- Nelson, Andrew W.; May, Dustin; Knight, Andrew W.; Eitrheim, Eric S.; Mehrhoff, Marinea; Shannon, Robert; Litman, Robert; Schultz, Michael K.

- In: *Environmental Science & Technology Letters,* Vol. 1, Issue 3, pages 204-208.
- http://dx.doi.org/10.1021/ez5000379

Abstract: The rapid proliferation of horizontal drilling and hydraulic fracturing for natural gas mining has raised concerns about the potential for adverse environmental impacts. One specific concern is the radioactivity content of associated “flowback” wastewater (FBW), which is enhanced with respect to naturally occurring radium (Ra) isotopes. Thus, development and validation of effective methods for analysis of Ra in FBW are critical to appropriate regulatory and safety decision making. Recent government documents have suggested the use of EPA method 903.0 for isotopic Ra determinations. This method has been used effectively to determine Ra levels in drinking water for decades. However, analysis of FBW by this method is questionable because of the remarkably high ionic strength and dissolved solid content observed, particularly in FBW from the Marcellus Shale region. These observations led us to investigate the utility of several common Ra analysis methods using a representative Marcellus Shale FBW sample. Methods examined included wet chemical approaches, such as EPA method 903.0, manganese dioxide (MnO2) preconcentration, and 3M Empore RAD radium disks, and direct measurement techniques such as radon (Rn) emanation and high-purity germanium (HPGe) gamma spectroscopy. Nondestructive HPGe and emanation techniques were effective in determining Ra levels, while wet chemical techniques recovered as little as 1% of 226Ra in the FBW sample studied. Our results question the reliability of wet chemical techniques for the determination of Ra content in Marcellus Shale FBW (because of the remarkably high ionic strength) and suggest that nondestructive approaches are most appropriate for these analyses. For FBW samples with a very high Ra content, large dilutions may allow the use of wet chemical techniques, but detection limit objectives must be considered.

February 5, 2014. [*Categories:* Air Quality, Climate]

Atmospheric Emissions and Air Quality Impacts from Natural Gas Production and Use.

- Allen, David T.
- In: *Annual Review of Chemical and Biomolecular Engineering*, Vol. 5, pages 55-75 (June 2014).
- http://www.annualreviews.org/doi/abs/10.1146/annurev-chembioeng-060713-035938

Abstract: The US Energy Information Administration projects that hydraulic fracturing of shale formations will become a dominant source of domestic natural gas supply over the next several decades, transforming the energy landscape in the United States. However, the environmental impacts associated with fracking for shale gas have made it controversial. This review examines emissions and impacts of air pollutants associated with shale gas production and use. Emissions and impacts of greenhouse gases, photochemically active air pollutants, and toxic air pollutants are described. In addition to the direct atmospheric impacts of expanded natural gas production, indirect effects are also described. Widespread availability of shale gas can drive down natural gas prices, which, in turn, can impact the use patterns for natural gas. Natural gas production and use in electricity generation are used as a case study for examining these indirect consequences of expanded natural gas availability. Expected final online publication date for the Annual Review of Chemical and Biomolecular Engineering Volume 5 is June 07, 2014. Please see http://www.annualreviews.org/catalog/pubdates.aspx for revised estimates.

February 4, 2014. [*Category:* Water Quality]

Distribution and Origin of Groundwater Methane in the Wattenberg Oil and Gas Field of Northern Colorado.

- Li, Huishu; Carlson, Kenneth H.
- In: *Environmental Science & Technology*, Vol. 48, Issue 3, pages 1484-1491.
- http://dx.doi.org/10.1021/es404668b

Abstract: Public concerns over potential environmental contamination associated with oil and gas well drilling and fracturing in the Wattenberg field in northeast Colorado are increasing. One of the issues of concern is the migration of oil, gas, or produced water to a groundwater aquifer resulting in contamination of drinking water. Since methane is the major component of natural gas and it can be dissolved and transported with groundwater, stray gas in aquifers has elicited attention. The initial step toward understanding the environmental impacts of oil and gas activities, such as well drilling and fracturing, is to determine the occurrence, where it is and where it came from. In this study, groundwater methane data that has been collected in response to a relatively new regulation in Colorado is analyzed. Dissolved methane was detected in 78% of groundwater wells with an average concentration of 4.0 mg/L and a range of 0-37.1 mg/L. Greater than 95% of the methane found in groundwater wells was classified as having a microbial origin, and there was minimal overlap between the C and H isotopic characterization of the produced gas and dissolved methane measured in the aquifer. Neither density of oil/gas wells nor distance to oil/gas wells had a significant impact on methane concentration suggesting other important factors were influencing methane generation and distribution. Thermogenic methane was detected in two aquifer wells indicating a potential contamination pathway from the producing formation, but microbial-origin gas was by far the predominant source of dissolved methane in the Wattenberg field.

February, 2014. [*Category:* Water Quality]

A geochemical context for stray gas investigations in the northern Appalachian Basin: Implications of analyses of natural gases from Neogene-through Devonian-age strata.

- Baldassare, Fred J.; McCaffrey, Mark A.; Harper, John A.

- In: *AAPG Bulletin*, Vol. 98, Issue 2, pages 341-372.
- http://search.datapages.com/data/doi/10.1306/06111312178

Abstract: As the pace of drilling activity in the Marcellus Formation in the northern Appalachian Basin has increased, so has the number of alleged incidents of stray natural gas migration to shallow aquifer systems. For this study, more than 2300 gas and water samples were analyzed for molecular composition and stable isotope compositions of methane and ethane. The samples are from Neogene- to Middle Devonian-age strata in a five-county study area in northeastern Pennsylvania. Samples were collected from the vertical and lateral sections of 234 gas wells during mud gas logging (MGL) programs and 67 private groundwater-supply wells during baseline groundwater-quality testing programs.

Evaluation of this geochemical database reveals that microbial, mixed microbial and thermogenic, and thermogenic gases of different thermal maturities occur in some shallow aquifer systems and throughout the stratigraphy above the Marcellus Formation. The gas occurrences predate Marcellus Formation drilling activity. Isotope data reveal that thermogenic gases are predominant in the regional Neogene and Upper Devonian rocks that comprise the potable aquifer system in the upper 305 m (1000 ft) (average $\Delta\ ^{13}C_1 = \Delta$ 43.53Δ ; average $\Delta\ ^{13}C_2 = \Delta$ 40.95Δ ; average Δ $DC_1 = \Delta$ 232.50) and Δ typically are distinct from gases in the Middle Devonian Marcellus Formation (average $\Delta\ ^{13}C_1 = \Delta$ 32.37Δ ; average $\Delta\ ^{13}C_2 = \Delta$ 38.48Δ ; average Δ $DC_1 = \Delta$ 162.34Δ). Additionally, isotope geochemistry at the site-specific level reveals a complex thermal and migration history with gas mixtures and partial isotope reversals ($\Delta\ ^{13}C_1 > \Delta\ ^{13}C_2$) in the units overlying the Marcellus Formation.

Identifying a source for stray natural gas requires the synthesis of multiple data types at the site-specific level. Molecular and isotope geochemistry provide evidence of gas origin and secondary processes that may have affected the gases during migration. Such data provide focus for investigations where the potential sources for stray gas include multiple, naturally occurring, and anthropogenic gases.

January 26, 2014. [*Category:* Regulation]

Unfinished business in the regulation of shale gas production in the United States.

- Centner, Terence J.; O'Connell, Laura Kathryn.
- In: *Science of the Total Environment*, Vol. 476-477, April 1, 2014, pages 359-367.
- http://www.sciencedirect.com/science/article/pii/S0048969713016021

Abstract: With increased drilling for natural gas, toxic chemicals used to fracture wells have been introduced into the environment accompanied by allegations of injuries. This article evaluates laws and regulations governing shale gas production to disclose ideas for offering further protection to people and the environment. The aim of the study is to offer state governments ideas for addressing contractual obligations of drilling operators, discerning health risks, disclosing toxic chemicals, and reporting sufficient information to detect problems and enforce regulations. The discussion suggests opportunities for state regulators to become more supportive of public health through greater oversight of shale gas extraction.

January 23, 2014. [*Category:* Community]

Marcellus Shale Development and the Susquehanna River: An Exploratory Analysis of Cross-Sector Attitudes on Natural Gas Hydraulic Fracturing.

- Heuer, Mark A.; Lee, Zui Chih.
- In: *Organization and Environment*, Vol. 27, Issue 1, pges 25-42.
- http://oae.sagepub.com/content/27/1/25

Abstract: In this exploratory analysis, we survey Susquehanna River basin stakeholders regarding the environmental, social, and economic impacts of natural gas hydraulic fracturing in the Marcellus Region. Our survey involved collecting data based on four categories: economic opportunity, protection of health and safety, preserving communities, and achieving energy security. We separated responses on a cross-sector basis in order to differentiate between the nonprofit, government, and private sectors. Overall, responses by the three sectors are relatively similar. Of the 21 questions measured by a 5-point Likert-type scale (with 5 being the highest priority), 17 questions measure above 3 for all three sectors. With hydraulic fracturing in the Marcellus Region in the early stages of a typical energy "boom-bust" cycle, the results of this survey provide baseline data to compare with stakeholder attitudes at later stages of the cycle.

January 16, 2014. [*Category:* Climate]

Natural Gas Pipeline Leaks Across Washington, DC.

- Jackson, Robert B.; Down, Adrian; Phillips, Nathan G.; Ackley, Robert C.; Cook, Charles W.; Plata, Desiree L.; Zhao, Kaiguang.
- In: *Environmental Science & Technology*, Vol. 48, Issue 3, pages 2051-2058.
- http://dx.doi.org/10.1021/es404474x

Abstract: Pipeline safety in the United States has increased in recent decades, but incidents involving natural gas pipelines still cause an average of 17 fatalities and $133 M in property damage annually. Natural gas leaks are also the largest anthropogenic source of the greenhouse gas methane (CH_4) in the U.S. To reduce pipeline leakage and increase consumer safety, we deployed a Picarro G2301 Cavity Ring-Down Spectrometer in a car, mapping 5893 natural gas leaks (2.5 to 88.6 ppm CH_4) across 1500 road miles of Washington, DC. The $\delta^{13}C$-isotopic signatures of the methane (−38.2‰ ± 3.9‰ s.d.) and ethane (−36.5 ± 1.1 s.d.) and the CH_4:C_2H_6 ratios (25.5 ± 8.9 s.d.) closely matched the pipeline gas (−39.0‰ and −36.2‰ for methane and ethane; 19.0 for CH_4/C_2H_6). Emissions from four street leaks ranged from 9200 to 38 200 L CH_4 day^{-1} each, comparable to natural gas used by 1.7 to 7.0 homes, respectively. At 19 tested locations, 12 potentially explosive (Grade 1) methane concentrations of 50 000 to 500 000 ppm were detected in manholes. Financial incentives and targeted programs among companies, public utility commissions, and scientists to reduce leaks and replace old cast-iron pipes will improve consumer safety and air quality, save money, and lower greenhouse gas emissions.

January 15, 2014. [*Category:* General (Comment / Review)]

An approach for assessing engineering risk from shale gas wells in the United States.

- Soeder, Daniel J.; Sharma, Shikha; Pekney, Natalie; Hopkinson, Leslie; Dilmore, Robert; Kutchko, Barbara; Stewart, Brian; Carter, Kimberly; Hakala, Alexandra; Capo, Rosemary.
- In: *International Journal of Coal Geology*, Vol. 126, pages 4-19 (June 1, 2014).
- http://www.sciencedirect.com/science/article/pii/S0166516214000068

Abstract: In response to a series of "energy crises" in the 1970s, the United States government began investigating the potential of unconventional, domestic sources of energy to offset imported oil. Hydraulic fracturing applied to vertical tight sand and coal bed methane wells achieved some degree of success during a period of high energy prices in the early 1980s, but shale gas remained largely untapped until the late 1990s with the application of directional drilling, a mature technology adapted from deepwater offshore platforms that allowed horizontal wells to penetrate kilometers of organic-rich shale, and staged hydraulic fracturing, which created high permeability flowpaths from the horizontal wells into a much greater volume of the target formations than previous completion methods. These new engineering techniques opened up vast unconventional natural gas and oil reserves, but also raised concerns about potential environmental impacts. These include short-term and long-term impacts to air and water quality from rig operations, potential migration of gas, fluids and chemicals through the ground, and effects on small watersheds and landscapes from roads, pads and other surface structures. Engineering risk assessment commonly uses integrated assessment models (IAMs), which define sources of risk from features, events and processes. The risk from each system element is assessed using high-fidelity models. Output from these is simplified into reduced-order models, so that a large, integrated site performance assessment can be run using the IAM. The technique has been applied to engineered systems in geologic settings for sequestering carbon dioxide, and it is also applicable to shale gas, albeit with some modifications of the various system elements. Preliminary findings indicate that shale gas well drilling and hydraulic fracturing techniques are generally safe when properly applied. Incident reports recorded by state environmental agencies suggest that human error resulting from the disregard of prescribed practices is the greatest cause of environmental incidents. This can only be addressed through education, regulations and enforcement.

January 11, 2014. [*Category:* Waste / Fluids]

Organic substances in produced and formation water from unconventional natural gas extraction in coal and shale.

- Orem, William; Tatu, Calin; Varonka, Matthew; Lerch, Harry; Bates, Anne; Engle, Mark; Crosby, Lynn; McIntosh, Jennifer.
- In: *International Journal of Coal Geology*, Vol. 126, June 1, 2014, pages 20-31.
- http://www.sciencedirect.com/science/article/pii/S0166516214000056

Abstract: Organic substances in produced and formation water from coalbed methane (CBM) and gas shale plays from across the USA were examined in this study. Disposal of produced waters from gas extraction in coal and shale is an important environmental issue because of the large volumes of water involved and the variable quality of this water. Organic substances in produced water may be environmentally relevant as pollutants, but have been little studied. Results from five CBM plays and two gas shale plays (including the Marcellus Shale) show a myriad of organic chemicals present in the produced and formation water. Organic compound classes present in produced and formation water in CBM plays include: polycyclic aromatic hydrocarbons (PAHs), heterocyclic compounds, alkyl phenols, aromatic amines, alkyl aromatics (alkyl benzenes, alkyl biphenyls), long-chain fatty acids, and aliphatic hydrocarbons. Concentrations of individual compounds range from < 1 to 100 μg/L, but total PAHs (the dominant compound class for most CBM samples) range from 50 to 100 μg/L. Total dissolved organic carbon (TOC) in CBM produced water is generally in the 1–4 mg/L range. Excursions from this general pattern in produced waters from individual wells arise from contaminants introduced by production activities (oils, grease, adhesives, etc.). Organic substances in produced and formation water from gas shale unimpacted by production chemicals have a similar range of compound classes as CBM produced water, and TOC levels of about 8 mg/L. However, produced water from the Marcellus Shale using hydraulic fracturing has TOC levels as high as 5500 mg/L and a range of added organic chemicals including, solvents, biocides, scale inhibitors, and other organic chemicals at levels of 1000 s of μg/L for individual compounds. Levels of these hydraulic fracturing chemicals and TOC decrease rapidly over the first 20 days of water recovery and some level of residual organic contaminants remain up to 250 days after hydraulic fracturing. Although the environmental impacts of the organics in produced water are not well defined, results suggest that care should be exercised in the disposal and release of produced waters containing these organic substances into the environment because of the potential toxicity of many of these substances.

January 10, 2014. [*Categories:* Water Usage, Water Quality]

Water resource impacts during unconventional shale gas development: The Pennsylvania experience.

- Brantley, Susan L.; Yoxtheimer, Dave; Arjmand, Sina; Grieve, Paul; Vidic, Radisav; Pollak, Jon; Llewellyn, Garth T.; Abad, Jorge; Simon, Cesar.
- In: *International Journal of Coal Geology*, Vol. 126, June 1, 2014, pages 140-156.
- http://www.sciencedirect.com/science/article/pii/S016651621300284X

Abstract: Improvements in horizontal drilling and hydrofracturing have revolutionized the energy landscape by allowing the development of so-called “unconventional” gas resources. The Marcellus play in the northeastern U.S.A. documents how fast this technology developed: the number of unconventional Marcellus wells in Pennsylvania (PA) increased from 8 in 2005 to ~ 7234 today. Publicly available databases in PA show only rare evidence of contamination of surface and groundwaters. This could document that incidents that impact PA waters have been relatively rare and that contaminants were quickly diluted. However, firm conclusions are hampered by i) the lack of information about location and timing of incidents; ii) the tendency to not release water quality data related to specific incidents due to liability or confidentiality agreements; iii) the sparseness of sample and sensor data for the analytes of interest; iv) the presence of pre-existing water impairments that make it difficult to determine potential impacts from shale-gas activity; and v) the fact that sensors can malfunction or drift. Although the monitoring data available to assess contamination events in PA are limited, the state manages an online database of violations. Overall, one fifth of gas wells drilled were given at least one non-administrative notice of violation (NOV) from the PA regulator. Through March 2013, 3.4% of gas wells were issued NOVs for well construction issues and 0.24% of gas wells received NOVs related to methane migration into groundwater. Between 2008 and 2012, 161 of the ~ 1000 complaints received by the state described contamination that implicated oil or gas activity: natural gas was reported for 56% and brine salt components for 14% of the properties. Six percent of the properties were impacted by sediments, turbidity, and/or drill cuttings. Most of the sites of groundwater contamination with methane and/or salt components were in previously glaciated northern PA where fracture flow sometimes allows long distance fluid transport. No cases of subsurface transport of fracking or flowback fluids into water supplies were documented. If Marcellus-related flowback/production waters did enter surface or groundwaters, the most likely contaminants to be detected would be Na, Ca, and Cl, but those elements are already common in natural waters. The most Marcellus-specific “fingerprint” elements are Sr, Ba, and Br. For example, variable Br concentrations measured in southwestern PA streams were attributed to permitted release of wastewaters from unconventional shale gas wells into PA streams through municipal or industrial wastewater treatment plants before 2011. Discharge has now been discontinued except for brines from a few plants still permitted to discharge conventional oil/gas brines after treatment. Overall, drinking water supply problems determined by the regulator to implicate oil/gas activities peaked in frequency in 2010 while spill rates increased through 2012. Although many minor violations and temporary problems have been reported, the picture that emerges from PA is that the fast shale-gas start may have led to relatively few environmental incidents of significant impact compared to wells drilled; however, the impacts remain difficult to assess due to the lack of transparent and accessible data.

January 9, 2014. [*Category:* General (Comment / Review)]

Fracking and Pollution: Can China Rescue Its Environment In Time?

- Guo, Meiyu; Xu, Yuan.
- In: *Environmental Science & Technology*, Vol. 48, Issue 2, pages 891-892.
- http://dx.doi.org/10.1021/es405608b

Extract: In response to concerns about energy security and coal-related environmental degradation, China has outlined ambitious plans to develop its vast shale gas resources, with production targets of 6.5 billion m^3 by 2015 and 60–100 billion m^3 by 2020, while in 2012 China's total natural gas production was 108 billion m^3. Potentially serious environmental impacts require technological solutions with financial backing. However, an even greater challenge in China is a weak regulatory climate, in which environmental policies are rarely rigorously enforced.

Environmental regulation cannot be effective without qualified regulatory rules. Shale gas development is subject to existing rules for conventional oil and gas industries. However, to address specific problems in this new industry, methodology and guidelines are inadequately detailed and often not pertinent. For example, our field trip in June 2013 to China's shale gas wells found that although operators did pay serious attention to methane leakage due to safety concerns, the leaked methane had not been quantified for the purpose of controlling greenhouse gas emissions, largely due to the absence of regulatory rules.

January 8, 2014. [*Categories:* General (Comment / Review), Waste / Fluids]

Exposure pathways related to shale gas development and procedures for reducing environmental and public risk.

- Ziemkiewicz, P. F.; Quaranta, J. D.; Darnell, A.; Wise, R.
- In: *Journal of Natural Gas Science and Engineering*, Vol. 16, January 2014, pages 77-84.
- http://www.sciencedirect.com/science/article/pii/S1875510013001042

Abstract: Hydraulic fracturing, combined with horizontal well development, has resulted in rapid expansion of gas production in the Appalachian Marcellus shale formation. In the past three years, over 2,000 horizontal/hydraulic fracture (HHF) wells have been developed in Pennsylvania, presenting significant potential for environmental degradation and human health risk if wastes are not isolated and handled properly. This study examined the waste streams from HHF development in the Marcellus formation and proposes protective measures that would minimize exposure. The results showed that flowback, drilling muds, and HHF fluids all exceeded SDWA limits to varying degrees. Due to the contaminants found in these substances, proper handling and containment is essential to prevent harm to the environment. Field evaluations on a subset of pits and impoundments indicated several construction and maintenance deficiencies related to the containment systems and transport pipelines. The geomembrane liners were evaluated for tears and anchoring deficiencies, while liquid transfer pipes were assessed for bracing support against rupture. An out-of-sample probability analysis using the binomial distribution identifies trends to focus field construction and maintenance efforts in order to minimize exposure pathways of frac fluids to the environment.

January 2, 2014. [*Category:* Air Quality]

The Data Gap: Can a Lack of Monitors Obscure Loss of Clean Air Act Benefits in Fracking Areas?

- Carlton, Annmarie G.; Little, Eleana; Moeller, Michael; Odoyo, Stella; Shepson, Paul B.
- In: *Environmental Science & Technology*, Vol. 48, Issue 2, pages 893-894.
- http://dx.doi.org/10.1021/es405672t

Extract: The U.S. is shifting to a greater reliance on natural gas to meet its energy needs, and a large part of this demand is being met by the development of shale gas formations. The increased utilization of natural gas is driven by the supply and thus lower cost, which largely results from new advances in engineering techniques. Primarily, gas production from horizontal drilling and high-volume hydraulic fracturing of shale and other low-porosity rock drives the favorable economics. Discussion of the environmental impacts of these operations has largely focused on water quality issues, but air pollution is also an important potential impact due to emissions associated with drilling, extraction, and associated transportation activities. Recently, air quality impacts have been measured in active oil and gas well areas. The extent to which these increased emissions impact air quality, especially in highly developed shale gas regions where there are no air monitors represents a substantial data gap and hinders effective air quality management.

January, 2014. [*Category:* Water Quality]

The Verification of a Method for Detecting and Quantifying Diethylene Glycol, Triethylene Glycol, Tetraethylene Glycol, 2-Butoxyethanol and 2-Methoxyethanol in Ground and Surface Waters.

- Schumacher, Brian A.; Zintek, Lawrence.
- By: *United States Environmental Protection Agency*.
- http://www2.epa.gov/sites/production/files/2014-07/documents/schumacherzintecverification_glycols_method.pdf

Executive Summary Extract:

This verification study was a special project designed to determine the efficacy of a draft standard operating procedure (SOP) developed by US EPA Region 3 for the determination of selected glycols and glycol ethers in drinking waters that may have been impacted by active unconventional oil and gas operations utilizing hydraulic fracturing (HF) extraction. HF has become increasingly prevalent as a method of extracting energy resources from "unconventional" reservoirs, such as coalbeds, shales, and tight sands. Concerns have been raised about the potential for hydraulic fracturing fluid chemical additives to enter ground water aquifers that, in turn, may be used as drinking water sources.

One group of hydraulic fracturing fluid chemical additives that concerns have been raised about includes the additives: 2-methoxyethanol (2-ME), 2-butoxyethanol (2-BE), diethylene glycol (Di-EG), triethylene glycol (Tri-EG), and tetraethylene glycol (Tetra-EG). The primary objective of this study was to verify the performance of the draft standard operating procedure developed by US EPA Region 3 in multiple laboratories. This study verified a simple and rapid high performance-liquid chromatography/tandem mass spectrometry (HPLC/MS/MS) method for the quantitation of these five chemical additives in aqueous samples. The draft method was quick, required little to no sample preparation, and utilized the sensitivity that HPLC/MS/MS provides.

The verification of the draft SOP included volunteer federal, state, municipal, and commercial analytical laboratories. Each laboratory tested the efficacy of the draft SOP using the HPLC/MS/MS instrumentation present in their laboratories. Four different water matrices were used to spike batches of samples at various concentrations. Three source matrix waters were collected from bulk water samples acquired from three drinking water source wells (prior to treatment) around the country in areas where active shale oil and gas operations are occurring or where they may occur in the future. The source matrix waters were collected at Avella, Pennsylvania, Raleigh, North Carolina, and Ada, Oklahoma. Laboratory deionized water, from Las Vegas, Nevada, was used as a fourth matrix. Batches of 36 blind samples, prepared by EPA, were distributed to the volunteer laboratories for analysis following the draft SOP.

December 24, 2013. [*Category:* Waste / Fluids]

Radium and Barium Removal through Blending Hydraulic Fracturing Fluids with Acid Mine Drainage.

- Kondash, Andrew J.; Warner, Nathaniel R.; Lahav, Ori; Vengosh, Avner.

- In: *Environmental Science & Technology*, Vol. 48, Issue 2, pages 1334-1342.
- http://pubs.acs.org/doi/abs/10.1021/es403852h

Abstract: Wastewaters generated during hydraulic fracturing of the Marcellus Shale typically contain high concentrations of salts, naturally occurring radioactive material (NORM), and metals, such as barium, that pose environmental and public health risks upon inadequate treatment and disposal. In addition, fresh water scarcity in dry regions or during periods of drought could limit shale gas development. This paper explores the possibility of using alternative water sources and their impact on NORM levels through blending acid mine drainage (AMD) effluent with recycled hydraulic fracturing flowback fluids (HFFFs). We conducted a series of laboratory experiments in which the chemistry and NORM of different mix proportions of AMD and HFFF were examined after reacting for 48 h. The experimental data combined with geochemical modeling and X-ray diffraction analysis suggest that several ions, including sulfate, iron, barium, strontium, and a large portion of radium (60-100%), precipitated into newly formed solids composed mainly of Sr barite within the first ∼10 h of mixing. The results imply that blending AMD and HFFF could be an effective management practice for both remediation of the high NORM in the Marcellus HFFF wastewater and beneficial utilization of AMD that is currently contaminating waterways in northeastern U.S.A.

December 18, 2013. [*Category:* Air Quality]

An exploratory study of air emissions associated with shale gas development and production in the Barnett Shale.

- Rich, Alisa; Grover, James P.; Sattler, Melanie L.

- In: *Journal of the Air & Waste Management Association*, Vol. 64, Issue 1, pages 61-72 (2014).
- http://www.tandfonline.com/doi/abs/10.1080/10962247.2013.832713

Abstract: Information regarding air emissions from shale gas extraction and production is critically important given production is occurring in highly urbanized areas across the United States. Objectives of this exploratory study were to collect ambient air samples in residential areas within 61 m (200 feet) of shale gas extraction/production and determine whether a "fingerprint" of chemicals can be associated with shale gas activity. Statistical analyses correlating fingerprint chemicals with methane, equipment, and processes of extraction/production were performed. Ambient air sampling in residential areas of shale gas extraction and production was conducted at six counties in the Dallas/Fort Worth (DFW) Metroplex from 2008 to 2010. The 39 locations tested were identified by clients that requested monitoring. Seven sites were sampled on 2 days (typically months later in another season), and two sites were sampled on 3 days, resulting in 50 sets of monitoring data. Twenty-four-hour passive samples were collected using summa canisters. Gas chromatography/mass spectrometer analysis was used to identify organic compounds present. Methane was present in concentrations above laboratory detection limits in 49 out of 50 sampling data sets. Most of the areas investigated had atmospheric methane concentrations considerably higher than reported urban background concentrations (1.8–2.0 ppmv). Other chemical constituents were found to be correlated with presence of methane. A principal components analysis (PCA) identified multivariate patterns of concentrations that potentially constitute signatures of emissions from different phases of operation at natural gas sites. The first factor identified through the PCA proved most informative. Extreme negative values were strongly and statistically associated with the presence of compressors at sample sites. The seven chemicals strongly associated with this factor (o-xylene, ethylbenzene, 1,2,4-trimethylbenzene, m- and p-xylene, 1,3,5-trimethylbenzene, toluene, and benzene) thus constitute a potential fingerprint of emissions associated with compression. Implications: Information regarding air emissions from shale gas development and production is critically important given production is now occurring in highly urbanized areas across the United States. Methane, the primary shale gas constituent, contributes substantially to climate change; other natural gas constituents are known to have adverse health effects. This study goes beyond previous Barnett Shale field studies by encompassing a wider variety of production equipment (wells, tanks, compressors, and separators) and a wider geographical region. The principal components analysis, unique to this study, provides valuable information regarding the ability to anticipate associated shale gas chemical constituents.

December 18, 2013. [*Category:* General (Comment / Review)]

An overview of Canadian shale gas production and environmental concerns.

- Rivard, Christine; Lavoie, Denis; Lefebvre, René; Séjourné, Stephan; Lamontagne, Charles; Duchesne, Mathieu.
- In: *International Journal of Coal Geology*, Vol. 126, pages 64-76 (June 1, 2014).
- http://www.sciencedirect.com/science/article/pii/S0166516213002711

Abstract: Production of hydrocarbons from Canadian shales started slowly in 2005 and has significantly increased since. Natural gas is mainly being produced from Devonian shales in the Horn River Basin and from the Triassic Montney shales and siltstones, both located in northeastern British Columbia and, to a lesser extent, in the Devonian Duvernay Formation in Alberta (western Canada). Other shales with natural gas potential are currently being evaluated, including the Upper Ordovician Utica Shale in southern Quebec and the Mississippian Frederick Brook Shale in New Brunswick (eastern Canada). This paper describes the status of shale gas exploration and production in Canada, including discussions on geological contexts of the main shale formations containing natural gas, water use for hydraulic fracturing, the types of hydraulic fracturing, public concerns and on-going research efforts. As the environmental debate concerning the shale gas industry is rather intense in Quebec, the Utica Shale context is presented in more detail.

December 16, 2013. [*Categories:* Health, Water Quality]

Estrogen and Androgen Receptor Activities of Hydraulic Fracturing Chemicals and Surface and Ground Water in a Drilling-Dense Region.

- Kassotis, Christopher D.; Tillitt, Donald E.; Davis, J. Wade; Hormann, Annette M.; Nagel, Susan C.
- In: *Endocrinology*, Vol. 155, Issue 3, pages 897-907.
- http://press.endocrine.org/doi/abs/10.1210/en.2013-1697

Abstract: The rapid rise in natural gas extraction using hydraulic fracturing increases the potential for contamination of surface and ground water from chemicals used throughout the process. Hundreds of products containing more than 750 chemicals and components are potentially used throughout the extraction process, including more than 100 known or suspected endocrine-disrupting chemicals. We hypothesized that a selected subset of chemicals used in natural gas drilling operations and also surface and ground water samples collected in a drilling-dense region of Garfield County, Colorado, would exhibit estrogen and androgen receptor activities. Water samples were collected, solid-phase extracted, and measured for estrogen and androgen receptor activities using reporter gene assays in human cell lines. Of the 39 unique water samples, 89%, 41%, 12%, and 46% exhibited estrogenic, antiestrogenic, androgenic, and antiandrogenic activities, respectively. Testing of a subset of natural gas drilling chemicals revealed novel antiestrogenic, novel antiandrogenic, and limited estrogenic activities. The Colorado River, the drainage basin for this region, exhibited moderate levels of estrogenic, antiestrogenic, and antiandrogenic activities, suggesting that higher localized activity at sites with known natural gas–related spills surrounding the river might be contributing to the multiple receptor activities observed in this water source. The majority of water samples collected from sites in a drilling-dense region of Colorado exhibited more estrogenic, antiestrogenic, or antiandrogenic activities than reference sites with limited nearby drilling operations. Our data suggest that natural gas drilling operations may result in elevated endocrine-disrupting chemical activity in surface and ground water., Affiliations Department of Obstetrics, Gynecology and Women's Health and Division of Biological Sciences (C.D.K., A.M.H., S.C.N.), University of Missouri, Columbia, Missouri 65211; US Geological Survey (D.E.T.), Columbia Environmental Research Center, Columbia, Missouri 65201; and Departments of Statistics and Health Management and Informatics (J.W.D.), University of Missouri, Columbia, Missouri, 65211.

December 12, 2013. [*Categories:* Waste / Fluids; Water Quality]

Surface disposal of produced waters in western and southwestern Pennsylvania: Potential for accumulation of alkali-earth elements in sediments.

- Skalak, Katherine J.; Engle, Mark A.; Rowan, Elisabeth L.; Jolly, Glenn D.; Conko, Kathryn M.; Benthem, Adam J.; Kraemer, Thomas F.

- In: *International Journal of Coal Geology*, Vol. 126, pages 162-170.
- http://www.sciencedirect.com/science/article/pii/S0166516213002681

Abstract: Waters co-produced with hydrocarbons in the Appalachian Basin are of notably poor quality (concentrations of total dissolved solids (TDS) and total radium up to and exceeding 300,000 mg/L and 10,000 pCi/L, respectively). Since 2008, a rapid increase in Marcellus Shale gas production has led to a commensurate rise in associated wastewater while generation of produced water from conventional oil and gas activities has continued. In this study, we assess whether disposal practices from treatment of produced waters from both shale gas and conventional operations in Pennsylvania could result in the accumulation of associated alkali earth elements. The results from our 5 study sites indicate that there was no increase in concentrations of total Ra (Ra-226) and extractable Ba, Ca, Na, or Sr in fluvial sediments downstream of the discharge outfalls ($p > 0.05$) of publicly owned treatment works (POTWs) and centralized waste treatment facilities (CWTs). However, the use of road spreading of brines from conventional oil and gas wells for deicing resulted in accumulation of Ra-226 (1.2 ×), and extractable Sr (3.0 ×), Ca (5.3 ×), and Na (6.2 ×) in soil and sediment proximal to roads ($p < 0.05$). Although this study is an important initial assessment of the impacts of these disposal practices, more work is needed to consider the environmental consequences of produced waters management.

December 12, 2013. [*Category:* Waste / Fluids]

Geochemical evolution of produced waters from hydraulic fracturing of the Marcellus Shale, northern Appalachian Basin: A multivariate compositional data analysis approach.

- Engle, Mark A.; Rowan, Elisabeth L.

- In: *International Journal of Coal Geology,* Vol. 126, June 1, 2014, pages 45-56.
- http://www.sciencedirect.com/science/article/pii/S0166516213002644

Abstract: Multivariate compositional data analysis methods were used to investigate geochemical data for water injected during hydraulic fracturing and for water produced from 19 Marcellus Shale gas wells in the northern Appalachian Basin. The data were originally published as part of an industry report. The analysis was adapted to consider the compositional nature of the data and avoid potentially spurious correlations present in raw concentration data through the application of log-ratio transformations. Techniques such as robust variation arrays, robust principal component analysis, and relative variation plots were applied to log-ratio transformed data. Results from this battery of multivariate tools indicate that two primary processes affect the chemical evolution of the water returned to the surface during the first 90 days of production: mixing of injected water with formation brines of evaporated paleoseawater origin and injection of sulfate-rich water during hydraulic fracturing may stimulate sulfate reduction at some sites. Spatial variability in sulfate/alkalinity ratios appears to influence variations in geochemical controls on strontium versus barium with elevated proportions of strontium being found in more bicarbonate-poor environments, while barium is a larger proportion in sulfate-poor areas. Comparison of results using a log-ratio approach versus the more common analysis of concentration data reveals both similarities and some marked differences in the resulting interpretations. Results from this work are important in terms of both demonstrating methods to avoid mathematical inconsistencies from using raw brine geochemical data and to further investigate the geochemical controls on produced waters generated from shale gas reservoirs.

December 12, 2013. [*Category:* Ecology]

Quantifying habitat impacts of natural gas infrastructure to facilitate biodiversity offsetting.

- Jones, Isabel L.; Bull, Joseph W.; Milner-Gulland, Eleanor J.; Esipov, Alexander V.; Suttle, Kenwyn B.
- In: *Ecology and Evolution*, Vol. 4, Issue 1, pages 79-90.
- http://www.ncbi.nlm.nih.gov/pmc/articles/PMC3894890/

Abstract: Habitat degradation through anthropogenic development is a key driver of biodiversity loss. One way to compensate losses is biodiversity offsetting (wherein biodiversity impacted is replaced through restoration elsewhere). A challenge in implementing offsets, which has received scant attention in the literature, is the accurate determination of residual biodiversity losses. We explore this challenge for offsetting gas extraction in the Ustyurt Plateau, Uzbekistan. Our goal was to determine the landscape extent of habitat impacts, particularly how the footprint of linear infrastructure (i.e. roads, pipelines), often disregarded in compensation calculations, compares with hub infrastructure (i.e. extraction facilities). We measured vegetation cover and plant species richness using the line-intercept method, along transects running from infrastructure/control sites outward for 500m, accounting for wind direction to identify dust deposition impacts. Findings from 24 transects were extrapolated to the broader plateau by mapping total landscape infrastructure network using GPS data and satellite imagery. Vegetation cover and species richness were significantly lower at development sites than controls. These differences disappeared within 25m of the edge of the area physically occupied by infrastructure. The current habitat footprint of gas infrastructure is 220 +/- 19km(2) across the Ustyurt (total similar to 100,000km(2)), 37 +/- 6% of which is linear infrastructure. Vegetation impacts diminish rapidly with increasing distance from infrastructure, and localized dust deposition does not conspicuously extend the disturbance footprint. Habitat losses from gas extraction infrastructure cover 0.2% of the study area, but this reflects directly eliminated vegetation only. Impacts upon fauna pose a more difficult determination, as these require accounting for behavioral and demographic responses to disturbance by elusive mammals, including threatened species. This study demonstrates that impacts of linear infrastructure in regions such as the Ustyurt should be accounted for not just with respect to development sites but also associated transportation and delivery routes.

December 12, 2013. [*Categories:* Waste / Fluids, Water Quality]

A review of environmental impacts of salts from produced waters on aquatic resources.

- Farag, Aïda M.; Harper, David D.
- In: *International Journal of Coal Geology*, Vol. 126, pages 157-161.
- http://www.sciencedirect.com/science/article/pii/S0166516213002735

Abstract: Salts are frequently a major constituent of waste waters produced during oil and gas production. These produced waters or brines must be treated and/or disposed and provide a daily challenge for operators and resource managers. Some elements of salts are regulated with water quality criteria established for the protection of aquatic wildlife, e.g. chloride (Cl^-), which has an acute standard of 860 mg/L and a chronic standard of 230 mg/L. However, data for establishing such standards has only recently been studied for other components of produced water, such as bicarbonate (HCO_3^-), which has acute median lethal concentrations (LC50s) ranging from 699 to > 8000 mg/L and effects on chronic toxicity from 430 to 657 mg/L. While Cl^- is an ion of considerable importance in multiple geographical regions, knowledge about the effects of hardness (calcium and magnesium) on its toxicity and about mechanisms of toxicity is not well understood. A multiple-approach design that combines studies of both individuals and populations, conducted both in the laboratory and the field, was used to study toxic effects of bicarbonate (as $NaHCO_3$). This approach allowed interpretations about mechanisms related to growth effects at the individual level that could affect populations in the wild. However, additional mechanistic data for HCO_3^-, related to the interactions of calcium (Ca^{2+}) precipitation at the microenvironment of the gill would dramatically increase the scientific knowledge base about how $NaHCO_3$ might affect aquatic life. Studies of the effects of mixtures of multiple salts present in produced waters and more chronic effect studies would give a better picture of the overall potential toxicity of these ions. Organic constituents in hydraulic fracturing fluids, flowback waters, etc. are a concern because of their carcinogenic properties and this paper is not meant to minimize the importance of maintaining vigilance with respect to potential organic contamination.

December 12, 2013. [*Category:* Water Quality]

Hydraulic fracturing in faulted sedimentary basins: Numerical simulation of potential contamination of shallow aquifers over long time scales.

- Gassiat, Claire; Gleeson, Tom; Lefebvre, René; McKenzie, Jeffrey.
- In: *Water Resources Research*, Vol. 49, Issue 12, pages 8310-8327.
- http://onlinelibrary.wiley.com/doi/10.1002/2013WR014287/abstract

Abstract: Hydraulic fracturing, used to economically produce natural gas from shale formations, has raised environmental concerns. The objective of this study is to assess one of the largely unexamined issues, which is the potential for slow contamination of shallow groundwater due to hydraulic fracturing at depth via fluid migration along conductive faults. We compiled publically available data of shale gas basins and hydraulic fracturing operations to develop a two-dimensional, single-phase, multispecies, density-dependent, finite-element numerical groundwater flow and mass transport model. The model simulates hydraulic fracturing in the vicinity of a permeable fault zone in a generic, low-recharge, regional sedimentary basin in which shallow, active groundwater flow occurs above nearly stagnant brine. A sensitivity analysis of contaminant migration along the fault considered basin, fault and hydraulic fracturing parameters. Results show that specific conditions are needed for the slow contamination of a shallow aquifer: a high permeability fault, high overpressure in the shale unit, and hydrofracturing in the upper portion of the shale near the fault. Under such conditions, contaminants from the shale unit reach the shallow aquifer in less than 1000 years following hydraulic fracturing, at concentrations of solutes up to 90% of their initial concentration in the shale, indicating that the impact on groundwater quality could be significant. Important implications of this result are that hydraulic fracturing should not be carried out near potentially conductive faults, and that impacts should be monitored for long timespans. Further work is needed to assess the impact of multiphase flow on contaminant transport along natural preferential pathways.

December 12, 2013. [*Category:* Health]

The importance of public health agency independence: Marcellus shale gas drilling in Pennsylvania.

- Goldstein, Bernard D.
- In: *American Journal of Public Health*, Vol. 104, Issue 2, pages e13-15.
- http://www.ncbi.nlm.nih.gov/pubmed/24328620

Abstract: Public health often deals with inconvenient truths. These are best communicated and acted on when public health agencies are independent of the organizations or individuals for whom the truths are inconvenient. The importance of public health independence is exemplified by the lack of involvement of the Pennsylvania Department of Health in responding to health concerns about shale gas drilling. Pennsylvania Department of Health involvement has been forestalled by the state governor, who has intensely supported shale gas development.

December 12, 2013. [*Category:* Waste / Fluids]

A semi-analytical model for multi-stage fractured horizontal wells.

- Yao, Shanshan; Zeng, Fanhua; Liu, Hong; Zhao, Gang.

- In: *Journal of Hydrology*, Vol. 507, pages 201-212.
- http://www.sciencedirect.com/science/article/pii/S0022169413007622

Abstract: Multi-stage fractured horizontal wells are widely applied when developing tight reservoirs and shale gas reservoirs. As such, testing and evaluating fractured horizontal wells' productivity become necessary for further improving the wells' performance. Analyzing post-fracturing transient pressure data provides estimation of some key parameters that affect the productivity, including effective fracture lengths, fracture conductivities, fracture skin factors and average formation permeability. This paper presents a semi-analytical model based on Green's functions and the source/sink method to facilitate the transient pressure analysis for a multi-stage fractured horizontal well in a closed box-shaped reservoir. Four kinds of fluid flow in the multi-stage fractured horizontal well system, including fluid from the reservoir to the fractures and from the reservoir to the horizontal wellbore, fluid inside the fractures as well as fluid flow inside the horizontal wellbore, are all taken into consideration. Compared with previous models, this study considers the pressure drops caused by pipe flow inside the wellbore. For the model's accuracy and robustness, the fractures and the horizontal wellbore are discretized into vertical plane segments and horizontal line segments, respectively. Correspondingly, the fluid flow from the reservoir to the fracture as well as the fluid flow directly from the reservoir to the horizontal wellbore at each segment are modeled by analytical solutions of vertical plane source and horizontal line source, respectively. In addition, the fluid flow inside the fractures is modeled as 1-D linear flow. The fluid flow inside the horizontal wellbore is described with Penmatcha and Aziz's model (1999). Finally, interface flux- and pressure-continuity conditions are used to couple the equations of aforementioned four kinds of fluid flow. The effects of fluid flow directly from the reservoir to the horizontal wellbore, fracture spacing, fracture lengths, fracture conductivities, and fracture skin factors on the transient pressure behavior are studied and type curves are generated. The results suggest that, in a tight or shale-gas reservoir, fracture stage, fracture lengths, conductivities and skin factors have significant influence on the transient pressure behavior during a testing period while the fluid flow directly from the reservoir into the horizontal wellbore reduces the pressure drops slightly. Then, a field case is analyzed and reliable results are obtained. This model can be further applied to optimize the fracture spacing and fracture lengths for a multi-stage fractured horizontal well.

December 6, 2013. [*Category:* Waste / Fluids]

Microbial diversity and methanogenic activity of Antrim Shale formation waters from recently fractured wells.

- Wuchter, Cornelia; Banning, Erin; Mincer, Tracy J.; Drenzek, Nicholas J.; Coolen, Marco J. L.

- In: *Frontiers in Microbiology*, Vol. 4, December 2013, article 367 (14 pages).
- http://journal.frontiersin.org/Journal/10.3389/fmicb.2013.00367/full

Abstract: The Antrim Shale in the Michigan Basin is one of the most productive shale gas formations in the U.S., but optimal resource recovery strategies must rely on a thorough understanding of the complex biogeochemical, microbial, and physical interdependencies in this and similar systems. We used Illumina MiSeq 16S rDNA sequencing to analyze the diversity and relative abundance of prokaryotic communities present in Antrim shale formation water of three closely spaced recently fractured gas-producing wells. In addition, the well waters were incubated with a suite of fermentative and methanogenic substrates in an effort to stimulate microbial methane generation. The three wells exhibited substantial differences in their community structure that may arise from their different drilling and fracturing histories. Bacterial sequences greatly outnumbered those of archaea and shared highest similarity to previously described cultures of mesophiles and moderate halophiles within the Firmicutes, Bacteroidetes, and δ- and ε-Proteobacteria. The majority of archaeal sequences shared highest sequence similarity to uncultured euryarchaeotal environmental clones. Some sequences closely related to cultured methylotrophic and hydrogenotrophic methanogens were also present in the initial well water. Incubation with methanol and trimethylamine stimulated methylotrophic methanogens and resulted in the largest increase in methane production in the formation waters, while fermentation triggered by the addition of yeast extract and formate indirectly stimulated hydrogenotrophic methanogens. The addition of sterile powdered shale as a complex natural substrate stimulated the rate of methane production without affecting total methane yields. Depletion of methane indicative of anaerobic methane oxidation (AMO) was observed over the course of incubation with some substrates. This process could constitute a substantial loss of methane in the shale formation.

November 27, 2013. [*Categories:* General (Comment / Review), Water Quality]

Fracking – eine Gefahr für das Trinkwasser? (Hydraulic Fracturing – A Hazard for Drinking Water?)

- Ewers, U.; Gordalla, B.; Frimmel, F.
- In: *Gesundheitswesen* (Bundesverband der Ärzte des Öffentlichen Gesundheitsdienstes (Germany), Vol. 75, Issue 11, pages 735-741.
- https://www.thieme-connect.com/DOI/DOI?10.1055/s-0033-1355369

Zusammenfassung

Im Rahmen der Erdgasförderung soll in Deutschland vermehrt das hydraulische Fracking eingesetzt werden. In der Öffentlichkeit bestehen große Besorgnisse und Zweifel bzgl. der Sicherheit dieser Technik. Kritisch gesehen wird insbesondere die Gefahr einer Kontamination des Grundwassers und des Trinkwassers. In dem vorliegenden Beitrag werden die Risiken der Fracking-Technologie in Bezug auf eine mögliche Kontamination des Grundwassers erörtert. Im Vordergrund steht die toxikologische Bewertung der beim Fracking eingesetzten Hilfsstoffe (Additive), die im Falle eines Störfalls im Grund- und Trinkwasser auftreten könnten. Aufgrund der in Deutschland bestehenden Sicherheitsanforderungen und im Hinblick auf die vor jedem Frac erforderliche geologische und hydrogeologische Standortprüfung wird das Risiko einer Kontamination des Grundwassers und des Trinkwassers durch Additive von Frack-Flüssigkeiten als gering eingeschätzt. Bei zukünftig durchzuführenden Fracs sollte ein Grundwasser-Monitoring obligatorisch sein. In die Genehmigungsverfahren für Fracs, die bisher allein von den Bergbehörden durchgeführt werden, sollten zukünftig auch die zuständigen Wasserbehörden eingebunden werden. In Wasserschutzgebieten sollte grundsätzlich auf das Fracking verzichtet werden.

Abstract

Hydraulic fracturing (fracking) is a technique used to release and promote the extraction of natural gas (including shale gas, tight gas, and coal bed methane) from deep natural gas deposits. Among the German public there is great concern with regard to the potential environmental impacts of fracking including the contamination of ground water, the most important source of drinking water in Germany. In the present article the risks of ground water contamination through fracking are discussed. Due to the present safety requirements and the obligatory geological and hydrogeological scrutiny of the underground, which has to be performed prior to fracking, the risk of ground water contamination by fracking can be regarded as very low. The toxicity of chemical additives of fracking fluids is discussed. It is recommended that in the future environmental impact assessment and approval of fracs should be performed by the mining authorities in close cooperation with the water authorities. Furthermore, it is recommended that hydraulic fracturing in the future should be accompanied by obligatory ground water monitoring.

November 27, 2013. [*Category:* Ecology]

Comparing the ecological impacts of wind and oil & gas development: a landscape scale assessment.

- Jones, Nathan F.; Pejchar, Liba.
- In: *PloS One*, Vol. 8, Issue 11, page 81391.
- http://www.ncbi.nlm.nih.gov/pubmed/24312296

Abstract: Energy production in the United States is in transition as the demand for clean and domestic power increases. Wind energy offers the benefit of reduced emissions, yet, like oil and natural gas, it also contributes to energy sprawl. We used a diverse set of indicators to quantify the ecological impacts of oil, natural gas, and wind energy development in Colorado and Wyoming. Aerial imagery was supplemented with empirical data to estimate habitat loss, fragmentation, potential for wildlife mortality, susceptibility to invasion, biomass carbon lost, and water resources. To quantify these impacts we digitized the land-use footprint within 375 plots, stratified by energy type. We quantified the change in impacts per unit area and per unit energy produced, compared wind energy to oil and gas, and compared landscapes with and without energy development. We found substantial differences in impacts between energy types for most indicators, although the magnitude and direction of the differences varied. Oil and gas generally resulted in greater impacts per unit area but fewer impacts per unit energy compared with wind. Biologically important and policy-relevant outcomes of this study include: 1) regardless of energy type, underlying land-use matters and development in already disturbed areas resulted in fewer total impacts; 2) the number and source of potential mortality varied between energy types, however, the lack of robust mortality data limits our ability to use this information to estimate and mitigate impacts; and 3) per unit energy produced, oil and gas extraction was less impactful on an annual basis but is likely to have a much larger cumulative footprint than wind energy over time. This rapid evaluation of landscape-scale energy development impacts could be replicated in other regions, and our specific findings can help meet the challenge of balancing land conservation with society's demand for energy.

November 21, 2013. [*Category:* Economics]

A decade of natural gas development: The makings of a resource curse?

- Jeremy G. Weber.
- In: *Resource and Energy Economics*, Vol. 37, pages 168-183 (August 2014).
- http://www.sciencedirect.com/science/article/pii/S0928765513000882

Abstract: Many studies find that areas more dependent on natural resources grow more slowly – a relationship known as the resource curse. For counties in the south-central U.S., I find little evidence of an emerging curse from greater natural gas production in the 2000s. Each gas-related mining job created more than one nonmining job, indicating that counties did not become more dependent on mining as measured by employment. Increases in population largely mitigated a rise in earnings per job and crowding out. Furthermore, changes in the adult population by education level reveal that greater production did not lead to a less educated population.

November 20, 2013. [*Category:* General (Comment/Review)]

He who has the pipeline calls the tune? Russia's energy power against the background of the shale "revolutions."

- Kropatcheva, Elena.
- In: *Energy Policy*, Vol. 66, March 2014, pages 1-10.
- http://www.sciencedirect.com/science/article/pii/S0301421513010811

Abstract: Russian energy policy is usually considered in the regional context – in terms of its energy power capability and strength vis-à-vis the EU and the post-Soviet states. This study shows that in order to understand Russia's energy power, even in the regional context of its relations with the EU, it is necessary to consider the impact of international changes in the energy sector. The oil and gas shale "revolutions" represent such a global factor of influence. Even if their consequences are not yet clear, they have already become an important challenge for Russian energy policy and power. This policy-oriented article, guided by neoclassical realism, analyzes what the shale "revolutions" mean for Russia's energy policy and its power capabilities vis-à-vis the EU, how the Russian political elite perceive this development and how Russia reacts to it. In this context, Russian power capabilities look more moderate.

November 19, 2013. [*Category:* Waste / Fluids]

Suggested Reporting Parameters for Investigations of Wastewater from Unconventional Shale Gas Extraction.

- Bibby, Kyle J.; Brantley, Susan L.; Reible, Danny D.; Linden, Karl G.; Mouser, Paula J.; Gregory, Kelvin B.; Ellis, Brian R.; Vidic, Radisav D.
- In: *Environmental Science & Technology*, Vol. 47, Issue 23, pages 13220-13221.
- http://pubs.acs.org/doi/abs/10.1021/es404960z

Extract: The recent boom in natural gas extraction from shale formations using high-volume hydraulic fracturing ("fracking") has created a nascent environmental research field investigating the challenges associated with wastewater management from these unconventional reservoirs. In operations using high-volume hydraulic fracturing for natural gas, thousands of cubic meters of fracturing fluid are injected into the subsurface under high pressure to fracture the shale formation and release trapped gas. The exact makeup of fracturing fluid is unique for each service company and protected as a trade secret. Fracturing fluid is typically greater than 98% water and sand with the remainder composed of chemical additives designed to aid gas recovery processes and protect well infrastructure, such as friction reducers, antiscalants, viscosity modifiers and biocides. During well completion, fracturing fluid returns to the surface as flowback water. Once a well is placed in production, reduced quantities of water, known as produced water, are brought to the surface with gas for most of the well life. Flowback water typically contains both the chemicals used in the fracturing process as well as elevated levels of total dissolved solids (TDS). Produced water generally contains insignificant levels of fracturing fluid chemical compounds but contains higher levels of TDS than the flowback water. The high TDS is generally attributed to rock-water equilibration and mixing of the fracturing fluid with subsurface brines.

November 19, 2013. [*Category:* Water Usage]

Surface water withdrawals for Marcellus Shale gas development: performance of alternative regulatory approaches in the Upper Ohio River Basin.

- Mitchell, Austin L.; Small, Mitchell; Casman, Elizabeth A.
- In: *Environmental Science & Technology*, Vol. 47, Issue 22, pages 12669-12678.
- http://www.ncbi.nlm.nih.gov/pubmed/24125505

Abstract: Almost all of the water used for developing Marcellus Shale gas is withdrawn from surface water sources. State environmental and interstate water authorities take different approaches to managing these withdrawals. In the Upper Ohio River Basin, which covers the western third of Pennsylvania, the Pennsylvania Department of Environmental Protection requires that all water sources used for development have an approved water management plan. For surface water sources the plans stipulate the amount and timing of withdrawals from each source as a function of annual streamflow statistics. Neighboring regulatory authorities and some environmental groups now favor the use of monthly streamflow statistics to establish the conditions for water withdrawals. Our analysis indicates that, given the state of flow measurement data in the Upper Ohio River Basin, the annual streamflow statistics are more likely to prevent water withdrawals during the driest times of the year when aquatic ecosystems are most stressed, and to result in fewer and smaller occurrences of computed low-flow ecodeficits.

November 18, 2013. [*Category:* Economics]

Gas production in the Barnett Shale obeys a simple scaling theory.

- Patzek, Tad W.; Male, Frank; Marder, Michael.
- In: *Proceedings of the National Academy of Sciences*, Vol. 110, Issue 49, pages 19731-19736.
- http://www.pnas.org/content/early/2013/11/12/1313380110

Abstract: Natural gas from tight shale formations will provide the United States with a major source of energy over the next several decades. Estimates of gas production from these formations have mainly relied on formulas designed for wells with a different geometry. We consider the simplest model of gas production consistent with the basic physics and geometry of the extraction process. In principle, solutions of the model depend upon many parameters, but in practice and within a given gas field, all but two can be fixed at typical values, leading to a nonlinear diffusion problem we solve exactly with a scaling curve. The scaling curve production rate declines as 1 over the square root of time early on, and it later declines exponentially. This simple model provides a surprisingly accurate description of gas extraction from 8,294 wells in the United States' oldest shale play, the Barnett Shale. There is good agreement with the scaling theory for 2,057 horizontal wells in which production started to decline exponentially in less than 10 y. The remaining 6,237 horizontal wells in our analysis are too young for us to predict when exponential decline will set in, but the model can nevertheless be used to establish lower and upper bounds on well lifetime. Finally, we obtain upper and lower bounds on the gas that will be produced by the wells in our sample, individually and in total. The estimated ultimate recovery from our sample of 8,294 wells is between 10 and 20 trillion standard cubic feet.

November 17, 2013. [*Categories:* General (Comment / Review), Health]

Harms unknown: health uncertainties cast doubt on the role of unconventional gas in Australia's energy future.

- Coram, Alicia; Moss, Jeremy; Blashki, Grant.
- In: *Medical Journal of Australia*, Vol. 200, Issue 4, March 3, 2014, pages 210-213.
- https://www.mja.com.au/journal/2014/200/4/harms-unknown-health-uncertainties-cast-doubt-role-unconventional-gas-australias

Summary: There is a push to increase production of unconventional gas in Australia, which would intensify the use of the controversial technique of hydraulic fracturing. The uncertainties surrounding the health implications of unconventional gas, when considered together with doubts surrounding its greenhouse gas profile and cost, weigh heavily against proceeding with proposed future developments. The health and environmental impacts of hydraulic fracturing have been the source of widespread public concern. A review of available literature shows a considerable degree of uncertainty, but an emerging consensus about the main risks. Gas is often claimed to be a less climate-damaging alternative to coal; however, this is called into question by the fugitive emissions produced by unconventional gas extraction and the consequences of its export. While the health effects associated with fracturing chemicals have attracted considerable public attention, risks posed by wastewater, community disruption and the interaction between exposures are of also of concern. The health burdens of unconventional gas are likely to fall disproportionately on rural communities, the young and the elderly. While the health and environmental risks and benefits must be compared with other energy choices, coal provides a poor benchmark.

November 16, 2013. [*Category:* General (Comment / Review)]

The role of ethics in shale gas policies.

- De Melo-Martín, Inmaculada; Hays, Jake; Finkel, Madelon L.
- In: *Science of the Total Environment*, Vol. 470-471, pages 1114-1119.
- http://www.sciencedirect.com/science/article/pii/S0048969713012321

Abstract: The United States has experienced a boom in natural gas production due to recent technological innovations that have enabled natural gas to be produced from unconventional sources, such as shale. There has been much discussion about the costs and benefits of developing shale gas among scientists, policy makers, and the general public. The debate has typically revolved around potential gains in economics, employment, energy independence, and national security as well as potential harms to the environment, the climate, and public health. In the face of scientific uncertainty, national and international governments must make decisions on how to proceed. So far, the results have been varied, with some governments banning the process, others enacting moratoria until it is better understood, and others explicitly sanctioning shale gas development. These policies reflect legislature's preferences to avoid false negative errors or false positive ones. Here we argue that policy makers have a prima facie duty to minimize false negatives based on three considerations: (1) protection from serious harm generally takes precedence over the enhancement of welfare; (2) minimizing false negatives in this case is more respectful to people's autonomy; and (3) alternative solutions exist that may provide many of the same benefits while minimizing many of the harms.

November 15, 2013. [*Category:* Community]

"Fracking" controversy and communication: Using national survey data to understand public perceptions of hydraulic fracturing.

- Boudet, Hilary; Clarke, Christopher; Bugden, Dylan; Maibach, Edward; Roser-Renouf, Connie; Leiserowitz, Anthony.
- In: *Energy Policy*, Vol. 65, February 2014, pages 57-67.
- http://www.sciencedirect.com/science/article/pii/S0301421513010392

Abstract: The recent push to develop unconventional sources of oil and gas both in the U.S. and abroad via hydraulic fracturing ("fracking") has generated a great deal of controversy. Effectively engaging stakeholders and setting appropriate policies requires insights into current public perceptions of this issue. Using a nationally representative U.S. sample (N=1061), we examine public perceptions of hydraulic fracturing including: "top of mind" associations; familiarity with the issue; levels of support/opposition; and predictors of such judgments. Similar to findings on other emerging technologies, our results suggest limited familiarity with the process and its potential impacts and considerable uncertainty about whether to support it. Multiple regression analysis (r2=.49) finds that women, those holding egalitarian worldviews, those who read newspapers more than once a week, those more familiar with hydraulic fracturing, and those who associate the process with environmental impacts are more likely to oppose fracking. In contrast, people more likely to support fracking tend to be older, hold a bachelor's degree or higher, politically conservative, watch TV news more than once a week, and associate the process with positive economic or energy supply outcomes. Based on these findings, we discuss recommendations for future research, risk communication, and energy policy.

November 4, 2013. [*Category:* Water Quality]

Groundwater Ages and Mixing in the Piceance Basin Natural Gas Province, Colorado.

- McMahon, Peter B.; Thomas, Judith C.; Hunt, Andrew G.
- In: *Environmental Science & Technology*, Vol. 47, Issue 23, pages 13250-13257.
- http://pubs.acs.org/doi/abs/10.1021/es402473c

Abstract: Reliably identifying the effects of energy development on groundwater quality can be difficult because baseline assessments of water quality completed before the onset of energy development are rare and because interactions between hydrocarbon reservoirs and aquifers can be complex, involving both natural and human processes. Groundwater age and mixing data can strengthen interpretations of monitoring data from those areas by providing better understanding of the groundwater flow systems. Chemical, isotopic, and age tracers were used to characterize groundwater ages and mixing with deeper saline water in three areas of the Piceance Basin natural gas province. The data revealed a complex array of groundwater ages (<10 to >50,000 years) and mixing patterns in the basin that helped explain concentrations and sources of methane in groundwater. Age and mixing data also can strengthen the design of monitoring programs by providing information on time scales at which water quality changes in aquifers might be expected to occur. This information could be used to establish maximum allowable distances of monitoring wells from energy development activity and the appropriate duration of monitoring.

November 2, 2013. [*Category:* Ecology]

Modeling and prediction of natural gas fracking pad landscapes in the Marcellus Shale region, USA.

- Meng, Qingmin.
- In: *Landscape and Urban Planning*, Vol. 121, January 2014, pages 109-116.
- http://www.sciencedirect.com/science/article/pii/S0169204613001849

Abstract: Natural gas fracking pad sites, as a type of industrial landscape, have been blooming up in Marcellus Shale region especially within the State of Pennsylvania in the last few years. However, no study has explored the driving landscape and environmental variables of fracking pad sites, and how gas fracking pads as a specific landscape spread out in the Marcellus Shale region. Using the Washington County, Pennsylvania, USA as the study area, this paper proposes a novel GIS landscape modeling approach to model the relationships between landscape variables and natural gas fracking pad sites. The impacts of significant landscape variables on natural gas fracking pad sites are assessed. Statistic diagnostics of spatial logistic regression modeling find significant landscape variables of elevation, slope, and land use land cover. Higher elevation will result in higher probability to be fracking pad sites, while deeper slopes will result in a lower probability to be fracking pad sites. Natural gas fracking pad sites do not randomly intrude the initial landscapes, while land use land cover experiences different invasive risks of natural gas fracking, and in the order of open water, developed land, barren land, forest land, shrub land, grassland, agriculture land, and wetland, the probability of being intruded by natural gas fracking sites increases at 3.76%. This landscape model finally is used to predict natural gas fracking pad sites. The predicted spatial distribution provides significant insight for landscape and natural resources regulation, land use administration, transportation and urban planning, and ecosystem and environment conservations.

November 1, 2013. [*Category:* Regulation]

Disclosure of hydraulic fracturing fluid chemical additives: analysis of regulations.

- Maule, Alexis L.; Makey, Colleen M.; Benson, Eugene B.; Burrows, Isaac J.; Scammell, Madeleine K.

- In: *New Solutions: A Journal of Environmental and Occupational Health Policy: NS,* Vol. 23, Issue 1, pages 167-187.
- http://baywood.metapress.com/openurl.asp?genre=article&id=doi:10.2190/NS.23.1.j

Abstract: Hydraulic fracturing is used to extract natural gas from shale formations. The process involves injecting into the ground fracturing fluids that contain thousands of gallons of chemical additives. Companies are not mandated by federal regulations to disclose the identities or quantities of chemicals used during hydraulic fracturing operations on private or public lands. States have begun to regulate hydraulic fracturing fluids by mandating chemical disclosure. These laws have shortcomings including nondisclosure of proprietary or "trade secret" mixtures, insufficient penalties for reporting inaccurate or incomplete information, and timelines that allow for after-the-fact reporting. These limitations leave lawmakers, regulators, public safety officers, and the public uninformed and ill-prepared to anticipate and respond to possible environmental and human health hazards associated with hydraulic fracturing fluids. We explore hydraulic fracturing exemptions from federal regulations, as well as current and future efforts to mandate chemical disclosure at the federal and state level.

November 1, 2013. [*Category:* Water Quality]

The Utica Shale and gas play in southern Quebec: Geological and hydrogeological syntheses and methodological approaches to groundwater risk evaluation.

- Lavoie, D.; Rivard, C.; Lefebvre, R.; Séjourné, S.; Thériault, R.; Duchesne, M. J.; Ahad, J. M. E.; Wang, B.; Benoit, N.; Lamontagne, C.

- In: *International Journal of Coal Geology*, Vol. 126, June 2014, pages 77-91.
- http://www.sciencedirect.com/science/article/pii/S0166516213002437

Abstract: The risk of groundwater contamination from shale gas exploration and development is a major societal concern, especially in populated areas where groundwater is an essential source of drinking water and for agricultural or industrial use. Since groundwater decontamination is difficult, or nearly impossible, it is essential to evaluate exploration and production conditions that would prevent or at least minimize risks of groundwater contamination. The current consensus in recent literature is that these risks are primarily related to engineering issues, including casing integrity and surface activities, such as truck traffic (equipment and fluid haulage), waste management (mainly drill cuttings), and water storage and treatment when hydraulic fracturing is utilized. Concerns have also been raised with respect to groundwater contamination that could result from potential fracture or fault interconnections between the shale unit and surficial aquifers, which would allow fracturing fluids and methane to reach the surface away from the wellbore. Despite the fact that groundwater resources are relatively well characterized in some regions, there is currently no recognized method to evaluate the vulnerability or risks to aquifers resulting from hydrocarbon industry operations carried out at great depths. This paper focuses on the Utica Shale of the St. Lawrence Platform (Quebec), where an environmental study aiming to evaluate potential risks for aquifers related to shale gas development has been initiated. To provide the context of these research efforts, this paper describes the regional tectono-stratigraphic evolution and current stress regime of the Cambrian–Ordovician St. Lawrence Platform, as well as the Utica Shale internal stratigraphy, mineralogy and thermal maturation. Then, the hydrogeological context of the St. Lawrence Platform is discussed. Finally, the methodology for this environmental study, based on geological, geophysical, geomechanical, hydrogeological and geochemical data, is presented.

November, 2013. [*Category:* General (Comment / Review)]

Obfuscation does not provide comfort: response to the article by Fryzek et al on hydraulic fracturing and childhood cancer.

- Goldstein, Bernard D.; Malone, Samantha.
- In: *Journal of Occupational and Environmental Medicine / American College of Occupational and Environmental Medicine*, Vol. 55, Issue 11, pages 1376-1378.
- http://www.ncbi.nlm.nih.gov/pubmed/24202245

METHODS: This study was a cross-sectional study of laboratory workers, using questionnaires and stool sample polymerase chain reaction (PCR) testing to look for evidence of Helicobacter infection in workers and laboratory mice from the same facility. The study took place in a previously described university animal research laboratory. All nonpregnant full-time day-shift employees …

October 31, 2013. [*Category:* Waste / Fluids]

Microbial community changes in hydraulic fracturing fluids and produced water from shale gas extraction.

- Murali Mohan, Arvind; Hartsock, Angela; Bibby, Kyle J.; Hammack, Richard W.; Vidic, Radisav D.; Gregory, Kelvin B.
- In: *Environmental Science & Technology*, Vol. 47, Issue 22, pages 13141-13150.
- http://www.ncbi.nlm.nih.gov/pubmed/24088205

Abstract: Microbial communities associated with produced water from hydraulic fracturing are not well understood, and their deleterious activity can lead to significant increases in production costs and adverse environmental impacts. In this study, we compared the microbial ecology in prefracturing fluids (fracturing source water and fracturing fluid) and produced water at multiple time points from a natural gas well in southwestern Pennsylvania using 16S rRNA gene-based clone libraries, pyrosequencing, and quantitative PCR. The majority of the bacterial community in prefracturing fluids constituted aerobic species affiliated with the class Alphaproteobacteria. However, their relative abundance decreased in produced water with an increase in halotolerant, anaerobic/facultative anaerobic species affiliated with the classes Clostridia, Bacilli, Gammaproteobacteria, Epsilonproteobacteria, Bacteroidia, and Fusobacteria. Produced water collected at the last time point (day 187) consisted almost entirely of sequences similar to Clostridia and showed a decrease in bacterial abundance by 3 orders of magnitude compared to the prefracturing fluids and produced water samples from earlier time points. Geochemical analysis showed that produced water contained higher concentrations of salts and total radioactivity compared to prefracturing fluids. This study provides evidence of long-term subsurface selection of the microbial community introduced through hydraulic fracturing, which may include significant implications for disinfection as well as reuse of produced water in future fracturing operations.

October 25, 2013. [*Category:* General (Comment / Review)]

Shale and tight gas in Poland—legal and environmental issues.

- Uliasz-Misiak, Barbara; Przybycin, Andrzej; Winid, Bogumila.
- In: *Energy Policy*, Vol. 65, February 2014, pages 68-77.
- http://www.sciencedirect.com/science/article/pii/S0301421513010483

Abstract: Exploitation of unconventional gas is limited by a number of economic, legal, environmental and social factors. When it comes to Poland, legal and environmental factors are of special importance, as they might significantly impact the exploitation of both tight gas and shale gas. Exploitation of unconventional gas deposits, because of the technology needed for opening of these deposits, has relatively great impact on the balance sheet and the quality of water. Polish water resources are limited and depend on time and local circumstances. Therefore, obtaining adequate amounts of water needed to hydraulic fracturing of unconventional gas reservoirs may cause some problems. Another problem is return water management. Injection of contaminated water into the rockmass on a large scale seems to be impossible in Poland. Water discharge to surface waters, which seems to be the most probable solution, would result in deterioration of the purity of Polish rivers. Around 32% of Poland is covered by different forms of protection, which might include limitations in exploitation of hydrocarbon deposits (depending on the type of area). Exploration, documentation and exploitation of unconventional gas in Poland is regulated mainly by the laws and regulations regulating geological and mining activities, environmental protection and waste management.

October 22, 2013. [*Category:* General (Comment / Review)]

Wake-up Call for China to Re-Evaluate Its Shale-Gas Ambition.

- Wang, Changjian; Wang, Fei; Li, Lianrong; Zhang, Xinlin.
- In: *Environmental Science & Technology*, Vol. 47, Issue 21, pages 11920-11921.
- http://pubs.acs.org/doi/abs/10.1021/es403642u

Extract: Climate change and increasing reliance on energy imports justify the development of unconventional energy around the world, while the only actual case of shale-gas mining happens in the United States. The contaminated drinking water close to the exploitation spot serves as a wake-up call for China to re-evaluate its shale gas ambition.

Fast economic growth devours all kinds of natural resources and brings about serious environmental devastation in China. Stuck in the dilemma for a long time, China has been trying desperately to strike a balance between booming economy and degrading environment. The Chinese government believes that shale-gas, a type of substitute energy, might help reduce coal consumption and control the release of $PM_{2.5}$ into the air. The Chinese government granted 13 provinces the rights to mine shale-gas and has made an ambitious but unachievable plan to produce 6.5 billion m^3 by 2015, 60–100 billion m^3 by 2020, amounting to 10% of the national gross energy output.

October 21, 2013. [*Category:* Health]

Hydraulic fracturing: a new public health problem 138 years in the making?

- Mackie, P.; Johnman, C.; Sim, F.
- In: *Public Health*, Vol. 127, Issue 10, pages 887-888.
- http://www.publichealthjrnl.com/article/S0033-3506%2813%2900302-8/fulltext

Extract, Paragraphs 1, 2 & 5:

In 1875, a well drilled for the purposes of geological research was the first recorded UK well to discover shale gas. Sunk near Battle in East Sussex, the first well reached a depth of over 1000 feet before excavations were suspended. A second well, which was sunk nearby, reached over 1900 feet before an explosion at the base of the shaft brought an end to drilling.

Roll forward to the summer of 2013 when the quiet village of Balcombe in West Sussex became the frontline in the battle over hydraulic fracturing, the technology developed to extract what is described as ‘unconventional gas’. Better known by most people as ‘fracking’, the extraction of natural gas trapped within shale and other geological formations is a controversial technology. To some, it is an efficient method for extracting a previously untapped source of plentiful fuel that can help address our ever growing demand for cheap energy. For others it is an environmental disaster in the making; not only costly in the use of resources, but also able to release potential carcinogens, pollute groundwater sources, even cause earthquakes.

In this issue of *Public Health* we are pleased to publish a review paper which considers the health impacts of hydraulic fracture on the basis of current US evidence. In what can be described as a ‘work in progress’, the review concludes that there is an absence of evidence on health impacts, but reminds us all that this is not to be interpreted as evidence for an absence of impacts.

October 17, 2013. [*Category:* Water Quality]

The RealGas and RealGasH2O options of the TOUGH+ code for the simulation of coupled fluid and heat flow in tight/shale gas systems.

- Moridis, George J.; Freeman, Craig M.
- In: *Computers & Geosciences*, Vol. 65, April 2014, pages 56-71.
- http://www.sciencedirect.com/science/article/pii/S0098300413002501

Abstract: We developed two new EOS additions to the TOUGH+ family of codes, the RealGasH2O and RealGas. The RealGasH2O EOS option describes the non-isothermal two-phase flow of water and a real gas mixture in gas reservoirs, with a particular focus in ultra-tight (such as tight-sand and shale gas) reservoirs. The gas mixture is treated as either a single-pseudo-component having a fixed composition, or as a multicomponent system composed of up to 9 individual real gases. The RealGas option has the same general capabilities, but does not include water, thus describing a single-phase, dry-gas system. In addition to the standard capabilities of all members of the TOUGH+ family of codes (fully-implicit, compositional simulators using both structured and unstructured grids), the capabilities of the two codes include coupled flow and thermal effects in porous and/or fractured media, real gas behavior, inertial (Klinkenberg) effects, full micro-flow treatment, Darcy and non-Darcy flow through the matrix and fractures of fractured media, single- and multi-component gas sorption onto the grains of the porous media following several isotherm options, discrete and fracture representation, complex matrix–fracture relationships, and porosity–permeability dependence on pressure changes. The two options allow the study of flow and transport of fluids and heat over a wide range of time frames and spatial scales not only in gas reservoirs, but also in problems of geologic storage of greenhouse gas mixtures, and of geothermal reservoirs with multi-component condensable (H2O and CH4) and non-condensable gas mixtures. The codes are verified against available analytical and semi-analytical solutions. Their capabilities are demonstrated in a series of problems of increasing complexity, ranging from isothermal flow in simpler 1D and 2D conventional gas reservoirs, to non-isothermal gas flow in 3D fractured shale gas reservoirs involving 4 types of fractures, micro-flow, non-Darcy flow and gas composition changes during production.

October 11, 2013. [*Categories:* Air Quality, Health]

An Exploratory Study of Air Quality near Natural Gas Operations.

- Colborn, Theo; Schultz, Kim; Herrick, Lucille; Kwiatkowski, Carol.
- In: *Human and Ecological Risk Assessment: An International Journal*, Vol. 20, Issue 1, pages 86-105.
- http://www.tandfonline.com/doi/abs/10.1080/10807039.2012.749447

Abstract: This exploratory study was designed to assess air quality in a rural western Colorado area where residences and gas wells co-exist. Sampling was conducted before, during, and after drilling and hydraulic fracturing of a new natural gas well pad. Weekly air sampling for 1 year revealed that the number of non-methane hydrocarbons (NMHCs) and their concentrations were highest during the initial drilling phase and did not increase during hydraulic fracturing in this closed-loop system. Methylene chloride, a toxic solvent not reported in products used in drilling or hydraulic fracturing, was detected 73% of the time; several times in high concentrations. A literature search of the health effects of the NMHCs revealed that many had multiple health effects, including 30 that affect the endocrine system, which is susceptible to chemical impacts at very low concentrations, far less than government safety standards. Selected polycyclic aromatic hydrocarbons (PAHs) were at concentrations greater than those at which prenatally exposed children in urban studies had lower developmental and IQ scores. The human and environmental health impacts of the NMHCs, which are ozone precursors, should be examined further given that the natural gas industry is now operating in close proximity to human residences and public lands.

October 9, 2013. [*Category:* Health]

The implications of unconventional drilling for natural gas: a global public health concern.

- Finkel, M.L.; Hays, J.
- In: *Public Health*, Vol. 127, Issue 10, pages 889-893.
- http://www.sciencedirect.com/science/article/pii/S0033350613002412

Abstract: Unconventional drilling for natural gas by means of high volume horizontal hydraulic fracturing (fracking) is an important global public health issue. Given that no sound epidemiologic study has been done to assess the extent of exposure-related adverse health effects among populations living in areas where natural gas extraction is going on, it is imperative that research be conducted to quantify the potential risks to the environment and to human health not just in the short-term, but over a longer time period since many diseases (i.e., cancers) appear years after exposure. It should not be concluded that an absence of data implies that no harm is being done.

October 8, 2013. [*Category:* Climate]

Anthropogenic emissions of methane in the United States.

- Miller, Scot M.; Wofsy, Steven C.; Michalak, Anna M.; Kort, Eric A.; Andrews, Arlyn E.; Biraud, Sebastien C.; Dlugokencky, Edward J.; Eluszkiewicz, Janusz; Fischer, Marc L.; Janssens-Maenhout, Greet; Miller, Ben R.; Miller, John B.; Montzka, Stephen A.; Nehrkorn, Thomas; Sweeney, Colm.

- In: *Proceedings of the National Academy of Sciences*, Vol. 110, Issue 50, pages 20018-20022.
- http://www.pnas.org/content/110/50/20018

Abstract: This study quantitatively estimates the spatial distribution of anthropogenic methane sources in the United States by combining comprehensive atmospheric methane observations, extensive spatial datasets, and a high-resolution atmospheric transport model. Results show that current inventories from the US Environmental Protection Agency (EPA) and the Emissions Database for Global Atmospheric Research underestimate methane emissions nationally by a factor of ∼1.5 and ∼1.7, respectively. Our study indicates that emissions due to ruminants and manure are up to twice the magnitude of existing inventories. In addition, the discrepancy in methane source estimates is particularly pronounced in the south-central United States, where we find total emissions are ∼2.7 times greater than in most inventories and account for 24 ± 3% of national emissions. The spatial patterns of our emission fluxes and observed methane–propane correlations indicate that fossil fuel extraction and refining are major contributors (45 ± 13%) in the south-central United States. This result suggests that regional methane emissions due to fossil fuel extraction and processing could be 4.9 ± 2.6 times larger than in EDGAR, the most comprehensive global methane inventory. These results cast doubt on the US EPA's recent decision to downscale its estimate of national natural gas emissions by 25–30%. Overall, we conclude that methane emissions associated with both the animal husbandry and fossil fuel industries have larger greenhouse gas impacts than indicated by existing inventories.

October 5, 2013. [*Category:* Waste / Fluids]

Biodegradation in Waters from Hydraulic Fracturing: Chemistry, Microbiology, and Engineering.

- Strong, Lisa C.; Gould, Trevor; Kasinkas, Lisa; Sadowsky, Michael J.; Aksan, Alptekin; Wackett, Lawrence P.
- In: *Journal of Environmental Engineering*, Vol. 140, Issue 5, page B4013001.
- http://ascelibrary.org/doi/10.1061/%28ASCE%29EE.1943-7870.0000792

Abstract: Hydraulic fracturing is a method of oil and gas extraction from shale in which substantial volumes of water return to the surface containing chemicals and microorganisms. This paper begins to address the microbial composition and aqueous chemistry and the potential for intrinsic and enhanced bioremediation of these waters. The waters from a gas and oil shale in the Marcellus and Bakken regions, respectively, were analyzed for inorganic elements, organic chemicals, microbial taxonomic composition, and biodegradative capabilities. The waters were highly saline, reaching NaCl concentrations up to 3.5 N, but no significant levels of radioactive elements were detected. More than 1,000 organic compounds were separated and identified by comprehensive two-dimensional gas chromatography time-of-flight mass spectrometry. The major classes of organic compounds, in order of decreasing abundance, were aliphatics, cycloaliphatics, single-ring aromatics, and polycyclic aromatic compounds. The bacterial genera found natively in the waters were identified by sequencing the 16S rRNA genes within the extracted DNA. The major genera identified included strains known to thrive under saline conditions (*Halanaerobium, Marinobacter, Oceanimonas, Streptohalobacillus*) and degrade petroleum hydrocarbons (*Thauera, Pseudomonas, Marinobacterium, Williamsia, Colwellia*). Microbial populations were extracted from the Bakken shale waters, encapsulated within silica gels, and then reintroduced into their waters of origin. Both intrinsic biodegradation from the free native microorganisms and enhanced biodegradation with the addition of encapsulated bacteria were observed. In total, this paper begins to better define the properties of waters derived from hydraulic fracturing and suggests a potential for the application of bioremediation to remove organic contaminants.

October 5, 2013. [*Category:* General (Comment / Review)]

Natural gas from shale formation – The evolution, evidences and challenges of shale gas revolution in United States.

- Wang, Qiang; Chen, Xi; Jha, Awadhesh N.; Rogers, Howard.
- In: *Renewable and Sustainable Energy Reviews*, Vol. 30, February 2014, pages 1-28.
- http://www.sciencedirect.com/science/article/pii/S1364032113006059

Abstract: Extraction of natural gas from shale rock in the United States (US) is one of the landmark events in the 21st century. The combination of horizontal drilling and hydraulic fracturing can extract huge quantities of natural gas from impermeable shale formations, which were previously thought to be either impossible or uneconomic to produce. This review offers a comprehensive insight into US shale gas opportunities, appraising the evolution, evidence and the challenges of shale gas production in the US. The history of US shale gas in this article is divided into three periods and based on the change of oil price (i.e., the period before the 1970s oil crisis, the period from 1970s to 2000, and the period since 2000), the US has moved from being one of the world's biggest importers of gas to being self-sufficient in less than a decade, with the shale gas production increasing 12-fold (from 2000 to 2010). The US domestic natural gas price hit a 10-year low in 2012. The US domestic natural gas price in the first half of 2012 was about $2 per million British Thermal Unit (BTU), compared with Brent crude, the world benchmark price for oil, now about $ 80–100/barrel, or $14–17 per million BTU. Partly due to an increase in gas-fired power generation in response to low gas prices, US carbon emissions from fossil-fuel combustion fell by 430 million ton CO2 – more than any other country – between 2006 and 2011. Shale gas also stimulated economic growth, creating 600,000 new jobs in the US by 2010. However, the US shale gas revolution would be curbed, if the environmental risks posed by hydraulic fracturing are not managed effectively. The hydraulic fracturing is water intensive, and can cause pollution in the marine environment, with implications for long-term environmental sustainability in several ways. Also, large amounts of methane, a powerful greenhouse gas, can be emitted during the shale gas exploration and production. Hydraulic fracturing also may induce earthquakes. These environmental risks need to be managed by good practices which is not being applied by all the producers in all the locations. Enforcing stronger regulations are necessary to minimize risk to the environment and on human health. Robust regulatory oversight can however increase the cost of extraction, but stringent regulations can foster an historic opportunity to provide cheaper and cleaner gas to meet the consumer demand, as well as to usher in the future growth of the industry.

October 2, 2013. [*Categories:* Waste / Fluids, Water Quality]

Impacts of Shale Gas Wastewater Disposal on Water Quality in Western Pennsylvania.

- Warner, Nathaniel R.; Christie, Cidney A.; Jackson, Robert B.; Vengosh, Avner.
- In: *Environmental Science & Technology*, Vol. 57, Issue 20, pages 11849-11857.
- http://pubs.acs.org/doi/abs/10.1021/es402165b

Abstract: The safe disposal of liquid wastes associated with oil and gas production in the United States is a major challenge given their large volumes and typically high levels of contaminants. In Pennsylvania, oil and gas wastewater is sometimes treated at brine treatment facilities and discharged to local streams. This study examined the water quality and isotopic compositions of discharged effluents, surface waters, and stream sediments associated with a treatment facility site in western Pennsylvania. The elevated levels of chloride and bromide, combined with the strontium, radium, oxygen, and hydrogen isotopic compositions of the effluents reflect the composition of Marcellus Shale produced waters. The discharge of the effluent from the treatment facility increased downstream concentrations of chloride and bromide above background levels. Barium and radium were substantially (>90%) reduced in the treated effluents compared to concentrations in Marcellus Shale produced waters. Nonetheless, ^{226}Ra levels in stream sediments (544-8759 Bq/kg) at the point of discharge were ~200 times greater than upstream and background sediments (22-44 Bq/kg) and above radioactive waste disposal threshold regulations, posing potential environmental risks of radium bioaccumulation in localized areas of shale gas wastewater disposal.

October 1, 2013. [*Category:* Health]

Shale Gas Extraction in North Carolina: Research Recommendations and Public Health Implications.

- Down, Adrian; Armes, Martin; Jackson, Robert B.
- In: *Environmental Health Perspectives*, Vol. 121, Issue 10, pages A292-A293.
- http://www.ncbi.nlm.nih.gov/pmc/articles/PMC3801474/

Extract: North Carolina has no history of large-scale commercial oil and gas extraction, and the state's legislative framework for regulating drilling was, until recently, based on laws passed in the 1940s. However, areas of the state are likely to undergo horizontal drilling and hydraulic fracturing for natural gas and oil in the near future. North Carolina thus has a unique opportunity to produce a legislative framework that *a*) incorporates experiences from other states, *b*) includes state-of-the-art technologies and best practices, and *c*) protects the health of North Carolina's citizens and ecosystems.

Knowledge of the health risks associated with hydraulic fracturing is sparse. Some of the chemicals that can be used in the hydraulic fracturing process are toxic (Bamberger and Oswald 2012; Colborn et al. 2011). However, the concentrations of these chemicals used at a given well site are not disclosed in most states; thus, evaluating the risk of exposure and associated health impacts is difficult. Residents living < 1 km from hydraulically fractured wells are potentially at greater risk for health effects from natural gas development, which in some cases may include exposure to trimethylbenzenes, xylenes, and aliphatic hydrocarbons in air (McKenzie et al. 2012). These residents can also, but do not always, have higher concentrations of dissolved methane and other gases in their drinking water (Jackson et al. 2013; Osborn et al. 2011; Warner et al. 2013).

October 1, 2013. [*Category:* Water Quality]

Hydraulic fracturing in unconventional gas reservoirs: risks in the geological system part 1.

- Lange, Torsten; Sauter, Martin; Heitfeld, Michael; Schetelig, Kurt; Brosig, Karolin; Jahnke, Wiebke; Kissinger, Alexander; Helmig, Rainer; Ebigbo, Anozie; Class, Holger.
- In: *Environmental Earth Sciences*, Vol. 70, Issue 8, pages 3839-3853.
- http://link.springer.com/article/10.1007/s12665-013-2803-3

Abstract: Hydraulic fracturing of unconventional gas reservoirs rapidly developed especially in the USA to an industrial scale during the last decade. Potential adverse effects such as the deterioration of the quality of exploitable groundwater resources, areal footprints, or even the climate impact were not assessed. Because hydraulic fracturing has already been practised for a long time also in conventional reservoirs, the expansion into the unconventional domain was considered to be just a minor but not a technological step, with potential environmental risks. Thus, safety and environmental protection regulations were not critically developed or refined. Consequently, virtually no baseline conditions were documented before on-site applications as proof of evidence for the net effect of environmental impacts. Not only growing concerns in the general public, but also in the administrations in Germany promoted the commissioning of several expert opinions, evaluating safety, potential risks, and footprints of the technology in focus. The first two publications of the workgroup “Risks in the Geological System” of the independent “Information and Dialogue process on hydraulic fracturing” (commissioned by ExxonMobil Production Deutschland GmbH) comprises the strategy and approaches to identify and assess the potential risks of groundwater contamination of the exploitable groundwater system in the context of hydraulic fracturing operations in the Münsterland cretaceous basin and the Lower Saxony Basin, Germany. While being specific with respect to local geology and the estimation of effective hydraulic parameters, generalized concepts for the contamination risk assessment were developed. The work focuses on barrier effectiveness of different units of the overburden with respect to the migration of fracking fluids and methane, and considers fault zones as potential fluid pathway structures.

October, 2013. [*Category:* Economics]

A Preliminary Energy Return on Investment Analysis of Natural Gas from the Marcellus Shale.

- Aucott, Michael L.; Melillo, Jacqueline M.
- In: *Journal of Industrial Ecology*, Vol. 17, Issue 5, pages 668-679.

Abstract: An analysis of the energy return on investment (EROI) of natural gas obtained from horizontal, hydraulically fractured wells in the Marcellus Shale was conducted using net external energy ratio methodology and available data and estimates of energy inputs and outputs. Used as sources of input data were estimates of carbon dioxide and nitrogen oxides emitted from the gas extraction processes, as well as fuel-use reports from industry and other sources. Estimates of quantities of materials used and the associated embodied energy as well as other energy-using steps were also developed from available data. Total input energy was compared with the energy expected to be made available to end users of the natural gas produced from a typical Marcellus well. The analysis indicates that the EROI of a typical well is likely between 64:1 and 112:1, with a mean of approximately 85:1. This range assumes an estimated ultimate recovery (EUR) of 3.0 billion cubic feet (Bcf) per well. EROI values are directly proportionate to EUR values. If the EUR is greater or lesser than 3 Bcf, the EROI would be proportionately higher or lower. EROI is also sensitive to the energy used or embedded in gathering and transmission pipelines and associated infrastructure and energy used for their construction, energy consumed in well drilling and well completion, and energy used for wastewater treatment.

September 27, 2013. [*Category:* Economics]

Unconventional reservoir potential of the upper Permian Zechstein Group: a slope to basin sequence stratigraphic and sedimentological evaluation of carbonates and organic-rich mudrocks, Northern Germany.

- Hammes, Ursula; Krause, Michael; Mutti, Maria.
- In: *Environmental Earth Sciences*, Vol. 70, Issue 8, page 3797-3816.
- http://link.springer.com/article/10.1007/s12665-013-2724-1

Abstract: The Late Permian Zechstein Group in northeastern Germany is characterized by shelf and slope carbonates that rimmed a basin extending from eastern England through the Netherlands and Germany to Poland. Conventional reservoirs are found in grainstones rimming islands created by pre-existing paleohighs and platform-rimming shoals that compose steep margins in the north and ramp deposits in the southern part. The slope and basin deposits are characterized by debris flows and organic-rich mudstones. Lagoonal and basinal evaporites formed the seal for these carbonate and underlying sandstone reservoirs. The objective of this investigation is to evaluate potential unconventional reservoirs in organic-rich, fine-grained and/or tight mudrocks in slope and basin as well as platform carbonates occurring in this stratigraphic interval. Therefore, a comprehensive study was conducted that included sedimentology, sequence stratigraphy, petrography, and geochemistry. Sequence stratigraphic correlations from shelf to basin are crucial in establishing a framework that allows correlation of potential productive facies in fine-grained, organic-rich basinal siliceous and calcareous mudstones or interfingering tight carbonates and siltstones, ranging from the lagoon, to slope to basin, which might be candidates for forming an unconventional reservoir. Most organic-rich shales worldwide are associated with eustatic transgressions. The basal Zechstein cycles, Z1 and Z2, contain organic-rich siliceous and calcareous mudstones and carbonates that form major transgressive deposits in the basin. Maturities range from over–mature (gas) in the basin to oil-generation on the slope with variable TOC contents. This sequence stratigraphic and sedimentologic evaluation of the transgressive facies in the Z1 and Z2 assesses the potential for shale-gas/oil and hybrid unconventional plays. Potential unconventional reservoirs might be explored in laminated organic-rich mudstones within the oil window along the northern and southern slopes of the basin. Although the Zechstein Z1 and Z2 cycles might have limited shale-gas potential because of low thickness and deep burial depth to be economic at this point, unconventional reservoir opportunities that include hybrid and shale-oil potential are possible in the study area.

September 25, 2013. [*Categories:* Air Quality, Health]

Evaluation of impact of shale gas operations in the Barnett Shale region on volatile organic compounds in air and potential human health risks.

- Bunch, A. G.; Perry, C. S.; Abraham, L.; Wikoff, D. S.; Tachovsky, J. A.; Hixon, J. G.; Urban, J. D.; Harris, M. A.; Haws, L. C.
- In: *Science of the Total Environment*, Vol. 468-469, pages 832-842.
- http://www.sciencedirect.com/science/article/pii/S0048969713010073

Abstract: Shale gas exploration and production (E&P) has experienced substantial growth across the U.S. over the last decade. The Barnett Shale, in north-central Texas, contains one of the largest, most active onshore gas fields in North America, stretching across 5000 square miles and having an estimated 15,870 producing wells as of 2011. Given that these operations may occur in relatively close proximity to populated/urban areas, concerns have been expressed about potential impacts on human health. In response to these concerns, the Texas Commission on Environmental Quality established an extensive air monitoring network in the region. This network provides a unique data set for evaluating the potential impact of shale gas E&P activities on human health. As such, the objective of this study was to evaluate community-wide exposures to volatile organic compounds (VOCs) in the Barnett Shale region. In this current study, more than 4.6 million data points (representing data from seven monitors at six locations, up to 105 VOCs/monitor, and periods of record dating back to 2000) were evaluated. Measured air concentrations were compared to federal and state health-based air comparison values (HBACVs) to assess potential acute and chronic health effects. None of the measured VOC concentrations exceeded applicable acute HBACVs. Only one chemical (1,2-dibromoethane) exceeded its applicable chronic HBACV, but it is not known to be associated with shale gas production activities. Annual average concentrations were also evaluated in deterministic and probabilistic risk assessments and all risks/hazards were below levels of concern. The analyses demonstrate that, for the extensive number of VOCs measured, shale gas production activities have not resulted in community-wide exposures to those VOCs at levels that would pose a health concern. With the high density of active wells in this region, these findings may be useful for understanding potential health risks in other shale play regions.

September 23, 2013. [*Category:* Air Quality]

Volatile organic compound distributions during the NACHTT campaign at the Boulder Atmospheric Observatory: Influence of urban and natural gas sources.

- Swarthout, Robert F.; Russo, Rachel S.; Zhou, Yong; Hart, Andrew H.; Sive, Barkley C.
- In: *Journal of Geophysical Research: Atmospheres*, Vol. 118, Issue 18, 2013, pages 10,614-10,637.
- http://onlinelibrary.wiley.com/doi/10.1002/jgrd.50722/abstract

Abstract: A comprehensive suite of volatile organic compounds (VOCs) was measured at the semirural Boulder Atmospheric Observatory (BAO) in northeast Colorado during the Nitrogen, Aerosol Composition, and Halogens on a Tall Tower (NACHTT) campaign during the winter of 2011. A signature of elevated nonmethane hydrocarbon (NMHC) mixing ratios was observed throughout the campaign. The C_2-C_5 alkane mixing ratios were an order of magnitude greater than the regional background. Light alkane mixing ratios were similar to those at urban sites impacted by petrochemical industry emissions with ethane and propane reaching maximums of over 100 ppbv. The mean (± standard deviation) calculated total OH reactivity ($7.0 \pm 5.0\ s^{-1}$) was also similar to urban sites. Analysis of VOC wind direction dependence, emission ratios with tracer compounds, and vertical profiles up to 250 m implicated regional natural gas production activities as the source of the elevated VOCs to the northeast of BAO and urban combustion emissions as the major VOC source to the south of BAO. Elevated acetonitrile and dimethyl sulfide mixing ratios were also associated with natural gas emissions. Fluxes of natural gas associated NMHCs were determined to estimate regional emission rates which ranged from 40 ± 14 Gg yr^{-1} for propane to 0.03 ± 0.01 Gg yr^{-1} for n-nonane. These emissions have the potential to impact downwind air quality as natural gas associated NMHCs comprised ≈24% of the calculated OH reactivity. The measurements described here provide a baseline for determining the efficacy of future policies designed to control emissions from natural gas production activities.

September 17, 2013. [*Category:* General (Comment / Review)]

"Fracking democracy": Issue management and locus of policy decision-making in the Marcellus Shale gas drilling debate.

- Smith, Michael F.; Ferguson, Denise P.
- In: *Public Relations Review*, Vol. 39, Issue 4, pages 377-386.
- http://www.sciencedirect.com/science/article/pii/S0363811113001161

Abstract: This study examined a two-year period in which natural gas development in the Marcellus Shale region of Pennsylvania expanded rapidly, as did public policy proposals meant to deal with the myriad legal, economic, and environmental issues that accompanied this growth. Focusing on the use of legitimacy strategies during the critical phase of the issue of hydraulic fracturing, the study examined how activists and energy industry advocates argued that different levels of government policy making – local, state, and federal – should be the locus of policy decisions. Both the "fractivists" and the energy industry sought to legitimize state-level legislators and regulators. Activists viewed federal-level intervention as legitimate leverage for their work in the state, while the energy industry saw federal regulators as redundant and restrictive. Finally, while both sides viewed local authorities as legitimate actors, the energy industry sought to limit their ability to act against the development of new wells.

September 7, 2013. [*Category:* Economics]

The shale gas potential of Tournaisian, Visean, and Namurian black shales in North Germany: baseline parameters in a geological context.

- Kerschke, Dorit I.; Schulz, Hans-Martin.
- In: *Environmental Earth Sciences*, Vol. 70, Issue 8, pages 3817-3837.
- http://link.springer.com/article/10.1007/s12665-013-2745-9

Abstract: Carboniferous black mudrocks with known petroleum potential occur throughout Northern Germany. However, despite numerous boreholes exploring for conventional hydrocarbons, the potential for shale gas resources remains uncertain. Therefore, an integrated investigation was conducted to elucidate the shale gas potential for three different Carboniferous facies incorporating baseline parameters from sedimentological and organic-geochemical analyses. Tournaisian–Namurian fine-grained rocks of the Culm-facies, with Type II + III kerogen were deposited in the basin center. TOC contents of up to 7% occur in the Lower Alum Shale (3.6% VRr) and up to 6% in the Upper Alum Shale (4.4% VRr). Bands of organic-rich black shales, reflecting sea-level variations controlled by global eustatic cycles, occur within the Tournaisian–Visean *"Kohlenkalk"*-facies north of the Rhenish Slate Mountains and in the Rügen island area. In both areas the organic matter is characterized by a kerogen Type II + III with TOC contents of up to 7% and maturities of up to 4.2 and 1.8% VRr, respectively. Black hemipelagites intercalated with coarser-grained silt- and sandstones occur in the Synorogenic Flysch Formation of the Namurian A along the southern basin margin. TOC contents vary from 0.5 to 2.0% with Type III kerogen dominated organic matter and maturities of up to 2.5% VRr. The baseline parameters presented in this paper indicate a shale gas potential for the sediments of the Culm-facies on the southern basin margin and of the *"Kohlenkalk"*-facies in the Rügen area.

September 4, 2013. [*Category:* Water Usage]

Life Cycle Water Consumption for Shale Gas and Conventional Natural Gas.

- Clark, Corrie E.; Horner, Robert M.; Harto, Christopher B.
- In: *Environmental Science & Technology*, Vol. 47, Issue 20, pages 11829-11836.
- http://pubs.acs.org/doi/abs/10.1021/es4013855

Abstract: Shale gas production represents a large potential source of natural gas for the nation. The scale and rapid growth in shale gas development underscore the need to better understand its environmental implications, including water consumption. This study estimates the water consumed over the life cycle of conventional and shale gas production, accounting for the different stages of production and for flowback water reuse (in the case of shale gas). This study finds that shale gas consumes more water over its life cycle (13-37 L/GJ) than conventional natural gas consumes (9.3-9.6 L/GJ). However, when used as a transportation fuel, shale gas consumes significantly less water than other transportation fuels. When used for electricity generation, the combustion of shale gas adds incrementally to the overall water consumption compared to conventional natural gas. The impact of fuel production, however, is small relative to that of power plant operations. The type of power plant where the natural gas is utilized is far more important than the source of the natural gas.

September 3, 2013. [*Category:* Waste / Fluids]

Desalination and Reuse of High-Salinity Shale Gas Produced Water: Drivers, Technologies, and Future Directions.

- Shaffer, Devin L.; Arias Chavez, Laura H.; Ben-Sasson, Moshe; Romero-Vargas Castrillón, Santiago; Yip, Ngai Yin; Elimelech, Menachem.

- In: *Environmental Science & Technology*, Vol. 47, Issue 17, pages 9569-9583.
- http://dx.doi.org/10.1021/es401966e

Abstract: In the rapidly developing shale gas industry, managing produced water is a major challenge for maintaining the profitability of shale gas extraction while protecting public health and the environment. We review the current state of practice for produced water management across the United States and discuss the interrelated regulatory, infrastructure, and economic drivers for produced water reuse. Within this framework, we examine the Marcellus shale play, a region in the eastern United States where produced water is currently reused without desalination. In the Marcellus region, and in other shale plays worldwide with similar constraints, contraction of current reuse opportunities within the shale gas industry and growing restrictions on produced water disposal will provide strong incentives for produced water desalination for reuse outside the industry. The most challenging scenarios for the selection of desalination for reuse over other management strategies will be those involving high-salinity produced water, which must be desalinated with thermal separation processes. We explore desalination technologies for treatment of high-salinity shale gas produced water, and we critically review mechanical vapor compression (MVC), membrane distillation (MD), and forward osmosis (FO) as the technologies best suited for desalination of high-salinity produced water for reuse outside the shale gas industry. The advantages and challenges of applying MVC, MD, and FO technologies to produced water desalination are discussed, and directions for future research and development are identified. We find that desalination for reuse of produced water is technically feasible and can be economically relevant. However, because produced water management is primarily an economic decision, expanding desalination for reuse is dependent on process and material improvements to reduce capital and operating costs.

August 29, 2013. [*Category:* Climate]

Estimating the Carbon Sequestration Capacity of Shale Formations Using Methane Production Rates.

- Tao, Zhiyuan; Clarens, Andres.
- In: *Environmental Science & Technology*, Vol. 47, Issue 19, pages 11318-11325.
- http://dx.doi.org/10.1021/es401221j

Abstract: Hydraulically fractured shale formations are being developed widely for oil and gas production. They could also represent an attractive repository for permanent geologic carbon sequestration. Shales have a low permeability, but they can adsorb an appreciable amount of CO2 on fracture surfaces. Here, a computational method is proposed for estimating the CO2 sequestration capacity of a fractured shale formation and it is applied to the Marcellus shale in the eastern United States. The model is based on historical and projected CH4 production along with published data and models for CH4/CO2 sorption equilibria and kinetics. The results suggest that the Marcellus shale alone could store between 10.4 and 18.4 Gt of CO2 between now and 2030, which represents more than 50% of total U.S. CO2 emissions from stationary sources over the same period. Other shale formations with comparable pressure/temperature conditions, such as Haynesville and Barnett, could provide significant additional storage capacity. The mass transfer kinetic results indicate that injection of CO2 would proceed several times faster than production of CH4. Additional considerations not included in this model could either reinforce (e.g., leveraging of existing extraction and monitoring infrastructure) or undermine (e.g., leakage or seismicity potential) this approach, but the sequestration capacity estimated here supports continued exploration into this pathway for producing carbon neutral energy.

August 29, 2013. [*Categories:* Waste / Fluids, Water Quality]

Discharges of produced waters from oil and gas extraction via wastewater treatment plants are sources of disinfection by-products to receiving streams.

- Hladik, Michelle L.; Focazio, Michael J.; Engle, Mark.
- In: *Science of the Total Environment*, Vol. 466-467, pages 1085-1093 (January 1, 2014).
- http://www.sciencedirect.com/science/article/pii/S0048969713009224

Abstract: Fluids co-produced with oil and gas production (produced waters) are often brines that contain elevated concentrations of bromide. Bromide is an important precursor of several toxic disinfection by-products (DBPs) and the treatment of produced water may lead to more brominated DBPs. To determine if wastewater treatment plants that accept produced waters discharge greater amounts of brominated DBPs, water samples were collected in Pennsylvania from four sites along a large river including an upstream site, a site below a publicly owned wastewater treatment plant (POTW) outfall (does not accept produced water), a site below an oil and gas commercial wastewater treatment plant (CWT) outfall, and downstream of the POTW and CWT. Of 29 DBPs analyzed, the site at the POTW outfall had the highest number detected (six) ranging in concentration from 0.01 to 0.09 μg L^{-1} with a similar mixture of DBPs that have been detected at POTW outfalls elsewhere in the United States. The DBP profile at the CWT outfall was much different, although only two DBPs, dibromochloronitromethane (DBCNM) and chloroform, were detected, DBCNM was found at relatively high concentrations (up to 8.5 μg L^{-1}). The water at the CWT outfall also had a mixture of inorganic and organic precursors including elevated concentrations of bromide (75 mg L^{-1}) and other organic DBP precursors (phenol at 15 μg L^{-1}). To corroborate these DBP results, samples were collected in Pennsylvania from additional POTW and CWT outfalls that accept produced waters. The additional CWT also had high concentrations of DBCNM (3.1 μg L^{-1}) while the POTWs that accept produced waters had elevated numbers (up to 15) and concentrations of DBPs, especially brominated and iodinated THMs (up to 12 μg L^{-1} total THM concentration). Therefore, produced water brines that have been disinfected are potential sources of DBPs along with DBP precursors to streams wherever these wastewaters are discharged.

August 27, 2013. [*Category:* Climate]

Methane emissions estimate from airborne measurements over a western United States natural gas field.

- Karion, Anna; Sweeney, Colm; Pétron, Gabrielle; Frost, Gregory; Michael Hardesty, R.; Kofler, Jonathan; Miller, Ben R.; Newberger, Tim; Wolter, Sonja; Banta, Robert; Brewer, Alan; Dlugokencky, Ed; Lang, Patricia; Montzka, Stephen A.; Schnell, Russell; Tans, Pieter; Trainer, Michael; Zamora, Robert; Conley, Stephen.
- In: *Geophysical Research Letters*, Vol. 40, Issue 16, pages 4393-4397.
- http://onlinelibrary.wiley.com/doi/10.1002/grl.50811/abstract

Abstract: Methane (CH4) emissions from natural gas production are not well quantified and have the potential to offset the climate benefits of natural gas over other fossil fuels. We use atmospheric measurements in a mass balance approach to estimate CH4 emissions of 55 ± 15 × 103 kg h−1 from a natural gas and oil production field in Uintah County, Utah, on 1 day: 3 February 2012. This emission rate corresponds to 6.2%–11.7% (1σ) of average hourly natural gas production in Uintah County in the month of February. This study demonstrates the mass balance technique as a valuable tool for estimating emissions from oil and gas production regions and illustrates the need for further atmospheric measurements to determine the representativeness of our single-day estimate and to better assess inventories of CH4 emissions.

August 25, 2013. [*Categories:* Economics, General (Comment/Review)]

An institutional theory of hydraulic fracturing policy.

- Holahan, Robert; Arnold, Gwen.
- In: *Ecological Economics*, Vol. 94, pages 127-134 (October, 2013).
- http://www.sciencedirect.com/science/article/pii/S0921800913002206

Abstract: The use of high-volume horizontal hydraulic fracturing (fracking) has increased substantially over the past five years in the United States. Use of this drilling technology to extract natural gas from hitherto impermeable shale is expected to increase even more in coming decades. Two institutions, integration contracts and well spacing requirements, evolved to mitigate the common-pool economic wastes associated with conventional oil and gas drilling. U.S. regulators have applied these institutions to fracking. However, shale plays differ geologically from conventional plays and are subject to different extractive technologies. We theorize that the point-source pollution characteristics of conventional drilling allowed integration contracts and well space requirements to minimize local negative environmental externalities as an unintended byproduct of minimizing common-pool economic wastes. The non-point source pollution characteristics of fracking, however, make these institutions insufficient to minimize negative environmental externalities associated with drilling in shale plays, because the economic waste problem is different. If policymakers understand the crucial differences between conventional oil and gas plays and shale plays and the drilling technologies applied to them, they should be better equipped to craft fracking regulatory policies that internalize problematic externalities.

August 23, 2013. [*Category:* Regulation]

Urban gas drilling and distance ordinances in the Texas Barnett Shale.

- Fry, Matthew.
- In: *Energy Policy*, Vol. 62, November 2013, pages 79-89.
- http://www.sciencedirect.com/science/article/pii/S0301421513007507

Abstract: Newly accessible shale deposits and other unconventional sources of natural gas have dramatically increased global gas reserves and are regarded as major future energy sources. Shale gas drilling began in Texas and is expanding throughout the U.S. and globally. In Texas and other regions, large population centers overlie these deposits. As a result, city residents increasingly come into contact with extraction activities. The proximity of drilling activities to residential areas raises a number of concerns, including noise, dust and emissions hazards, public safety, diminished quality of life, and effects on neighborhood aesthetics and property values. Cities in Texas address these concerns through setback ordinances that regulate the distance between gas wells and residences, schools, floodplains, etc. Although the state of Texas permits drilling 200 ft (61 m) from residences, many municipalities in the Dallas–Fort Worth Metroplex (DFW) have established longer setback distances. This paper analyzes the purpose and basis for setback distances among 26 municipalities in DFW. Findings show that there is no uniform setback distance, distances have increased over time, and, rather than technically-based, setbacks are political compromises. For policy makers confronted with urban shale gas drilling, deriving setback distances from advanced emissions monitoring could decrease setback distance ambiguity.

August 23, 2013. [*Category:* Economics]

The impact of the shale gas revolution on the U.S. and Japanese natural gas markets.

- Wakamatsu, Hiroki; Aruga, Kentaka.
- In: *Energy Policy*, Vol. 62, November 2013, pages 1002-1009.
- http://www.sciencedirect.com/science/article/pii/S0301421513007817

Abstract: We investigated whether the increase in the US shale gas production changed the structures of the US and Japanese natural gas markets using market data for the period 2002:5–2012:5. Our analysis consists of a structural break test and market integration analysis. The Bai and Perron structural break test detected a break point of natural gas prices and consumption in 2005 as well as other external shocks – Hurricane Katrina and the Lehman Shock – that are irrelevant to shale gas development. We eliminated the impact of these shocks by separating the data set using the breaks identified in our analysis. We found the breaks skewed the estimation; a market linkage existed between the US and Japanese markets in the original data set, while it did not in the separated data. The vector autoregressive (VAR) model also indicated a significant change before and after the break point; the US market had a one-side influence on the Japanese market before 2005, but the influence disappeared after 2005. Our results implied that the shale gas revolution, triggered by the increase in shale gas production in 2005, caused the change in the relationship between the US and Japanese natural gas markets.

August 23, 2013. [*Category:* Seismicity]

Two-year survey of earthquakes and injection/production wells in the Eagle Ford Shale, Texas, prior to the 20 October 2011 earthquake.

- Frohlich, Cliff; Brunt, Michael.
- In: *Earth and Planetary Science Letters*, Vol. 379, October 1, 2013, pages 56-63.
- http://www.sciencedirect.com/science/article/pii/S0012821X13004007

Abstract: Between November 2009 and September 2011 the EarthScope USArray program deployed ~25 temporary seismograph stations on a 70-km grid in south-central Texas between 27°N–31°N and 96°W–101°W. This area includes the Eagle Ford Shale. For decades this geographic region has produced gas and oil from other strata using conventional methods, but recent developments in hydrofracturing technology has allowed extensive development of natural gas resources from within the Eagle Ford. Our study surveys small-magnitude seismic events and evaluates their correlation with fluid extraction and injection in the Eagle Ford, identifying and locating 62 probable earthquakes, including 58 not reported by the U.S. Geological Survey. The 62 probable earthquakes occur singly or in clusters at 14 foci; of these foci, two were situated near wells injecting recently increased volumes of water; eight were situated near wells extracting recently increased volumes of oil and/or water; and four were not situated near wells reporting significant injection/extraction increases. Thus in this region, while the majority of small earthquakes may be triggered/induced by human activity, they are more often associated with fluid extraction than with injection. We also investigated the $_{MW}$4.8MW4.8 20 October 2011 Fashing earthquake—the largest historically reported earthquake in south-central Texas—that occurred two weeks after the removal of the temporary USArray stations. A field study indicated that the highest-intensity (MMI VI) region was about 10 km south of 2010–2011 foreshock activity, and that there were no high-volume injection wells within 20 km of the MMI V–VI region or the foreshocks. However, the 20 October 2011 earthquake did coincide with a significant increase in oil/water extraction volumes at wells within the MMI V–VI region, and this was also true for previous earthquakes felt at Fashing in 1973 and 1983. In contrast, our study found significant increases in injection prior to an m_{bLG}3.6 20 July 1991 earthquake near Falls City, Texas. Thus the Eagle Ford geographic region, with seismic activity associated both with extraction and injection, appears to be more complex than the Barnett Shale of northeast Texas, where a similar survey found possible correlations only with fluid injection.

August 13, 2013. [*Category:* General (Comment / Review)]

Fracking in the UK press: Threat dynamics in an unfolding debate.

- Jaspal, Rusi; Nerlich, Brigitte.
- In: *Public Understanding of Science (Bristol, England)*, Vol. 23, Issue 3, pages 348-363.
- http://www.academia.edu/2256599/Fracking_in_the_UK_Press_Threat_Dynamics_in_an_Unfolding_Debate

Abstract: Shale gas is a novel source of fossil fuel which is extracted by induced hydraulic fracturing, or "fracking". This article examines the socio-political dimension of fracking as manifested in the UK press at three key temporal points in the debate on the practice. Three newspaper corpora were analysed qualitatively using Thematic Analysis and Social Representations Theory. Three overarching themes are discussed: "April-May 2011: From Optimism to Scepticism"; "November 2011: (De-)Constructing and Re-Constructing Risk and Danger"; "April 2012: Consolidating Social Representations of Fracking". In this article, we examine the emergence of and inter-relations between competing social representations, discuss the dynamics of threat positioning and show how threat can be re-construed in order to serve particular socio-political ends in the debate on fracking.

August 19, 2013. [*Category:* Climate]

Measurements of methane emissions at natural gas production sites in the United States.

- Allen, David T.; Torres, Vincent M.; Thomas, James; Sullivan, David W.; Harrison, Matthew; Hendler, Al; Herndon, Scott C.; Kolb, Charles E.; Fraser, Matthew P.; Hill, A. Daniel; Lamb, Brian K.; Miskimins, Jennifer; Sawyer, Robert F.; Seinfeld, John H.
- In: *Proceedings of the National Academy of Sciences*, Vol. 10, Issue 44, pages 17768-17773.
- http://www.pnas.org/content/early/2013/09/10/1304880110

Abstract: Engineering estimates of methane emissions from natural gas production have led to varied projections of national emissions. This work reports direct measurements of methane emissions at 190 onshore natural gas sites in the United States (150 production sites, 27 well completion flowbacks, 9 well unloadings, and 4 workovers). For well completion flowbacks, which clear fractured wells of liquid to allow gas production, methane emissions ranged from 0.01 Mg to 17 Mg (mean = 1.7 Mg; 95% confidence bounds of 0.67–3.3 Mg), compared with an average of 81 Mg per event in the 2011 EPA national emission inventory from April 2013. Emission factors for pneumatic pumps and controllers as well as equipment leaks were both comparable to and higher than estimates in the national inventory. Overall, if emission factors from this work for completion flowbacks, equipment leaks, and pneumatic pumps and controllers are assumed to be representative of national populations and are used to estimate national emissions, total annual emissions from these source categories are calculated to be 957 Gg of methane (with sampling and measurement uncertainties estimated at ±200 Gg). The estimate for comparable source categories in the EPA national inventory is ∼1,200 Gg. Additional measurements of unloadings and workovers are needed to produce national emission estimates for these source categories. The 957 Gg in emissions for completion flowbacks, pneumatics, and equipment leaks, coupled with EPA national inventory estimates for other categories, leads to an estimated 2,300 Gg of methane emissions from natural gas production (0.42% of gross gas production).

August 16, 2013. [*Category:* Economics]

Probabilistic Decline Curve Analysis of Barnett, Fayetteville, Haynesville, and Woodford Gas Shales.

- Fanchi, J. R.; Cooksey, M. J.; Lehman, K. M.; Smith, A.; Fanchi, A. C.; Fanchi, C. J.
- In: *Journal of Petroleum Science and Engineering*, vol. 109, September 2013, pages 308-311.
- http://www.sciencedirect.com/science/article/pii/S0920410513001770

Abstract: This paper presents a probabilistic decline curve workflow to model shale gas production from the Barnett, Fayetteville, Haynesville, and Woodford shales. Ranges of model input parameters for four gas shales are provided to guide the preparation of uniform and triangle probability distributions. The input parameter ranges represent realistic distributions of model parameters for specific gas shales.

August 16, 2013. [*Category:* Community]

The United States experience as a reference of success for shale gas development: The case of Mexico.

- Juan Roberto Lozano Maya.
- In: *Energy Policy*, Vol. 62, November 2013, pages 70-78.
- http://www.sciencedirect.com/science/article/pii/S0301421513007313

Abstract: Shale gas has gained increasing worldwide attention in the light of the rapid production and significant effects seen in the United States. Using this case as a reference, several countries have taken the first steps to develop their own resources, with Mexico in particular including shale gas in its energy planning priorities and rushing towards its commercial production, although results have still remained elusive. This paper argues that due to the intrinsic complexity embedded in the shale gas development of the United States, its use as a benchmark by Mexico for policy making purposes is misleading, given the challenges in reproducing the same factors of success on the basis of the contextual differences between both countries. The findings presented can ultimately be helpful for other countries looking forward to or in the process of developing their shale gas resources driven by the same reference.

August 15, 2013. [*Categories:* Community, Economics]

Social costs from proximity to hydraulic fracturing in New York State.

- Popkin, Jennifer H.; Duke, Joshua M.; Borchers, Allison M.; Ilvento, Thomas.
- In: *Energy Policy*, Vol. 62, November 2013, pages 62-69.
- http://www.sciencedirect.com/science/article/pii/S0301421513007234

Abstract: The study reports data from an economic choice experiment to determine the likely welfare impacts of hydraulic fracturing, in this case using natural gas extracted by hydraulic fracturing for household electricity. Data were collected from an Internet survey of 515 residents of New York State. The welfare analysis indicated that on average households incur a welfare loss from in-state hydraulic fracturing as the source of their electricity. The evidence suggests that households in shale counties bear more costs from HF electricity than households out of shale counties. The average welfare loss is substantive, estimated at 40–46% of average household electric bills in shale counties and 16–20% of bills in counties without shale. The evidence also suggests that relative proximity to HF well sites also increases cost borne by households.

August 13, 2014. [*Category:* Waste / Fluids]

Microbial communities in flowback water impoundments from hydraulic fracturing for recovery of shale gas.

- Mohan, Arvind Murali; Hartsock, Angela; Hammack, Richard W.; Vidic, Radisav D.; Gregory, Kelvin B.
- In: *FEMS Microbiology Ecology*, Vol. 86, Issue 3, pages 567-580.
- http://www.ncbi.nlm.nih.gov/pubmed/23875618

Abstract: Hydraulic fracturing for natural gas extraction from shale produces waste brine known as flowback that is impounded at the surface prior to reuse and/or disposal. During impoundment, microbial activity can alter the fate of metals including radionuclides, give rise to odorous compounds, and result in biocorrosion that complicates water and waste management and increases production costs. Here, we describe the microbial ecology at multiple depths of three flowback impoundments from the Marcellus shale that were managed differently. 16S rRNA gene clone libraries revealed that bacterial communities in the untreated and biocide-amended impoundments were depth dependent, diverse, and most similar to species within the taxa -proteobacteria, -proteobacteria, -proteobacteria, Clostridia, Synergistetes, Thermotogae, Spirochetes, and Bacteroidetes. The bacterial community in the pretreated and aerated impoundment was uniform with depth, less diverse, and most similar to known iodide-oxidizing bacteria in the -proteobacteria. Archaea were identified only in the untreated and biocide-amended impoundments and were affiliated to the Methanomicrobia class. This is the first study of microbial communities in flowback water impoundments from hydraulic fracturing. The findings expand our knowledge of microbial diversity of an emergent and unexplored environment and may guide the management of flowback impoundments.

August 13, 2013. [*Categories:* General (Comment / Review), Water Quality]

Hydraulic fracturing: a toxicological threat for groundwater and drinking-water?

- Gordalla, Birgit C.; Ewers, Ulrich; Frimmel, Fritz H.

- In: *Environmental Earth Sciences*, Vol. 70, Issue 8, pages 3875-3893.
- http://link.springer.com/article/10.1007/s12665-013-2672-9

Abstract: This paper deals with the possible impact of hydraulic fracturing (fracking), employed in the exploitation of unconventional shale gas and tight gas reservoirs, on groundwater, which is the most important source of drinking-water in Germany and many other European countries. This assessment, which is part of an interdisciplinary study by a panel of neutral experts on the risks and environmental impact of hydraulic fracturing, is based mainly on data obtained from three ExxonMobil drilling sites in northern Germany. First, the basic technical aspects of fracking and its relevant water fluxes are explained. The type, purpose and fate of the constituents of the fracking fluids are discussed. The chemicals used in the fracking fluids are assessed with regard to their hazardous properties according to the Regulation (EC) No. 1272/2008 of the European Parliament and of the Council on the classification, labelling and packaging of substances and mixtures (CLP regulation) and the German "Water Hazard Classes". Contamination of groundwater by ingredients of fracking fluids may occur from under ground or may result from above-ground accidents associated with the transport, storage and handling of hazardous substances used as additives in fracking fluids. The degree of groundwater contamination cannot be predicted in a general way. Therefore, different dilutions of the fracking fluid in groundwater are considered. It is shown that the concentrations of most ingredients resulting from a 1:10,000 up to 1:100,000 dilution of the fracking fluid in groundwater are below health-based reference values such as the limit values of the European Drinking Water Directive, the WHO Guideline Values for Drinking-water Quality, and other health-based guide values for drinking-water. Regarding the salinity of fracking fluids, a dilution of 1:1,000 is sufficient to reach concentrations which are acceptable for drinking-water. From the human-toxicological point of view, the constituents of flowback water are more problematic with respect to drinking-water produced from groundwater than those of the fracking fluids. The few reliable data which have become available, as well as hydrogeological considerations, point in the direction of considerable salt concentrations and toxic constituents, e.g., Hg, As, Pb, Zn, Cd, BTX, PAHs, or even radioactive elements. The identification and assessment of reaction products and metabolites, which are produced as a result of the fracking operation and the metabolic activity of microorganisms, are important topics for further research. The recommendations include the need for a better understanding of the environmental impact of fracking operations, especially with regard to the development of sustainable rules for planning, permission, performance and management of fracking, and for the monitoring of groundwater quality around fracked drilling sites.

August 6, 2013. [*Category:* Air Quality]

Air pollutant emissions from the development, production, and processing of Marcellus Shale natural gas.

- Roy, Anirban A.; Adams, Peter J.; Robinson, Allen L.
- In: *Journal of the Air & Waste Management Association*, Vol. 64, Issue 1, pages 19-37.
- http://www.tandfonline.com/doi/abs/10.1080/10962247.2013.826151

Abstract: The Marcellus Shale is one of the largest natural gas reserves in the United States; it has recently been the focus of intense drilling and leasing activity. This paper describes an air emissions inventory for the development, production, and processing of natural gas in the Marcellus Shale region for 2009 and 2020. It includes estimates of the emissions of oxides of nitrogen (NOx), volatile organic compounds (VOCs), and primary fine particulate matter (≤2.5 μm aerodynamic diameter; PM2.5) from major activities such as drilling, hydraulic fracturing, compressor stations, and completion venting. The inventory is constructed using a process-level approach; a Monte Carlo analysis is used to explicitly account for the uncertainty. Emissions were estimated for 2009 and projected to 2020, accounting for the effects of existing and potential additional regulations. In 2020, Marcellus activities are predicted to contribute 6–18% (95% confidence interval) of the NOx emissions in the Marcellus region, with an average contribution of 12% (129 tons/day). In 2020, the predicted contribution of Marcellus activities to the regional anthropogenic VOC emissions ranged between 7% and 28% (95% confidence interval), with an average contribution of 12% (100 tons/day). These estimates account for the implementation of recently promulgated regulations such as the Tier 4 off-road diesel engine regulation and the U.S. Environmental Protection Agency's (EPA) Oil and Gas Rule. These regulations significantly reduce the Marcellus VOC and NOx emissions, but there are significant opportunities for further reduction in these emissions using existing technologies. Implications: The Marcellus Shale is one of the largest natural gas reserves in United States. The development and production of this gas may emit substantial amounts of oxides of nitrogen and volatile organic compounds. These emissions may have special significance because Marcellus development is occurring close to areas that have been designated nonattainment for the ozone standard. Control technologies exist to substantially reduce these impacts. PM2.5 emissions are predicted to be negligible in a regional context, but elemental carbon emissions from diesel powered equipment may be important.

August 1, 2013. [*Categories:* Ecology, Water Quality]

Histopathological Analysis of Fish from Acorn Fork Creek, Kentucky, Exposed to Hydraulic Fracturing Fluid Releases.

- Papoulias, Diana M.; Velasco, Anthony L.

- In: *Southeastern Naturalist*, Vol. 12, Issue sp4, pages 92-111.
- http://www.bioone.org/doi/abs/10.1656/058.012.s413

Abstract: Fracking fluids were released into Acorn Fork, KY, a designated Outstanding State Resource Water, and habitat for the threatened *Chrosomus cumberlandensis* (Blackside Dace). As a result, stream pH dropped to 5.6 and stream conductivity increased to 35,000 µS/cm, and aquatic invertebrates and fish were killed or distressed. The objective of this study was to describe post-fracking water quality in Acorn Fork and evaluate if the changes in water quality could have extirpated Blackside Dace populations. *Semotilus atromaculatus* (Creek Chub) and *Lepomis cyanellus* (Green Sunfish) were collected from Acorn Fork a month after fracking in lieu of unavailable Blackside Dace. Tissues were histologically analyzed for indicators of stress and percent of fish with lesions. Fish exposed to affected Acorn Fork waters showed general signs of stress and had a higher incidence of gill lesions than unexposed reference fish. Gill lesions observed were consistent with exposure to low pH and toxic concentrations of heavy metals. Gill uptake of aluminum and iron was demonstrated at sites with correspondingly high concentrations of these metals. The abrupt and persistent changes in post-fracking water quality resulted in toxic conditions that could have been deleterious to Blackside Dace health and survival.

August 1, 2013. [*Category:* Water Quality]

Marcellus Shale drilling and brominated THMs in Pittsburgh, Pa., drinking water.

- States, Stanley; Cyprych, Georgina; Stoner, Mark; Wydra, Faith; Kuchta, John; Monnell, Jason; Casson, Leonard.
- In: *American Water Works Association*, Vol. 105, pages E432-E448.ev
- http://www.awwa.org/publications/journal-awwa/abstract/articleid/38156568.aspx

Abstract: In 2010 the Pittsburgh (Pa.) Water and Sewer Authority (PWSA) observed a significant increase in the concentration of total trihalomethanes (TTHMs), especially brominated THM species, in its finished water. In an effort to explain these changes, PWSA and the University of Pittsburgh's Swanson School of Engineering investigated bromide concentrations in the Allegheny River (PWSA's source water) and THM formation in PWSA's drinking water. Results of the investigation indicated that elevated bromide concentrations in the source water were associated with increased concentrations of TTHMs, especially brominated THMs, in the drinking water. Additionally, a survey of the river system suggested that industrial wastewater treatment plants (brine plants) treating Marcellus Shale wastewater, as well as other wastewaters, were major contributors of bromide in the raw water. The study results also indicated that PWSA's conventional treatment process, which includes enhanced coagulation and secondary sedimentation, was ineffective at removing bromide from the source water. The increase in bromide concentrations in the Allegheny River system could affect the ability of conventional drinking water plants drawing water from this source to comply with the Stage 2 Disinfectants/ Disinfection Byproducts Rule.

August, 2013. [*Category:* Economics]

A numerical study of performance for tight gas and shale gas reservoir systems.

- Freeman, C. M.; Moridis, G.; Ilk, D.; Blasingame, T. A.
- In: Journal of Petroleum Science and Engineering, Vol. 108, pages 22-39.
- http://www.sciencedirect.com/science/article/pii/S0920410513001460

Abstract: Various analytical, semi-analytical, and empirical models have been proposed to characterize rate and pressure behavior as a function of time in tight gas and shale gas systems featuring horizontal wells with multiple hydraulic fractures. Despite a few analytical models, as well as a small number of published numerical studies, there is currently little consensus regarding the large-scale flow behavior over time in such systems, particularly regarding the dominant flow regimes and whether or not reservoir properties or volumes can be estimated from well performance data. We constructed a fit-for-purpose numerical simulator which accounts for a variety of production features pertinent to these systems—specifically ultra-tight matrix permeability, hydraulically fractured horizontal wells with induced fractures of various configurations, multiple porosity and permeability fields, and desorption. These features cover the production mechanisms which are currently believed to be most relevant in tight gas and shale gas systems. We employ the numerical simulator to examine various tight gas and shale gas systems and to identify and illustrate the various flow regimes which progressively occur over time. We perform this study at fine grid discretization on the order of 1 mm near fractures to accurately capture flow effects at all time periods. We visualize the flow regimes using specialized plots of rate and pressure functions, as well as maps of pressure and sorption distributions. We use pressure maps to visualize the various flow regimes and their transitions in tight gas systems. In a typical tight gas system, we illustrate the initial linear flow into the hydraulic fractures (i.e., formation linear flow), transitioning to compound formation linear flow, and eventually transforming into elliptical flow. We explore variations of possible shale gas system models. Based on diffusive flow (with and without desorption), we show that due to the extremely low permeability of shale matrix (a few nanodarcies), the flow behavior is dominated by the extent of and configuration of the fractures. This work expands our understanding of flow behavior in tight gas and shale gas systems, where such an understanding may ultimately be used to estimate reservoir properties and reserves in these types of reservoirs.

July 29, 2013. [*Categories:* Waste / Fluids, Water Quality]

Constraints on Upward Migration of Hydraulic Fracturing Fluid and Brine.

- Flewelling, Samuel A.; Sharma, Manu.
- In: *Groundwater*, Vol. 52, Issue 1, pages 9-19.
- http://onlinelibrary.wiley.com/doi/10.1111/gwat.12095/abstract

Abstract: Recent increases in the use of hydraulic fracturing (HF) to aid extraction of oil and gas from black shales have raised concerns regarding potential environmental effects associated with predictions of upward migration of HF fluid and brine. Some recent studies have suggested that such upward migration can be large and that timescales for migration can be as short as a few years. In this article, we discuss the physical constraints on upward fluid migration from black shales (e.g., the Marcellus, Bakken, and Eagle Ford) to shallow aquifers, taking into account the potential changes to the subsurface brought about by HF. Our review of the literature indicates that HF affects a very limited portion of the entire thickness of the overlying bedrock and therefore, is unable to create direct hydraulic communication between black shales and shallow aquifers via induced fractures. As a result, upward migration of HF fluid and brine is controlled by preexisting hydraulic gradients and bedrock permeability. We show that in cases where there is an upward gradient, permeability is low, upward flow rates are low, and mean travel times are long (often >106 years). Consequently, the recently proposed rapid upward migration of brine and HF fluid, predicted to occur as a result of increased HF activity, does not appear to be physically plausible. Unrealistically high estimates of upward flow are the result of invalid assumptions about HF and the hydrogeology of sedimentary basins.

July 26, 2013. [*Category:* Water Quality]

Hydraulic fracture height limits and fault interactions in tight oil and gas formations.

- Flewelling, Samuel A.; Tymchak, Matthew P.; Warpinski, Norm.
- In: *Geophysical Research Letters*, Vol. 40, Issue 14, pages 3602-3606.
- http://onlinelibrary.wiley.com/doi/10.1002/grl.50707/abstract

Abstract: The widespread use of hydraulic fracturing (HF) has raised concerns about potential upward migration of HF fluid and brine via induced fractures and faults. We developed a relationship that predicts maximum fracture height as a function of HF fluid volume. These predictions generally bound the vertical extent of microseismicity from over 12,000 HF stimulations across North America. All microseismic events were less than 600 m above well perforations, although most were much closer. Areas of shear displacement (including faults) estimated from microseismic data were comparatively small (radii on the order of 10 m or less). These findings suggest that fracture heights are limited by HF fluid volume regardless of whether the fluid interacts with faults. Direct hydraulic communication between tight formations and shallow groundwater via induced fractures and faults is not a realistic expectation based on the limitations on fracture height growth and potential fault slip.

July 25, 2013. [*Category:* Water Quality]

An Evaluation of Water Quality in Private Drinking Water Wells Near Natural Gas Extraction Sites in the Barnett Shale Formation.

- Fontenot, Brian E.; Hunt, Laura R.; Hildenbrand, Zacariah L.; Carlton Jr., Doug D.; Oka, Hyppolite; Walton, Jayme L.; Hopkins, Dan; Osorio, Alexandra; Bjorndal, Bryan; Hu, Qinhong H.; Schug, Kevin A.

- In: *Environmental Science & Technology*, Vol. 47, Issue 17, pages 10032-10040 (September 3, 2013).
- http://dx.doi.org/10.1021/es4011724

Abstract: Natural gas has become a leading source of alternative energy with the advent of techniques to economically extract gas reserves from deep shale formations. Here, we present an assessment of private well water quality in aquifers overlying the Barnett Shale formation of North Texas. We evaluated samples from 100 private drinking water wells using analytical chemistry techniques. Analyses revealed that arsenic, selenium, strontium and total dissolved solids (TDS) exceeded the Environmental Protection Agency's Drinking Water Maximum Contaminant Limit (MCL) in some samples from private water wells located within 3 km of active natural gas wells. Lower levels of arsenic, selenium, strontium, and barium were detected at reference sites outside the Barnett Shale region as well as sites within the Barnett Shale region located more than 3 km from active natural gas wells. Methanol and ethanol were also detected in 29% of samples. Samples exceeding MCL levels were randomly distributed within areas of active natural gas extraction, and the spatial patterns in our data suggest that elevated constituent levels could be due to a variety of factors including mobilization of natural constituents, hydrogeochemical changes from lowering of the water table, or industrial accidents such as faulty gas well casings.

July 19, 2013. [*Category:* Seismicity]

Induced seismicity associated with fluid injection into a deep well in Youngstown, Ohio.

- Kim, Won-Young.
- In: *Journal of Geophysical Research*, Vol. 118, Issue 7, July 2013, pages 3506-3518.
- http://onlinelibrary.wiley.com/doi/10.1002/jgrb.50247/abstract

Abstract: Over 109 small earthquakes (Mw 0.4–3.9) were detected during January 2011 to February 2012 in the Youngstown, Ohio area, where there were no known earthquakes in the past. These shocks were close to a deep fluid injection well. The 14 month seismicity included six felt earthquakes and culminated with a Mw 3.9 shock on 31 December 2011. Among the 109 shocks, 12 events greater than Mw 1.8 were detected by regional network and accurately relocated, whereas 97 small earthquakes ($0.4 < \text{Mw} < 1.8$) were detected by the waveform correlation detector. Accurately located earthquakes were along a subsurface fault trending ENE-WSW—consistent with the focal mechanism of the main shock and occurred at depths 3.5–4.0 km in the Precambrian basement. We conclude that the recent earthquakes in Youngstown, Ohio were induced by the fluid injection at a deep injection well due to increased pore pressure along the preexisting subsurface faults located close to the wellbore. We found that the seismicity initiated at the eastern end of the subsurface fault—close to the injection point, and migrated toward the west—away from the wellbore, indicating that the expanding high fluid pressure front increased the pore pressure along its path and progressively triggered the earthquakes. We observe that several periods of quiescence of seismicity follow the minima in injection volumes and pressure, which may indicate that the earthquakes were directly caused by the pressure buildup and stopped when pressure dropped.

July 12, 2013. [*Category:* Seismicity]

Injection-induced earthquakes.

- Ellsworth, William L.
- In: *Science* (New York, N.Y.), Vol. 341, Issue 6142, page 1225942.
- http://www.ncbi.nlm.nih.gov/pubmed/23846903

Abstract: Earthquakes in unusual locations have become an important topic of discussion in both North America and Europe, owing to the concern that industrial activity could cause damaging earthquakes. It has long been understood that earthquakes can be induced by impoundment of reservoirs, surface and underground mining, withdrawal of fluids and gas from the subsurface, and injection of fluids into underground formations. Injection-induced earthquakes have, in particular, become a focus of discussion as the application of hydraulic fracturing to tight shale formations is enabling the production of oil and gas from previously unproductive formations. Earthquakes can be induced as part of the process to stimulate the production from tight shale formations, or by disposal of wastewater associated with stimulation and production. Here, I review recent seismic activity that may be associated with industrial activity, with a focus on the disposal of wastewater by injection in deep wells; assess the scientific understanding of induced earthquakes; and discuss the key scientific challenges to be met for assessing this hazard.

July 11, 2013. [*Category:* Regulation]

Oversight of shale gas production in the United States and the disclosure of toxic substances.

- Centner, Terence J.
- In: *Resources Policy*, Vol. 38, Issue 3, September 2013, pages 233-240.
- http://www.sciencedirect.com/science/article/pii/S0301420713000147

Abstract: With the encouragement of shale gas production in the United States, governments have considered a range of legislative and regulatory proposals to manage health and environmental damages that may accompany extraction activities. Exceptions adopted by Congress to major federal environmental legislation have meant that individual US states have deemed it necessary to provide oversight through regulations to protect people and safeguard environmental quality. In responding, states have legal structures under which drilling firms may not need to disclose the toxic substances used in fracturing wells. Yet, with increasing numbers of drilling sites, more people are at risk from accidents and exposure to harmful substances used at fractured wells. To provide for meaningful health and safety protection, governments may need to reevaluate legal provisions offering trade secret protection for toxic substances used in fracturing.

July 10, 2013. [*Category:* Economics]

Exploring the uncertainty around potential shale gas development – A global energy system analysis based on TIAM (TIMES Integrated Assessment Model).

- Gracceva, Francesco; Zeniewski, Peter.
- In: *Energy*, Vol. 57, August 1, 2013, pages 443-457.
- http://www.sciencedirect.com/science/article/pii/S0360544213005045

Abstract: This paper aims to quantitatively explore the uncertainty around the global potential of shale gas development and its possible impacts, using a multi-regional energy system model, TIAM (TIMES Integrated Assessment Model). Starting from the premise that shale gas resource size and production cost are two key preconditions for its development, our scenario analysis reveals the way these and other variables interact with the global energy system, impacting on the regional distribution of gas production, interregional gas trade, demand and prices. The analysis shows how the reciprocal effects of substitutions on both the supply and demand-side play an important role in constraining or enabling the penetration of shale gas into the energy mix. Moreover, we systematically demonstrate that the global potential for shale gas development is contingent on a large number of intervening variables that manifest themselves in different ways across regionally-distinct energy systems. A simple theoretical model is derived from the results of the scenario analysis. Its purpose is to simplify and explain the complex behaviour of the system, by illustrating the chain of actions and feedbacks induced by different shale gas economics, their magnitude, their relative importance, and the necessary conditions for the global potential to be realised.

July 10, 2013. [*Category:* General (Comment / Review)]

Shale gas: Pollution fears in China.

- Yang, Hong; Flower, Roger J.; Thompson, Julian R.
- In: *Nature*, Vol. 499, Issue 7457, page 154.
- http://www.nature.com/nature/journal/v499/n7457/full/499154b.html#close

Extract: The confirmation of groundwater contamination owing to shale-gas extraction in the United States (see *Nature* **498**, 415–416; 2013) should be a wake-up call for China too. With Chinese groundwater resources deteriorating fast and shale-gas exploitation mushrooming, careful drilling operations and continuous monitoring are needed.

China has the world's largest shale-gas reserves.…

July 2013. [*Category:* Community]

Stakeholder Perceptions of Socioenvironmental Impacts from Unconventional Natural Gas Development and Hydraulic Fracturing in the Haynesville Shale.

- Ladd, Anthony E.
- In: *Journal of Rural Social Sciences*, Vol. 28, Issue 2, page 56.
- https://www.zotero.org/groups/pse_study_citation_database/items/EHITXES2

Abstract: Environmental controversy over unconventional natural gas development utilizing horizontal drilling and hydraulic "fracking" has been on the rise in recent years. While most of the media attention has been focused on the conflicts in states like Pennsylvania, New York, Texas, and Colorado, the discovery of huge natural gas reserves in the Haynesville Shale formation in 2008 set off a drilling rush that has resulted in differential benefits and risks for various residents. Drawing on current research and extensive interview data collected from a relevant cross-section of community stakeholders, this study offers a descriptive and comparative analysis of the types of benefits and opportunities perceived to accompany increased unconventional natural gas development, the range of perceived negative impacts and threats associated with such development, and the extent to which respondents viewed the benefits of the Haynesville boom as outweighing the costs. While most stakeholders perceived that natural gas development offered the community a host of positive socioeconomic benefits in the form of increased jobs, tax revenues, services, and new economic opportunities for local businesses and landowners, a substantial minority of residents also associated shale development with a larger number of negative social, economic, and environmental impacts. Those included the degradation of water resources; increased road damage, noise, and traffic accidents; and other assorted threats to public health, animals, and the rural landscape. Moreover, while most Haynesville residents believed that the socioeconomic benefits of development had outweighed the collective socioeconomic/environmental costs to the region, a substantial minority of respondents was also skeptical or disagreed that the benefits to date had been worth the risks. These findings both support and extend existing sociological research in several key respects. The implications of the study, both for the region and the national debate over fracking, are discussed.

July 2013. [*Category:* Health]

Childhood cancer incidence in Pennsylvania counties in relation to living in counties with hydraulic fracturing sites.

- Fryzek, Jon; Pastula, Susan; Jiang, Xiaohui; Garabrant, David H.
- In: *Journal of occupational and environmental medicine / American College of Occupational and Environmental Medicine*, Vol. 55, Issue 7, pages 796-801.
- http://www.ncbi.nlm.nih.gov/pubmed/23836020

Abstract: OBJECTIVE: Evaluate whether childhood cancer incidence is associated with counties with hydraulic fracturing (HF). METHODS: We compared cancer incidence in children in Pennsylvania counties before and after HF drilling began, using standardized incidence ratios (SIRs) and 95% confidence intervals (CIs). RESULTS: The total number of cancers observed was close to expected both before drilling began (SIR = 0.94; 95% CI, 0.90 to 0.99) and after drilling (SIR = 1.02; 95% CI, 0.98 to 1.07) for counties with oil and natural gas wells. Analyses for childhood leukemia were also unremarkable (SIR for leukemia before drilling = 0.97 [95% CI, 0.88 to 1.06]; SIR for leukemia after drilling = 1.01 [95% CI, 0.92 to 1.11]). A slightly elevated SIR was found for central nervous system tumors after drilling (SIR = 1.13; 95% CI, 1.02 to 1.25). This was because of a slight excess in those counties with the fewest number of wells. CONCLUSIONS: This study offers comfort concerning health effects of HF on childhood cancers.

June 28, 2013. [*Category:* Waste / Fluids]

TENORM radiological survey of Utica and Marcellus Shale.

- Ying, Leong; O’Connor, Frank.
- In: *Applied Radiation and Isotopes*, Vol. 80, October 2013, pages 95-98.
- http://www.sciencedirect.com/science/article/pii/S0969804313002777

Abstract: Comprehensive on-site radiological survey of processed sludge drilled materials extracted from the oil and gas production activities in the Utica and Marcellus Shale in Ohio has been conducted with a shielded isotopic identifier incorporating an advanced patented algorithmic processor to measure low-activity levels in compliance with environmental standards.

June 22, 2013. [*Categories:* General (Comment / Review), Water Quality]

Hydraulic fracturing in unconventional gas reservoirs: risks in the geological system, part 2.

- Kissinger, Alexander; Helmig, Rainer; Ebigbo, Anozie; Class, Holger; Lange, Torsten; Sauter, Martin; Heitfeld, Michael; Klünker, Johannes; Jahnke, Wiebke.
- In: *Environmental Earth Sciences*, Vol. 70, Issue 8, pages 3855-3873.
- http://link.springer.com/article/10.1007/s12665-013-2578-6

Abstract: Hydraulic fracturing is a method used for the production of unconventional gas resources. Huge amounts of so-called fracturing fluid (10,000–20,000 m3) are injected into a gas reservoir to create fractures in solid rock formations, upon which mobilised methane fills the pore space and the fracturing fluid is withdrawn. Hydraulic fracturing may pose a threat to groundwater resources if fracturing fluid or brine can migrate through fault zones into shallow aquifers. Diffuse methane emissions from the gas reservoir may not only contaminate shallow groundwater aquifers, but also escape into the atmosphere where methane acts as a greenhouse gas. The working group "Risks in the Geological System" as part of ExxonMobil's hydrofracking dialogue and information dissemination processes was tasked with the assessment of possible hazards posed by migrating fluids as a result of hydraulic fracturing activities. In this work, several flow paths for fracturing fluid, brine and methane are identified and scenarios are set up to qualitatively estimate under what circumstances these fluids would leak into shallower layers. The parametrisation for potential hydraulic fracturing sites in North Rhine-Westphalia and Lower Saxony (both in Germany) is derived from literature using upper and lower bounds of hydraulic parameters. The results show that a significant fluid migration is only possible if a combination of several conservative assumptions is met by a scenario.

June 14, 2013. [*Category:* Water Quality]

Isotope Approach to Assess Hydrologic Connections During Marcellus Shale Drilling.

- Sharma, Shikha; Mulder, Michon L.; Sack, Andrea; Schroeder, Karl; Hammack, Richard.

- In: *Groundwater*, Vol. 52, Issue 3, pages 424-433.
- http://www.ncbi.nlm.nih.gov/pubmed/23772970

Abstract: Water and gas samples were collected from (1) nine shallow groundwater aquifers overlying Marcellus Shale in north-central West Virginia before active shale gas drilling, (2) wells producing gas from Upper Devonian sands and Middle Devonian Marcellus Shale in southwestern Pennsylvania, (3) coal-mine water discharges in southwestern Pennsylvania, and (4) streams in southwestern Pennsylvania and north-central West Virginia. Our preliminary results demonstrate that the oxygen and hydrogen isotope composition of water, carbon isotope composition of dissolved inorganic carbon, and carbon and hydrogen isotope compositions of methane in Upper Devonian sands and Marcellus Shale are very different compared with shallow groundwater aquifers, coal-mine waters, and stream waters of the region. Therefore, spatiotemporal stable isotope monitoring of the different sources of water before, during, and after hydraulic fracturing can be used to identify migrations of fluids and gas from deep formations that are coincident with shale gas drilling.

June 11, 2013. [*Category:* Water Quality]

A Stream-Based Methane Monitoring Approach for Evaluating Groundwater Impacts Associated with Unconventional Gas Development.

- Heilweil, Victor M.; Stolp, Bert J.; Kimball, Briant A.; Susong, David D.; Marston, Thomas M.; Gardner, Philip M.

- Published in: *Groundwater*, Vol. 51, Issue 4, pages 511-523, July/August 2013.
- http://www.ncbi.nlm.nih.gov/pubmed/23758706

Abstract: Gaining streams can provide an integrated signal of relatively large groundwater capture areas. In contrast to the point-specific nature of monitoring wells, gaining streams coalesce multiple flow paths. Impacts on groundwater quality from unconventional gas development may be evaluated at the watershed scale by the sampling of dissolved methane (CH4) along such streams. This paper describes a method for using stream CH4 concentrations, along with measurements of groundwater inflow and gas transfer velocity interpreted by 1-D stream transport modeling, to determine groundwater methane fluxes. While dissolved ionic tracers remain in the stream for long distances, the persistence of methane is not well documented. To test this method and evaluate CH4 persistence in a stream, a combined bromide (Br) and CH4 tracer injection was conducted on Nine-Mile Creek, a gaining stream in a gas development area in central Utah. A 35% gain in streamflow was determined from dilution of the Br tracer. The injected CH4 resulted in a fivefold increase in stream CH4 immediately below the injection site. CH4 and δ13CCH4 sampling showed it was not immediately lost to the atmosphere, but remained in the stream for more than 2000 m. A 1-D stream transport model simulating the decline in CH4 yielded an apparent gas transfer velocity of 4.5 m/d, describing the rate of loss to the atmosphere (possibly including some microbial consumption). The transport model was then calibrated to background stream CH4 in Nine-Mile Creek (prior to CH4 injection) in order to evaluate groundwater CH4 contributions. The total estimated CH4 load discharging to the stream along the study reach was 190 g/d, although using geochemical fingerprinting to determine its source was beyond the scope of the current study. This demonstrates the utility of stream-gas sampling as a reconnaissance tool for evaluating both natural and anthropogenic CH4 leakage from gas reservoirs into groundwater and surface water.

June 15, 2011. [*Category:* Waste / Fluids]

Chemical and physical characterization of produced waters from conventional and unconventional fossil fuel resources.

- Alley, Bethany; Beebe, Alex; Rodgers Jr., John; Castle, James W.
- In: *Chemosphere*, Vol. 85, Issue 1, pages 74-82.
- http://www.sciencedirect.com/science/article/pii/S0045653511005960

Abstract: Characterization of produced waters (PWs) is an initial step for determining potential beneficial uses such as irrigation and surface water discharge at some sites. A meta-analysis of characteristics of five PW sources [i.e. shale gas (SGPWs), conventional natural gas (NGPWs), conventional oil (OPWs), coal-bed methane (CBMPWs), tight gas sands (TGSPWs)] was conducted from peer-reviewed literature, government or industry documents, book chapters, internet sources, analytical records from industry, and analyses of PW samples. This meta-analysis assembled a large dataset to extract information of interest such as differences and similarities in constituent and constituent concentrations across these sources of PWs. The PW data analyzed were comprised of 377 coal-bed methane, 165 oilfield, 137 tight gas sand, 4000 natural gas, and 541 shale gas records. Majority of SGPWs, NGPWs, OPWs, and TGSPWs contain chloride concentrations ranging from saline (>30 000 mg L^{-1}) to hypersaline (>40 000 mg L^{-1}), while most CBMPWs were fresh (<5000 mg L^{-1}). For inorganic constituents, most SGPW and NGPW iron concentrations exceeded the numeric criterion for irrigation and surface water discharge, while OPW and CBMPW iron concentrations were less than the criterion. Approximately one-fourth of the PW samples in this database are fresh and likely need minimal treatment for metal and metalloid constituents prior to use, while some PWs are brackish (5000–30 000 mg Cl^{-} L^{-1}) to saline containing metals and metalloids that may require considerable treatment. Other PWs are hypersaline and produce a considerable waste stream from reverse osmosis; remediation of these waters may not be feasible. After renovation, fresh to saline PWs may be used for irrigation and replenishing surface waters.

June 9, 2013. [*Category:* Waste / Fluids]

Characterization of Marcellus Shale natural gas well drill cuttings.

- Barry, B.; Klima, M. S.
- In: *Journal of Unconventional Oil and Gas Resources*, Vol. 1-2, pages 9-17.
- http://www.sciencedirect.com/science/article/pii/S2213397613000049

Abstract: Drilling operations in preparation for natural gas extraction from the Marcellus Shale formation generate large amounts of rock cuttings, which return to the surface coated in drilling mud. Solids control is commonly implemented so that the mud can be recycled, but total removal of the cuttings is uneconomical, so any non-reclaimed cuttings are processed to reduce moisture and then deposited in landfills. Laboratory analyses were conducted to characterize two samples of drill cuttings and to present characterization methods that may be relevant in assessing the beneficial reuse potential of drill cuttings. A key aspect of this study was to evaluate several approaches for providing consistent size distribution data. In addition, degradation testing was performed by submitting cuttings to moderate forms of attrition and sonication. Analyses provided particle size distributions, ash values, moisture content, and total organic carbon content of the samples. Materials analyzed included cuttings from the vertical portion of a wellbore mixed with water-based mud as well as Marcellus Shale cuttings from the horizontal portion of the same wellbore, mixed with oil-based mud. It was found that the size distribution of the water-based cuttings was much broader and finer than that of the oil-based cuttings for the samples analyzed in this study. Size degradation by attrition was minimal. Attempts to disperse the material using sonication were successful but lead to significant particle degradation. On a dry basis, the ash values of the water-based cuttings ranged from 94% to 98% by weight compared to 85–89% by weight for the oil-based cuttings. Total organic carbon content of the oil-based cuttings was approximately 10.6%. Additional testing may be required to ensure compliance with applicable regulations for beneficial reuse of the cuttings.

June 7, 2013. [*Category:* General (Comment / Review)]

Groundwater protection and unconventional gas extraction: the critical need for field-based hydrogeological research.

- Jackson, R. E.; Gorody, A. W.; Mayer, B.; Roy, J. W.; Ryan, M. C.; Van Stempvoort, D. R.
- In: *Groundwater*, Vol. 51, Issue 4, pages 488-510.
- http://www.ncbi.nlm.nih.gov/pubmed/23745972

Abstract: Unconventional natural gas extraction from tight sandstones, shales, and some coal-beds is typically accomplished by horizontal drilling and hydraulic fracturing that is necessary for economic development of these new hydrocarbon resources. Concerns have been raised regarding the potential for contamination of shallow groundwater by stray gases, formation waters, and fracturing chemicals associated with unconventional gas exploration. A lack of sound scientific hydrogeological field observations and a scarcity of published peer-reviewed articles on the effects of both conventional and unconventional oil and gas activities on shallow groundwater make it difficult to address these issues. Here, we discuss several case studies related to both conventional and unconventional oil and gas activities illustrating how under some circumstances stray or fugitive gas from deep gas-rich formations has migrated from the subsurface into shallow aquifers and how it has affected groundwater quality. Examples include impacts of uncemented well annuli in areas of historic drilling operations, effects related to poor cement bonding in both new and old hydrocarbon wells, and ineffective cementing practices. We also summarize studies describing how structural features influence the role of natural and induced fractures as contaminant fluid migration pathways. On the basis of these studies, we identify two areas where field-focused research is urgently needed to fill current science gaps related to unconventional gas extraction: (1) baseline geochemical mapping (with time series sampling from a sufficient network of groundwater monitoring wells) and (2) field testing of potential mechanisms and pathways by which hydrocarbon gases, reservoir fluids, and fracturing chemicals might potentially invade and contaminate useable groundwater.

June 3, 2013. [*Category:* Water Quality]

Increased stray gas abundance in a subset of drinking water wells near Marcellus shale gas extraction.

- Jackson, Robert B.; Vengosh, Avner; Darrah, Thomas H.; Warner, Nathaniel R.; Down, Adrian; Poreda, Robert J.; Osborn, Stephen G.; Zhao, Kaiguang; Karr, Jonathan D.
- In: *Proceedings of the National Academy of Sciences*, Vol. 110, Issue 28, pages 11250-11255.
- http://www.pnas.org/content/110/28/11250

Abstract: Horizontal drilling and hydraulic fracturing are transforming energy production, but their potential environmental effects remain controversial. We analyzed 141 drinking water wells across the Appalachian Plateaus physiographic province of northeastern Pennsylvania, examining natural gas concentrations and isotopic signatures with proximity to shale gas wells. Methane was detected in 82% of drinking water samples, with average concentrations six times higher for homes <1 km from natural gas wells ($P = 0.0006$). Ethane was 23 times higher in homes <1 km from gas wells ($P = 0.0013$); propane was detected in 10 water wells, all within approximately 1 km distance ($P = 0.01$). Of three factors previously proposed to influence gas concentrations in shallow groundwater (distances to gas wells, valley bottoms, and the Appalachian Structural Front, a proxy for tectonic deformation), distance to gas wells was highly significant for methane concentrations ($P = 0.007$; multiple regression), whereas distances to valley bottoms and the Appalachian Structural Front were not significant ($P = 0.27$ and $P = 0.11$, respectively). Distance to gas wells was also the most significant factor for Pearson and Spearman correlation analyses ($P < 0.01$). For ethane concentrations, distance to gas wells was the only statistically significant factor ($P < 0.005$). Isotopic signatures ($\delta 13C\text{-}CH_4$, $\delta 13C\text{-}C_2H_6$, and $\delta 2H\text{-}CH_4$), hydrocarbon ratios (methane to ethane and propane), and the ratio of the noble gas 4He to CH_4 in groundwater were characteristic of a thermally postmature Marcellus-like source in some cases. Overall, our data suggest that some homeowners living <1 km from gas wells have drinking water contaminated with stray gases.

June, 2013. [*Category:* Health]

Fracking, the Environment, and Health.

- McDermott-Levy, By Ruth; Kaktins, Nina; Sattler, Barbara.
- In: *American Journal of Nursing*, Vol. 133, Issue 6, pages 45-51.
- http://journals.lww.com/ajnonline/Abstract/2013/06000/Fracking,_the_Environment,_and_Health.30.aspx & http://www1.villanova.edu/content/dam/villanova/sustainability/McD-LFrackingEnvironmentHealth.pdf

Excerpts, page 51: Public and individual health concerns are rarely raised when energy policies are discussed on the state or federal level, and health professionals are typically excluded from these decision-making discussions. As Goldstein and colleagues noted last year, none of the advisory committees formed to investigate drilling activities on the Marcellus shale included representatives of state or federal public health agencies or individuals with expertise in the effects of environmental hazards on human health.

Nurses are being joined in their efforts by a wide range of stakeholders, ranging from the health professionals in the American Public Health Association and Physicians for Social Responsibility, to national organizations such as Breast Cancer Action and Food and Water Watch, to grassroots organizations such as Catskill Mountainkeeper and Frack Free Stark County. Many of the well-known national environmentalist organizations are actively engaged as well, such as the Sierra Club, the Nature Conservancy, and the Natural Resources Defense Council. National Nurses United and the ANA have both called for banning new fracking permits. These two nursing organizations have constituents throughout the country who are engaged in legislative and other policy initiatives regarding fracking.

June, 2013. [*Category:* Health]

Assessment and longitudinal analysis of health impacts and stressors perceived to result from unconventional shale gas development in the Marcellus Shale region.

- Ferrar, Kyle J.; Kriesky, Jill; Christen, Charles L.; Marshall, Lynne P.; Malone, Samantha L.; Sharma, Ravi K.; Michanowicz, Drew R.; Goldstein, Bernard D.
- In: *International Journal of Occupational and Environmental Health*, Vol. 19, Issue 2, pages 104-112.
- http://www.maneyonline.com/doi/abs/10.1179/2049396713Y.0000000024?token=00521ce4cd7bc4515dca5a666f3a7b6c2a407b6f5b6b354c48763c49264f65263a3d4f58762f46a101

Abstract: Introduction: Concerns for health and social impacts have arisen as a result of Marcellus Shale unconventional natural gas development. Our goal was to document the self-reported health impacts and mental and physical health stressors perceived to result from Marcellus Shale development. Methods: Two sets of interviews were conducted with a convenience sample of community members living proximal to Marcellus Shale development, session 1 March–September 2010 (n=33) and session 2 January–April 2012 (n=20). Symptoms of health impacts and sources of psychological stress were coded. Symptom and stressor counts were quantified for each interview. The counts for each participant were compared longitudinally. Results: Participants attributed 59 unique health impacts and 13 stressors to Marcellus Shale development. Stress was the most frequently-reported symptom. Over time, perceived health impacts increased (P=0.042), while stressors remained constant (P=0.855). Discussion: Exposure-based epidemiological studies are needed to address identified health impacts and those that may develop as unconventional natural gas extraction continues. Many of the stressors can be addressed immediately.

May 31, 2013. [*Category:* Waste / Fluids]

Hydraulic fracturing wastewater in Germany: composition, treatment, concerns.

- Olsson, Oliver; Weichgrebe, Dirk; Rosenwinkel, Karl-Heinz.
- In: *Environmental Earth Sciences*, Vol. 70, Issue 8, pages 3895-3906.
- http://link.springer.com/article/10.1007%2Fs12665-013-2535-4

Abstract: When studying technical methods and measures that could be applicable for flowback treatment, recycling and/or disposal, it is important to characterize the volumes and composition of hydraulic fracturing flowback. In this work, water volumes and water quality data are considered for investigating flowback at three selected drilling sites in Germany. The analysis highlighted an increase of chloride concentrations up to saturation limit over the time. High salinity concentrations were used as indicator for estimating the percentage of hydraulic fracturing fluid and formation water in flowback. For the studied shale gas well a proportion of formation water, 69 %, and hydraulic fracturing fluid, 31 %, in flowback were derived. Thus, 92 % of the hydraulic fracturing fluid remained in the formation. The physical/chemical properties of flowback were categorized in groups to enable the allocation of applicable treatment methods. The analysis revealed that no single technology can meet suitable effluent characteristics, thus two or more treatment systems might be used in series operation. In particular, for flowback containing high salinity concentrations the only treatment options are evaporation or crystallization. Hence, methodological distinctions need to be made between concentration, elimination, disposal and recycling, whereby for the existing concentrate treatment or disposal measures need to be completed and scaled up into the process.

May 29, 2013. [*Category:* Ecology]

Accumulated metals and metallothionein expression in organs of hares (Lepus europaeus Pallas) within natural gas fields of Podravina, Croatia.

- Tota, Marin; Jakovac, Hrvoje; Spirić, Zdravko; Srebočan, Emil; Milin, Čedomila.
- In: *Archives of Environmental & Occupational Health*, Vol. 70, Issue 3, 2015.
- http://www.ncbi.nlm.nih.gov/pubmed/24965325

Abstract: Environmental impact of natural gas facility near Molve (Podravina, Croatia) was assessed using hares (Lepus europaeus Pallas) as biomonitors. Elevated levels of heavy metals in the environment lead to their accumulation in different tissues of hares. We have tested accumulation and distribution of several metals in hares liver, kidney and muscle tissue. The accumulation of copper in hares liver and kidneys with concomitant decrease of zinc was observed in animals from Podravina region as opposed to control group of animals (Island Krk, Croatia). Secondly, the expression of metallothioneins was assessed because of their crucial role in metal homeostasis. Observed elevation of metallothionein expression in tested organs emphasizes the possible prolonged negative effects of heavy metals in the surroundings as well as a state of oxidative stress in animals. Further monitoring of the area is necessary for better control of hydrocarbon processing to diminish the possible negative environmental effects.

May 28, 2013. [*Category:* Climate]

Quantifying sources of methane using light alkanes in the Los Angeles basin, California.

- Peischl, J.; Ryerson, T. B.; Brioude, J.; Aikin, K. C.; Andrews, A. E.; Atlas, E.; Blake, D.; Daube, B. C.; de Gouw, J. A.; Dlugokencky, E.; Frost, G. J.; Gentner, D. R.; Gilman, J. B.; Goldstein, A. H.; Harley, R. A.; Holloway, J. S.; Kofler, J.; Kuster, W. C.; Lang, P. M.; Novelli, P. C.; Parrish, D. D.; Santoni, G. W.; Trainer, M.; Wofsy, S. C.
- In: *Journal of Geophysical Research: Atmospheres*, Vol. 118, Issue 10, pages 4974-4990.
- http://onlinelibrary.wiley.com/doi/10.1002/jgrd.50413/abstract

Abstract: Methane (CH4), carbon dioxide (CO2), carbon monoxide (CO), and C2–C5 alkanes were measured throughout the Los Angeles (L.A.) basin in May and June 2010. We use these data to show that the emission ratios of CH4/CO and CH4/CO2 in the L.A. basin are larger than expected from population-apportioned bottom-up state inventories, consistent with previously published work. We use experimentally determined CH4/CO and CH4/CO2 emission ratios in combination with annual State of California CO and CO2 inventories to derive a yearly emission rate of CH4 to the L.A. basin. We further use the airborne measurements to directly derive CH4 emission rates from dairy operations in Chino, and from the two largest landfills in the L.A. basin, and show these sources are accurately represented in the California Air Resources Board greenhouse gas inventory for CH4. We then use measurements of C2–C5 alkanes to quantify the relative contribution of other CH4 sources in the L.A. basin, with results differing from those of previous studies. The atmospheric data are consistent with the majority of CH4 emissions in the region coming from fugitive losses from natural gas in pipelines and urban distribution systems and/or geologic seeps, as well as landfills and dairies. The local oil and gas industry also provides a significant source of CH4 in the area. The addition of CH4 emissions from natural gas pipelines and urban distribution systems and/or geologic seeps and from the local oil and gas industry is sufficient to account for the differences between the top-down and bottom-up CH4 inventories identified in previously published work.

May 23, 2013. [*Category:* Ecology]

Risks to biodiversity from hydraulic fracturing for natural gas in the Marcellus and Utica shales.

- Kiviat, Erik.
- In: *Annals of the New York Academy of Sciences*, Vol. 1286, May 2013, pages 1-14.
- http://onlinelibrary.wiley.com/doi/10.1111/nyas.12146/abstract

Abstract: High-volume horizontal hydraulic fracturing (HVHHF) for mining natural gas from the Marcellus and Utica shales is widespread in Pennsylvania and potentially throughout approximately 280,000 km(2) of the Appalachian Basin. Physical and chemical impacts of HVHHF include pollution by toxic synthetic chemicals, salt, and radionuclides, landscape fragmentation by wellpads, pipelines, and roads, alteration of stream and wetland hydrology, and increased truck traffic. Despite concerns about human health, there has been little study of the impacts on habitats and biota. Taxa and guilds potentially sensitive to HVHHF impacts include freshwater organisms (e.g., brook trout, freshwater mussels), fragmentation-sensitive biota (e.g., forest-interior breeding birds, forest orchids), and species with restricted geographic ranges (e.g., Wehrle’s salamander, tongue-tied minnow). Impacts are potentially serious due to the rapid development of HVHHF over a large region.

May 23, 2013. [*Category:* Seismicity]

Enhanced Remote Earthquake Triggering at Fluid-Injection Sites in the Midwestern United States.

- Elst, Nicholas J. van der; Savage, Heather M.; Keranen, Katie M.; Abers, Geoffrey A.
- In: *Science*, Vol. 341, Issue 6142, pages 164-167.
- http://www.sciencemag.org/content/341/6142/164

Abstract: A recent dramatic increase in seismicity in the midwestern United States may be related to increases in deep wastewater injection. Here, we demonstrate that areas with suspected anthropogenic earthquakes are also more susceptible to earthquake-triggering from natural transient stresses generated by the seismic waves of large remote earthquakes. Enhanced triggering susceptibility suggests the presence of critically loaded faults and potentially high fluid pressures. Sensitivity to remote triggering is most clearly seen in sites with a long delay between the start of injection and the onset of seismicity and in regions that went on to host moderate magnitude earthquakes within 6 to 20 months. Triggering in induced seismic zones could therefore be an indicator that fluid injection has brought the fault system to a critical state. Movers and Shakers We tend to view earthquakes as unpredictable phenomena caused by naturally shifting stresses in Earth's crust. In reality, however, a range of human activity can also induce earthquakes. Ellsworth (p. 10.1126/science.1225942) reviews the current understanding of the causes and mechanics of earthquakes caused by human activity and the means to decrease their associated risk. Notable examples include injection of wastewater into deep formations and emerging technologies related to oil and gas recovery, including hydraulic fracturing. In addition to directly causing increased local seismic activity, activities such as deep fluid injection may have other ramifications related to earthquake occurrence. Van der Elst et al. (p. 164; see the news story by Kerr) demonstrate that in the midwestern United States, some areas with increased human-induced seismicity are also more prone to further earthquakes triggered by the seismic waves from large, remote earthquakes. Improved seismic monitoring and injection data near deep disposal sites will help to identify regions prone to remote triggering and, more broadly, suggest times when activities should, at least temporarily, be put on hold.

May 22, 2013. [*Category:* General (Comment / Review)]

Opportunity, challenges and policy choices for China on the development of shale gas.

- Hu, Desheng; Xu, Shengqing.
- In: *Energy Policy*, Vol. 60, September 2013, pages 21-26.
- http://www.sciencedirect.com/science/article/pii/S0301421513003212

Abstract: With the highest shale gas reserves worldwide and huge need for energy, the Chinese government has introduced many incentives to accelerate the development of shale gas, including subsidies and reduction or waiver of the related fees or taxes. However, the challenges posed by a lack of advanced technologies, environmental protection, a shortage of water in quantity and a knowledge of how to develop a good industry–local community relationship are anticipated in the realization of the predicted golden age of the Chinese shale gas industry. Based on the particular situation and available resources in China, and with reference to the experiences in countries with a developed shale gas industry (such as the U.S.A.) and suggestions by the International Energy Agency, recommendations about the choices facing China can be summarized as follows: allowing foreign investors directly to hold exploration and mining rights in shale gas could facilitate the obtainment of advanced technologies; the improvement of the regulatory arrangements related to environmental protection could make developers more responsible; prompting developers to improve their water-use efficiency could help in not worsening the water supply to some extent; and SLO-based mechanism guidance could be helpful in developing a mutual-trust and -benefit relationship between the shale gas industry and the local community.

May 22, 2013. [*Category:* Water Quality]

Development of the T+M coupled flow–geomechanical simulator to describe fracture propagation and coupled flow–thermal–geomechanical processes in tight/shale gas systems.

- Kim, Jihoon; Moridis, George J.
- In: *Computers & Geosciences*, Vol. 60, pages 184-198.
- http://www.sciencedirect.com/science/article/pii/S0098300413001234

Abstract: We developed a hydraulic fracturing simulator by coupling a flow simulator to a geomechanics code, namely T+M simulator. Modeling of the vertical fracture development involves continuous updating of the boundary conditions and of the data connectivity, based on the finite element method for geomechanics. The T+M simulator can model the initial fracture development during the hydraulic fracturing operations, after which the domain description changes from single continuum to double or multiple continua in order to rigorously model both flow and geomechanics for fracture–rock matrix systems. The T+H simulator provides two-way coupling between fluid-heat flow and geomechanics, accounting for thermo-poro-mechanics, treats nonlinear permeability and geomechanical moduli explicitly, and dynamically tracks changes in the fracture(s) and in the pore volume. We also fully account for leak-off in all directions during hydraulic fracturing. We first test the T+M simulator, matching numerical solutions with the analytical solutions for poromechanical effects, static fractures, and fracture propagations. Then, from numerical simulation of various cases of the planar fracture propagation, shear failure can limit the vertical fracture propagation of tensile failure, because of leak-off into the reservoirs. Slow injection causes more leak-off, compared with fast injection, when the same amount of fluid is injected. Changes in initial total stress and contributions of shear effective stress to tensile failure can also affect formation of the fractured areas, and the geomechanical responses are still well-posed.

May 21, 2013. [*Category:* Climate]

Process based life-cycle assessment of natural gas from the Marcellus Shale.

- Dale, Alexander T.; Khanna, Vikas; Vidic, Radisav D.; Bilec, Melissa M.
- In: *Environmental Science & Technology*, Vol. 47, Issue 10, pages 5459-5466.
- http://pubs.acs.org/doi/abs/10.1021/es304414q

Abstract: The Marcellus Shale (MS) represents a large potential source of energy in the form of tightly trapped natural gas (NG). Producing this NG requires the use of energy and water, and has varying environmental impacts, including greenhouse gases. One well-established tool for quantifying these impacts is life-cycle assessment (LCA). This study collected information from current operating companies to perform a process LCA of production for MS NG in three areas--greenhouse gas (GHG) emissions, energy consumption, and water consumption--under both present (2011-2012) and past (2007-2010) operating practices. Energy return on investment (EROI) was also calculated. Information was collected from current well development operators and public databases, and combined with process LCA data to calculate per-well and per-MJ delivered impacts, and with literature data on combustion for calculation of impacts on a per-kWh basis during electricity generation. Results show that GHG emissions through combustion are similar to conventional natural gas, with an EROI of 12:1 (90% confidence interval of 4:1-13:1), lower than conventional fossil fuels but higher than unconventional oil sources.

May 16, 2013. [*Categories:* General (Comment / Review), Health]

The Shale Gas Boom and the Need for Rational Policy.

- Finkel, Madelon; Hays, Jake; Law, Adam.
- In: *American Journal of Public Health*, Vol. 103, Issue 7, pages 1161-1163.
- http://ajph.aphapublications.org/doi/abs/10.2105/AJPH.2013.301285

Abstract: High-volume, slick water hydraulic fracturing of shale relies on pumping millions of gallons of surface water laced with toxic chemicals and sand under high pressure to create fractures to release the flow of gas.

The process, however, has the potential to cause serious and irreparable damage to the environment and the potential for harm to human and animal health. At issue is how society should form appropriate policy in the absence of well-designed epidemiological studies and health impact assessments.

The issue is fraught with environmental, economic, and health implications, and federal and state governments must establish detailed safeguards and ensure regulatory oversight, both of which are presently lacking in states where hydraulic fracturing is allowed.

May 14, 2013. [*Category:* Seismicity]

Modeling of fault reactivation and induced seismicity during hydraulic fracturing of shale-gas reservoirs.

- Rutqvist, Jonny; Rinaldi, Antonio P.; Cappa, Frédéric; Moridis, George J.
- In: *Journal of Petroleum Science and Engineering*, Vol. 107, July 2013, pages 31-44.
- http://www.sciencedirect.com/science/article/pii/S0920410513001241

Abstract: We have conducted numerical simulation studies to assess the potential for injection-induced fault reactivation and notable seismic events associated with shale-gas hydraulic fracturing operations. The modeling is generally tuned toward conditions usually encountered in the Marcellus shale play in the Northeastern US at an approximate depth of 1500 m (~4500 ft). Our modeling simulations indicate that when faults are present, micro-seismic events are possible, the magnitude of which is somewhat larger than the one associated with micro-seismic events originating from regular hydraulic fracturing because of the larger surface area that is available for rupture. The results of our simulations indicated fault rupture lengths of about 10–20 m, which, in rare cases, can extend to over 100 m, depending on the fault permeability, the in situ stress field, and the fault strength properties. In addition to a single event rupture length of 10–20 m, repeated events and aseismic slip amounted to a total rupture length of 50 m, along with a shear offset displacement of less than 0.01 m. This indicates that the possibility of hydraulically induced fractures at great depth (thousands of meters) causing activation of faults and creation of a new flow path that can reach shallow groundwater resources (or even the surface) is remote. The expected low permeability of faults in producible shale is clearly a limiting factor for the possible rupture length and seismic magnitude. In fact, for a fault that is initially nearly-impermeable, the only possibility of a larger fault slip event would be opening by hydraulic fracturing; this would allow pressure to penetrate the matrix along the fault and to reduce the frictional strength over a sufficiently large fault surface patch. However, our simulation results show that if the fault is initially impermeable, hydraulic fracturing along the fault results in numerous small micro-seismic events along with the propagation, effectively preventing larger events from occurring. Nevertheless, care should be taken with continuous monitoring of induced seismicity during the entire injection process to detect any runaway fracturing along faults.

May 17, 2013. [*Category:* Water Quality]

Impact of Shale Gas Development on Regional Water Quality.

- Vidic, R. D.; Brantley, S. L.; Vandenbossche, J. M.; Yoxtheimer, D.; Abad, J. D.

- In: *Science*, Vol. 340, Issue 6134.
- http://www.sciencemag.org/content/340/6134/1235009

Abstract: Unconventional natural gas resources offer an opportunity to access a relatively clean fossil fuel that could potentially lead to energy independence for some countries. Horizontal drilling and hydraulic fracturing make the extraction of tightly bound natural gas from shale formations economically feasible. These technologies are not free from environmental risks, however, especially those related to regional water quality, such as gas migration, contaminant transport through induced and natural fractures, wastewater discharge, and accidental spills. We review the current understanding of environmental issues associated with unconventional gas extraction. Improved understanding of the fate and transport of contaminants of concern and increased long-term monitoring and data dissemination will help manage these water-quality risks today and in the future. Background Natural gas has recently emerged as a relatively clean energy source that offers the opportunity for a number of regions around the world to reduce their reliance on energy imports. It can also serve as a transition fuel that will allow for the shift from coal to renewable energy resources while helping to reduce the emissions of CO2, criteria pollutants, and mercury by the power sector. Horizontal drilling and hydraulic fracturing make the extraction of tightly bound natural gas from shale formations economically feasible. These technologies are not free from environmental risks, however, especially those related to regional water quality, such as gas migration, contaminant transport through induced and natural fractures, wastewater discharge, and accidental spills. The focus of this Review is on the current understanding of these environmental issues. Drilling multiple horizontal wells from a single well pad allows access to as much as 1 square mile of shale that is located more than a mile below. [Image courtesy of Range Resources Appalachia] Advances The most common problem with well construction is a faulty seal that is emplaced to prevent gas migration into shallow groundwater. The incidence rate of seal problems in unconventional gas wells is relatively low (1 to 3%), but there is a substantial controversy whether the methane detected in private groundwater wells in the area where drilling for unconventional gas is ongoing was caused by well drilling or natural processes. It is difficult to resolve this issue because many areas have long had sources of methane unrelated to hydraulic fracturing, and pre-drilling baseline data are often unavailable. Water management for unconventional shale gas extraction is one of the key issues that will dominate environmental debate surrounding the gas industry. Reuse of produced water for hydraulic fracturing is currently addressing the concerns regarding the vast quantities of contaminants that are brought to the surface. As these well fields mature and the opportunities for wastewater reuse diminish, the need to find alternative management strategies for this wastewater will likely intensify. Outlook Improved understanding of the fate and transport of contaminants of concern and increased long-term monitoring and data dissemination will help effectively manage water-quality risks associated with unconventional gas industry today and in the future. Confidentiality requirements dictated by legal investigations combined with the expedited rate of development and the limited funding for research are major impediments to peer-reviewed research into environmental impacts. Now is the time to work on these environmental issues to avoid an adverse environmental legacy

similar to that from abandoned coal mine discharges in Pennsylvania. Fracturing Hydrology? Hydraulic fracturing, widely known as "fracking," is a relatively inexpensive way to tap into what were previously inaccessible natural gas resources. Vidic et al. (p. 826) review the current status of shale gas development and discuss the possible threats to water resources. In one of the hotbeds of fracking activity, the Marcellus Shale in the eastern United States, there is little evidence that additives have directly entered groundwater supplies, but the risk remains. Ensuring access to monitoring data is an important first step toward addressing any public and environmental health concerns.

May 16, 2013. [*Category:* Health]

Occupational Exposures to Respirable Crystalline Silica During Hydraulic Fracturing.

- Eric J. Esswein; Michael Breitenstein; John Snawder; Max Kiefer; W. Karl Sieber.
- In: *Journal of Occupational and Environmental Hygiene*, Vol. 10, Issue 7, 2013.
- http://www.tandfonline.com/doi/abs/10.1080/15459624.2013.788352?journalCode=uoeh20#.VLmaKXvRVAI

Abstract: This report describes a previously uncharacterized occupational health hazard: work crew exposures to respirable crystalline silica during hydraulic fracturing. Hydraulic fracturing involves high pressure injection of large volumes of water and sand, and smaller quantities of well treatment chemicals, into a gas or oil well to fracture shale or other rock formations, allowing more efficient recovery of hydrocarbons from a petroleum-bearing reservoir. Crystalline silica ("frac sand") is commonly used as a proppant to hold open cracks and fissures created by hydraulic pressure. Each stage of the process requires hundreds of thousands of pounds of quartz-containing sand; millions of pounds may be needed for all zones of a well. Mechanical handling of frac sand creates respirable crystalline silica dust, a potential exposure hazard for workers. Researchers at the National Institute for Occupational Safety and Health collected 111 personal breathing zone samples at 11 sites in five states to evaluate worker exposures to respirable crystalline silica during hydraulic fracturing. At each of the 11 sites, full-shift samples exceeded occupational health criteria (e.g., the Occupational Safety and Health Administration calculated permissible exposure limit, the NIOSH recommended exposure limit, or the ACGIH threshold limit value), in some cases, by 10 or more times the occupational health criteria. Based on these evaluations, an occupational health hazard was determined to exist for workplace exposures to crystalline silica. Seven points of dust generation were identified, including sand handling machinery and dust generated from the work site itself. Recommendations to control exposures include product substitution (when feasible), engineering controls or modifications to sand handling machinery, administrative controls, and use of personal protective equipment. To our knowledge, this represents the first systematic study of work crew exposures to crystalline silica during hydraulic fracturing. Companies that conduct hydraulic fracturing using silica sand should evaluate their operations to determine the potential for worker exposure to respirable crystalline silica and implement controls as necessary to protect workers.

May 14, 2013. [*Category:* Ecology]

Migrating Mule Deer: Effects of Anthropogenically Altered Landscapes.

- Lendrum, Patrick E.; Anderson, Charles R., Jr.; Monteith, Kevin L.; Jenks, Jonathan A.; Bowyer, R. Terry.

- In: *PLOS ONE*, Vol. 8, Issue 5, article e64548 (10 pages).
- http://dx.doi.org/10.1371/journal.pone.0064548

Abstract:

Background.

Migration is an adaptive strategy that enables animals to enhance resource availability and reduce risk of predation at a broad geographic scale. Ungulate migrations generally occur along traditional routes, many of which have been disrupted by anthropogenic disturbances. Spring migration in ungulates is of particular importance for conservation planning, because it is closely coupled with timing of parturition. The degree to which oil and gas development affects migratory patterns, and whether ungulate migration is sufficiently plastic to compensate for such changes, warrants additional study to better understand this critical conservation issue.

Methodology/Principal Findings

We studied timing and synchrony of departure from winter range and arrival to summer range of female mule deer (Odocoileus hemionus) in northwestern Colorado, USA, which has one of the largest natural-gas reserves currently under development in North America. We hypothesized that in addition to local weather, plant phenology, and individual life-history characteristics, patterns of spring migration would be modified by disturbances associated with natural-gas extraction. We captured 205 adult female mule deer, equipped them with GPS collars, and observed patterns of spring migration during 2008–2010.

Conclusions/Significance

Timing of spring migration was related to winter weather (particularly snow depth) and access to emerging vegetation, which varied among years, but was highly synchronous across study areas within years. Additionally, timing of migration was influenced by the collective effects of anthropogenic disturbance, rate of travel, distance traveled, and body condition of adult females. Rates of travel were more rapid over shorter migration distances in areas of high natural-gas development resulting in the delayed departure, but early arrival for females migrating in areas with high development compared with less-developed areas. Such shifts in behavior could have consequences for timing of arrival on birthing areas, especially where mule deer migrate over longer distances or for greater durations.

May 14, 2013. [*Category:* Water Quality]

Geochemical and isotopic variations in shallow groundwater in areas of the Fayetteville Shale development, north-central Arkansas.

- Warner, Nathaniel R.; Kresse, Timothy M.; Hays, Phillip D.; Down, Adrian; Karr, Jonathan D.; Jackson, Robert B.; Vengosh, Avner.

- In: *Applied Geochemistry*, Vol. 35, August 2013, pages 207-220.
- http://www.sciencedirect.com/science/article/pii/S0883292713001133

Abstract: Exploration of unconventional natural gas reservoirs such as impermeable shale basins through the use of horizontal drilling and hydraulic fracturing has changed the energy landscape in the USA providing a vast new energy source. The accelerated production of natural gas has triggered a debate concerning the safety and possible environmental impacts of these operations. This study investigates one of the critical aspects of the environmental effects; the possible degradation of water quality in shallow aquifers overlying producing shale formations. The geochemistry of domestic groundwater wells was investigated in aquifers overlying the Fayetteville Shale in north-central Arkansas, where approximately 4000 wells have been drilled since 2004 to extract unconventional natural gas. Monitoring was performed on 127 drinking water wells and the geochemistry of major ions, trace metals, CH4 gas content and its C isotopes (δ13CCH4), and select isotope tracers (δ11B, 87Sr/86Sr, δ2H, δ18O, δ13CDIC) compared to the composition of flowback-water samples directly from Fayetteville Shale gas wells. Dissolved CH4 was detected in 63% of the drinking-water wells (32 of 51 samples), but only six wells exceeded concentrations of 0.5 mg CH4/L. The δ13CCH4 of dissolved CH4 ranged from −42.3‰ to −74.7‰, with the most negative values characteristic of a biogenic source also associated with the highest observed CH4 concentrations, with a possible minor contribution of trace amounts of thermogenic CH4. The majority of these values are distinct from the reported thermogenic composition of the Fayetteville Shale gas (δ13CCH4 = −35.4‰ to −41.9‰). Based on major element chemistry, four shallow groundwater types were identified: (1) low (<100 mg/L) total dissolved solids (TDS), (2) TDS > 100 mg/L and Ca–HCO3 dominated, (3) TDS > 100 mg/L and Na–HCO3 dominated, and (4) slightly saline groundwater with TDS > 100 mg/L and Cl > 20 mg/L with elevated Br/Cl ratios (>0.001). The Sr (87Sr/86Sr = 0.7097–0.7166), C (δ13CDIC = −21.3‰ to −4.7‰), and B (δ11B = 3.9–32.9‰) isotopes clearly reflect water–rock interactions within the aquifer rocks, while the stable O and H isotopic composition mimics the local meteoric water composition. Overall, there was a geochemical gradient from low-mineralized recharge water to more evolved Ca–HCO3, and higher-mineralized Na–HCO3 composition generated by a combination of carbonate dissolution, silicate weathering, and reverse base-exchange reactions. The chemical and isotopic compositions of the bulk shallow groundwater samples were distinct from the Na–Cl type Fayetteville flowback/produced waters (TDS ∼10,000–20,000 mg/L). Yet, the high Br/Cl variations in a small subset of saline shallow groundwater suggest that they were derived from dilution of saline water similar to the brine in the Fayetteville Shale. Nonetheless, no spatial relationship was found between CH4 and salinity occurrences in shallow drinking water wells with proximity to shale-gas drilling sites. The integration of multiple geochemical and isotopic proxies shows no direct evidence of contamination in shallow drinking-water aquifers associated with natural gas extraction from the Fayetteville Shale.

May 7, 2013. [*Category:* Water Usage]

State-scale perspective on water use and production associated with oil and gas operations, Oklahoma, U.S.

- Murray, Kyle E.
- In: *Environmental Science & Technology*, Vol. 47, Issue 9, pages 4918-4925.
- http://www.ncbi.nlm.nih.gov/pubmed/23531128

Abstract: A common goal of water and energy management is to maximize the supply of one while minimizing the use of the other, so it is important to understand the relationship between water use and energy production. A larger proportion of horizontal wells and an increasing number of hydraulically fractured well bores are being completed in the United States, and consequently increasing water demand by oil and gas operations. Management, planning, and regulatory decisions for water, oil, and gas are largely made at the state-level; therefore, it is necessary to aggregate water use and energy production data at the state-scale. The purpose of this paper is to quantify annual volumes of water used for completion of oil and gas wells, coproduced during oil and gas production, injected via underground injection program wells, and used in water flooding operations. Data from well completion reports, and tax commission records were synthesized to arrive at these estimates for Oklahoma. Hydraulic fracturing required a median fluid volume of 11,350 m^3 per horizontal well in Oklahoma. Median fluid volume (~15,774 m^3) and volume per perforated interval (15.73 m^3 m^{-1}) were highest for Woodford Shale horizontal wells. State-scale annual water use for oil and gas well completions was estimated to be up to 16.3 Mm^3 in 2011 or less than 1% of statewide freshwater use. Statewide annual produced water volumes ranged from 128.5 to 146.6 Mm^3, with gas wells yielding an estimated 72.4% of the total coproduced water. Volumes of water injected into underground injection control program wells ranged from 206.8 to 305.4 Mm^3, which indicates that water flooding operations may use up to 167.0 Mm^3 per year. State-scale water use estimates for Oklahoma could be improved by requiring oil and gas operators to supplement well completion reports with water use and water production data. Reporting of oil and gas production data by well using a unique identifier (i.e., API number) would also allow for refinement of produced water quantity information. Reporting of wastewater disposal and water flooding volumes could be used to further develop state-scale water accounting and best management practices.

April 30, 2013. [*Category:* Waste / Fluids]

Selective oxidation of bromide in wastewater brines from hydraulic fracturing.

- Sun, Mei; Lowry, Gregory V.; Gregory, Kelvin B.
- In: *Water Research*, Vol. 47, Issue 11, pages 3723-3731.
- http://www.sciencedirect.com/science/article/pii/S0043135413003709

Abstract: Brines generated from oil and natural gas production, including flowback water and produced water from hydraulic fracturing of shale gas, may contain elevated concentrations of bromide (similar to 1 g/L). Bromide is a broad concern due to the potential for forming brominated disinfection byproducts (DBPs) during drinking water treatment. Conventional treatment processes for bromide removal is costly and not specific. Selective bromide removal is technically challenging due to the presence of other ions in the brine, especially chloride as high as 30-200 g/L. This study evaluates the ability of solid graphite electrodes to selectively oxidize bromide to bromine in flowback water and produced water from a shale gas operation in Southwestern PA. The bromine can then be outgassed from the solution and recovered, as a process well understood in the bromine industry. This study revealed that bromide may be selectively and rapidly removed from oil and gas brines (similar to 10 h^{-1} m^{-2} for produced water and similar to 60 h^{-1} m^{-2} for flowback water). The electrolysis occurs with a current efficiency between 60 and 90%, and the estimated energy cost is similar to 6 kJ/g Br. These data are similar to those for the chlor-alkali process that is commonly used for chlorine gas and sodium hydroxide production. The results demonstrate that bromide may be selectively removed from oil and gas brines to create an opportunity for environmental protection and resource recovery.

April 24, 2013. [*Categories:* General (Comment / Review), Health]

Modern Natural Gas Development and Harm to Health: The Need for Proactive Public Health Policies.

- Finkel, Madelon L.; Hays, Jake; Law, Adam.
- In: *ISRN Public Health,* Vol. 2013, article 408658, 5 pages.
- http://www.hindawi.com/journals/isrn/2013/408658/

Abstract: High-volume horizontal hydraulic fracturing of shale formations has the potential to make natural gas a significant, economical energy source, but the potential for harm to human health is often dismissed by proponents of this method. While adverse health outcomes of medical conditions with long latency periods will not be evident for years and will depend on the exposure, duration of exposure, dose, and other factors, we argue that it would be prudent to begin to track and monitor trends in the incidence and prevalence of diseases that already have been shown to be influenced by environmental agents. The dirty downside of modern, unconventional natural gas development, as well as the potential for harm, is discussed.

April 23, 2013. [*Category:* Water Quality]

The Effects of Shale Gas Exploration and Hydraulic Fracturing on the Quality of Water Resources in the United States.

- Vengosh, Avner; Warner, Nathaniel; Jackson, Rob; Darrah, Tom.
- In: *Procedia Earth and Planetary Science*, Vol. 7, 2013, pages 864-866.
- http://www.sciencedirect.com/science/article/pii/S1878522013002944

Abstract: Advances in drilling technologies and production strategies such as horizontal drilling and hydraulic fracturing have significantly improved the production of natural gas by stimulating fluid flow from wells. Since 2008, these technological developments have spurred exponential growth of gas well drilling across the U.S. While the new drilling for shale gas and hydraulic fracturing technologies have dramatically changed the energy landscape in the U.S., recent scientific findings show evidence for contamination of water resources. This paper provides key observations for the potential risks of shale gas drilling and hydraulic fracturing on the quality of water resources and include: (1) stray gas contamination of shallow groundwater overlying shale gas basins; (2) pathways and hydraulic connectivity between the deep shale gas formations and the overlying shallow drinking water aquifers; and (3) inadequate disposal of produced and flowback waters associated with shale gas exploration that causes contamination of surface waters and long-term ecological effects. By using geochemical (e.g., Br/Cl) integrated with oxygen, hydrogen, strontium, radium, and boron isotopic tracers, we have characterized the geochemical fingerprints of brines from several shale gas basins in the USA, including the Utica and Marcellus brines in the Appalachian Basin and the Fayetteville brines in Arkansas. We use these geochemical fingerprints to delineate the impact of shale gas associated fluids on the environment.

April 23, 2013. [*Category:* Water Quality]

The Energy-Water Nexus: Potential Groundwater-Quality Degradation Associated with Production of Shale Gas.

- Kharak, Y. K.; Thordsen, J. J.; Conaway, C. H.; Thomas, R. B.
- In: *Procedia Earth and Planetary Science*, Vol. 7, 2013, pages 417-422.
- http://www.sciencedirect.com/science/article/pii/S1878522013002130

Abstract: Oil and natural gas have been the main sources of primary energy in the USA, providing 63% of the total energy consumption in 2011. Petroleum production, drilling operations, and improperly sealed abandoned wells have caused significant local groundwater contamination in many states, including at the USGS OSPER sites in Oklahoma. The potential for groundwater contamination is higher when producing natural gas and oil from unconventional sources of energy, including shale and tight sandstones. These reservoirs require horizontally-completed wells and massive hydraulic fracturing that injects large volumes (up to 50,000 m^3/well) of high-pressured water with added proppant, and toxic organic and inorganic chemicals. Recent results show that flow back and produced waters from Haynesville (Texas) and Marcellus (Pennsylvania) Shale have high salinities (≥200,000 mg/L TDS) and high NORMs (up to 10,000 picocuries/L) concentrations. A major research effort is needed worldwide to minimize all potential environmental impacts, especially groundwater contamination and induced seismicity, when producing these extremely important new sources of energy.

April 22, 2013. [*Category:* Health]

Is shale gas drilling an energy solution or public health crisis?

- Rafferty, Margaret A.; Limonik, Elena.
- In: *Public Health Nursing (Boston, Mass.)*, Vol. 30, Issue 5, September – October, pages 454-462.
- http://www.ncbi.nlm.nih.gov/pubmed/24000919

Abstract: High-volume horizontal hydraulic fracturing, a controversial new mining technique used to drill for shale gas, is being implemented worldwide. Chemicals used in the process are known neurotoxins, carcinogens, and endocrine disruptors. People who live near shale gas drilling sites report symptoms that they attribute to contaminated air and water. When they seek help from clinicians, a diagnosis is often elusive because the chemicals to which the patients have been exposed are a closely guarded trade secret. Many nurses have voiced grave concern about shale gas drilling safety. Full disclosure of the chemicals used in the process is necessary in order for nurses and other health professionals to effectively care for patients. The economic exuberance surrounding natural gas has resulted in insufficient scrutiny into the health implications. Nursing research aimed at determining what effect unconventional drilling has on human health could help fill that gap. Public health nurses using the precautionary principle should advocate for a more concerted transition from fossil fuels to sustainable energy. Any initiation or further expansion of unconventional gas drilling must be preceded by a comprehensive Health Impact Assessment (HIA).

April 22, 2013. [*Category:* Seismicity]

Induced seismicity and hydraulic fracturing for the recovery of hydrocarbons.

- Davies, Richard; Foulger, Gillian; Bindley, Annette; Styles, Peter.
- In: *Marine and Petroleum Geology*, Vol. 45, August 2013, pages 171-185.
- http://www.sciencedirect.com/science/article/pii/S0264817213000846

Abstract: We compile published examples of induced earthquakes that have occurred since 1929 that have magnitudes equal to or greater than 1.0. Of the 198 possible examples, magnitudes range up to 7.9. The potential causes and magnitudes are (a) mining (M 1.6–5.6); (b) oil and gas field depletion (M 1.0–7.3); (c) water injection for secondary oil recovery (M 1.9–5.1); (d) reservoir impoundment (M 2.0–7.9); (e) waste disposal (M 2.0–5.3); (f) academic research boreholes investigating induced seismicity and stress (M 2.8–3.1); (g) solution mining (M 1.0–5.2); (h) geothermal operations (M 1.0–4.6) and (i) hydraulic fracturing for recovery of gas and oil from low-permeability sedimentary rocks (M 1.0–3.8). Reactivation of faults and resultant seismicity occurs due to a reduction in effective stress on fault planes. Hydraulic fracturing operations can trigger seismicity because it can cause an increase in the fluid pressure in a fault zone. Based upon the research compiled here we propose that this could occur by three mechanisms. Firstly, fracturing fluid or displaced pore fluid could enter the fault. Secondly, there may be direct connection with the hydraulic fractures and a fluid pressure pulse could be transmitted to the fault. Lastly, due to poroelastic properties of rock, deformation or 'inflation' due to hydraulic fracturing could increase fluid pressure in the fault or in fractures connected to the fault. The following pathways for fluid or a fluid pressure pulse are proposed: (a) directly from the wellbore; (b) through new, stimulated hydraulic fractures; (c) through pre-existing fractures and minor faults; or (d) through the pore network of permeable beds or along bedding planes. The reactivated fault could be intersected by the wellbore or it could be 10s to 100s of metres from it. We propose these mechanisms have been responsible for the three known examples of felt seismicity that are probably induced by hydraulic fracturing. These are in the USA, Canada and the UK. The largest such earthquake was M 3.8 and was in the Horn River Basin, Canada. To date, hydraulic fracturing has been a relatively benign mechanism compared to other anthropogenic triggers, probably because of the low volumes of fluid and short pumping times used in hydraulic fracturing operations. These data and analysis should help provide useful context and inform the current debate surrounding hydraulic fracturing technology.

April 18, 2013. [*Category:* Health]

The use of health impact assessment for a community undergoing natural gas development.

- Witter, Roxana Z; McKenzie, Lisa; Stinson, Kaylan E.; Scott, Kenneth; Newman, Lee S.; Adgate, John.
- In: *American Journal of Public Health*, Vol. 103, Issue 6, June 2013, pages 1002-1010.
- http://ajph.aphapublications.org/doi/pdf/10.2105/AJPH.2012.301017

Abstract: The development of natural gas wells is rapidly increasing, yet little is known about associated exposures and potential public health consequences. We used health impact assessment (HIA) to provide decision-makers with information to promote public health at a time of rapid decision making for natural gas development. We have reported that natural gas development may expose local residents to air and water contamination, industrial noise and traffic, and community changes. We have provided more than 90 recommendations for preventing or decreasing health impacts associated with these exposures. We also have reflected on the lessons learned from conducting an HIA in a politically charged environment. Finally, we have demonstrated that despite the challenges, HIA can successfully enhance public health policymaking.

April 10, 2013. [*Category:* Community]

Differing opinions about natural gas drilling in two adjacent counties with different levels of drilling activity.

- Kriesky, J.; Goldstein, B.D.; Zell, K.; Beach, S.
- In: *Energy Policy*, Vol. 58, pages 228-236.
- http://www.sciencedirect.com/science/article/pii/S0301421513001596

Abstract: The pace of development of shale gas plays varies greatly among US states and globally. Through analysis of telephone survey responses, we explore support for natural gas drilling in residents of Washington County (WC), PA (n=502) vs. residents of Allegheny County (AC), PA (n=799). WC has had intense Marcellus Shale (MS) drilling activity, in comparison to adjacent AC, which has had little drilling activity. WC residents are marginally more supportive of MS drilling than are AC residents (p=0.0768). Residents of WC are more likely to perceive MS as an economic opportunity than are AC residents (p=0.0015); to be in a family that has signed a MS lease (p<0.0001); to follow the MS issue closely (p=0.0003); to get MS information from neighbors, friends, and relatives (p<0.0001); and are marginally less likely to perceive MS as an environmental threat (p=0.1090). WC leaseholders are significantly more supportive of MS drilling than WC non-leaseholders and AC non-leaseholders (p=0.0024). Mediation analyses show that county-based differences in support of MS drilling are due to WC residents seeing more of an economic opportunity in the MS and their greater likelihood of having a family-held lease.

April 8, 2013. [*Category:* General (Comment / Review)]

***Impactos en salud pública del fracking (extracción de gas por medio de la fractura hidráulica) en Espa˜na* [Public health effects of fracking (gas extraction through hydraulic fracturing) in Spain].**

- Rojas-Rueda D.
- In: *Gaceta sanitaria / S.E.S.P.A.S*, Vol. 27, Issue 4, July-August 2013, page 382.
- http://www.ncbi.nlm.nih.gov/pubmed/23578525

First Paragraph: El pasado 27 de septiembre de 2012 se publicó, en el Diario Oficial de la Generalitat de Catalunya, la solicitud de dos permisos de exploración para la extracción de gas por medio del fracking, que afecta a 70 municipios de Catalu˜na. El fracking es una técnica de extracción de gas natural no convencional, mediante la perforación de yacimientos de gas que se encuentran atrapados en un sustrato rocoso, para la cual es necesario inyectar a presión agua, arena y una mezcla de compuestos químicos.

April 6, 2013. [*Category:* General (Comment / Review)]

Emerging importance of shale gas to both the energy & chemicals landscape.

- Armor, John N.
- In: *Journal of Energy Chemistry*, Vol. 22, Issue 1, pages 21-26.
- http://www.sciencedirect.com/science/article/pii/S2095495613600029

Abstract: This perspectives article is intended highlight the growing importance and emergence of shale gas as an energy resource and as a source of chemicals. Over the next decades huge amounts of newly discovered deposits of trapped gas are expected to be produced not only in the USA but elsewhere providing a wealth of methane and ethane not only used for energy production, but also for conversion to lower hydrocarbon chemicals. This manuscript seeks to focus on the potential of trapped natural gas around the world. The potential new volumes of trapped gas within shale or other mineral strata coming to the marketplace offer a tremendous opportunity if scientists can invent new, cost effective ways to convert this methane to higher value chemicals. Understanding how to selectively break a single C–H bond in methane while minimizing methane conversion to CO_2 is critical.

April 5, 2013. [*Category:* Water Quality]

Evaluation of methane sources in groundwater in northeastern Pennsylvania.

- Molofsky, Lisa J.; Connor, John A .; Wylie, Albert S.; Wagner, Tom; Farhat, Shahla K.
- In: *Groundwater*, Vol. 51, Issue 3, pages 333-349.
- http://onlinelibrary.wiley.com/doi/10.1111/gwat.12056/abstract

Abstract: Testing of 1701 water wells in northeastern Pennsylvania shows that methane is ubiquitous in groundwater, with higher concentrations observed in valleys vs. upland areas and in association with calcium-sodium-bicarbonate, sodium-bicarbonate, and sodium-chloride rich waters-indicating that, on a regional scale, methane concentrations are best correlated to topographic and hydrogeologic features, rather than shale-gas extraction. In addition, our assessment of isotopic and molecular analyses of hydrocarbon gases in the Dimock Township suggest that gases present in local water wells are most consistent with Middle and Upper Devonian gases sampled in the annular spaces of local gas wells, as opposed to Marcellus Production gas. Combined, these findings suggest that the methane concentrations in Susquehanna County water wells can be explained without the migration of Marcellus shale gas through fractures, an observation that has important implications for understanding the nature of risks associated with shale-gas extraction.

April 2, 2013. [*Categories:* Climate, Water Usage]

Life cycle greenhouse gas emissions and freshwater consumption of Marcellus shale gas.

- Laurenzi, Ian J.; Jersey, Gilbert R.
- In: *Environmental Science & Technology*, Vol. 47, Issue 9, pages 4896-4903.
- http://pubs.acs.org/doi/abs/10.1021/es305162w

Abstract: We present results of a life cycle assessment (LCA) of Marcellus shale gas used for power generation. The analysis employs the most extensive data set of any LCA of shale gas to date, encompassing data from actual gas production and power generation operations. Results indicate that a typical Marcellus gas life cycle yields 466 kg CO2eq/MWh (80% confidence interval: 450-567 kg CO2eq/MWh) of greenhouse gas (GHG) emissions and 224 gal/MWh (80% CI: 185-305 gal/MWh) of freshwater consumption. Operations associated with hydraulic fracturing constitute only 1.2% of the life cycle GHG emissions, and 6.2% of the life cycle freshwater consumption. These results are influenced most strongly by the estimated ultimate recovery (EUR) of the well and the power plant efficiency: increase in either quantity will reduce both life cycle freshwater consumption and GHG emissions relative to power generated at the plant. We conclude by comparing the life cycle impacts of Marcellus gas and U.S. coal: The carbon footprint of Marcellus gas is 53% (80% CI: 44-61%) lower than coal, and its freshwater consumption is about 50% of coal. We conclude that substantial GHG reductions and freshwater savings may result from the replacement of coal-fired power generation with gas-fired power generation.

April 1, 2013. [*Category:* Water Quality]

Estimating Wastewater Impacts from Fracking.

- Schmidt, Charles W.
- In: *Environmental Health Perspectives*, Vol. 121, Issue 4, page 117 ff.
- http://www.ncbi.nlm.nih.gov/pmc/articles/PMC3620738/

Extract: Wastewater produced by hydraulic fracturing ("fracking") for natural gas in the Marcellus Shale is already overwhelming disposal options and will continue to do so as gas development increases, according to newly published research. The investigation did not evaluate environmental consequences of the wastewater. But lead author Brian Lutz, an assistant professor in the Kent State University Department of Biology, says fracking wastewater could have a range of environmental and health impacts if not managed correctly. The analysis was limited to Pennsylvania, which along with West Virginia dominates Marcellus shale gas production today.

April 2013. [*Category:* Water Quality]

Analysis of BTEX groundwater concentrations from surface spills associated with hydraulic fracturing operations.

- Gross, Sherilyn A.; Avens, Heather J.; Banducci, Amber M.; Sahmel, Jennifer; Panko, Julie M.; Tvermoes, Brooke E.

- In: *Journal of the Air & Waste Management Association (1995),* Vol. 63, Issue 4, pages 424-432.
- http://www.ncbi.nlm.nih.gov/pubmed/23687727

Abstract: Concerns have arisen among the public regarding the potential for drinking-water contamination from the migration of methane gas and hazardous chemicals associated with hydraulic fracturing and horizontal drilling. However, little attention has been paid to the potential for groundwater contamination resulting from surface spills from storage and production facilities at active well sites. We performed a search for publically available data regarding groundwater contamination from spills at ULS. drilling sites. The Colorado Oil and Gas Conservation Commission (COGCC) database was selected for further analysis because it was the most detailed. The majority of spills were in Weld County, Colorado, which has the highest density of wells that used hydraulic fracturing for completion, many producing both methane gas and crude oil. We analyzed publically available data reported by operators to the COGCC regarding surface spills that impacted groundwater From July 2010 to July 2011, we noted 77 reported surface spills impacting the groundwater in Weld County, which resulted in surface spills associated with less than 0.5% of the active wells. The reported data included groundwater samples that were analyzed for benzene, toluene, ethylbenzene, andxylene (BTEX) components of crude oil. For groundwater samples taken both within the spill excavation area and on the first reported date of sampling, the BTEX measurements exceeded National Drinking Water maximum contaminant levels (MCLs) in 90, 30, 12, and 8% of the samples, respectively. However, actions taken to remediate the spills were effective at reducing BJTEX levels, with at least 84% of the spills reportedly achieving remediation as of May 2012. Our analysis demonstrates that surface spills are an important route of potential groundwater contamination from hydraulic fracturing activities and should be a focus of programs to protect groundwater.

IMPLICATIONS: While benzene can occur naturally in groundwater sources, spills and migration of chemicals used for hydraulic fracturing activities have recently been thought to be a main source of benzene contamination in groundwater. However, there is little scientific literature to support that claim. Therefore, we accessed a publically available database and tracked the number of reported surface spills with potential groundwater impact over a 1-year period. Although the number of surface spills was minimal, our analysis provides scientific evidence that benzene can contaminate groundwater sources following surface spills at active well sites.

March 26, 2013. [*Category:* Seismicity]

Potentially induced earthquakes in Oklahoma, USA: Links between wastewater injection and the 2011 M_w 5.7 earthquake sequence.

- Keranen, Katie M.; Savage, Heather M.; Abers, Geoffrey A.; Cochran, Elizabeth S.
- In: *Geology*, Vol. 41, pages 699-702.
- http://geology.geoscienceworld.org/content/early/2013/03/26/G34045.1.abstract

Abstract: Significant earthquakes are increasingly occurring within the continental interior of the United States, including five of moment magnitude (Mw) ≥ 5.0 in 2011 alone. Concurrently, the volume of fluid injected into the subsurface related to the production of unconventional resources continues to rise. Here we identify the largest earthquake potentially related to injection, an Mw 5.7 earthquake in November 2011 in Oklahoma. The earthquake was felt in at least 17 states and caused damage in the epicentral region. It occurred in a sequence, with 2 earthquakes of Mw 5.0 and a prolific sequence of aftershocks. We use the aftershocks to illuminate the faults that ruptured in the sequence, and show that the tip of the initial rupture plane is within ~200 m of active injection wells and within ~1 km of the surface; 30% of early aftershocks occur within the sedimentary section. Subsurface data indicate that fluid was injected into effectively sealed compartments, and we interpret that a net fluid volume increase after 18 yr of injection lowered effective stress on reservoir-bounding faults. Significantly, this case indicates that decades-long lags between the commencement of fluid injection and the onset of induced earthquakes are possible, and modifies our common criteria for fluid-induced events. The progressive rupture of three fault planes in this sequence suggests that stress changes from the initial rupture triggered the successive earthquakes, including one larger than the first.

March 26, 2013. [*Category:* Water Quality]

Shale gas development impacts on surface water quality in Pennsylvania.

- Olmstead, Sheila M.; Muehlenbachs, Lucija A.; Shih, Jhih-Shyang; Chu, Ziyan; Krupnick, Alan J.
- In: *Proceedings of the National Academy of Sciences of the United States of America*, Vol. 110, Issue 13, pages 4962-4967.
- http://www.ncbi.nlm.nih.gov/pubmed/23479604

Abstract: Concern has been raised in the scientific literature about the environmental implications of extracting natural gas from deep shale formations, and published studies suggest that shale gas development may affect local groundwater quality. The potential for surface water quality degradation has been discussed in prior work, although no empirical analysis of this issue has been published. The potential for large-scale surface water quality degradation has affected regulatory approaches to shale gas development in some US states, despite the dearth of evidence. This paper conducts a large-scale examination of the extent to which shale gas development activities affect surface water quality. Focusing on the Marcellus Shale in Pennsylvania, we estimate the effect of shale gas wells and the release of treated shale gas waste by permitted treatment facilities on observed downstream concentrations of chloride (Cl(-)) and total suspended solids (TSS), controlling for other factors. Results suggest that (i) the treatment of shale gas waste by treatment plants in a watershed raises downstream Cl(-) concentrations but not TSS concentrations, and (ii) the presence of shale gas wells in a watershed raises downstream TSS concentrations but not Cl(-) concentrations. These results can inform future voluntary measures taken by shale gas operators and policy approaches taken by regulators to protect surface water quality as the scale of this economically important activity increases.

March 22, 2013. [*Category:* Economics]

MENA's growing natural gas deficit and the issue of domestic prices.

- Darbouche, Hakim
- In: *Energy Strategy Reviews*, Vol. 2, Issue pages 116-121.
- http://www.sciencedirect.com/science/article/pii/S2211467X13000291

Abstract: Demand for natural gas in most countries of the Middle East and North Africa (MENA) region has, since the start of the 2000s, been growing at a much faster rate than supply, resulting in a costly deficit. The issue of domestic gas prices, which are kept at artificially-low levels by MENA governments, is a key feature of the region's gas supply–demand picture. This contribution analyses the political economy logic informing domestic gas pricing policies in the MENA region and argues that unless these are revised to take account of the new regional gas market realities, MENA's role in international gas markets will in future be more that of a growing demand and import centre than as a major source of new supply. It argues that, in spite of its limitations and short-term failures, the recent Iranian pricing reform experiment is a useful case study from which lessons can be learnt for other countries in the region.

March 20, 2013. [*Category:* Air Quality]

Ozone photochemistry in an oil and natural gas extraction region during winter: simulations of a snow-free season in the Uintah Basin, Utah.

- Edwards, P. M.; Young, C. J.; Aikin, K.; deGouw, J. A.; Dubé, W. P.; Geiger, F.; Gilman, J. B.; Helmig, D.; Holloway, J. S.; Kercher, J.; Lerner, B.; Martin, R.; McLaren, R.; Parrish, D. D.; Peischl, J.; Roberts, J. M.; Ryerson, T. B.; Thornton, J.; Warneke, C.; Williams, E. J.; Brown, S. S.
- In: *Atmospheric Chemistry and Physics Discussions*, Vol. 13, Issue 3, pages 7503-7552.
- http://www.atmos-chem-phys.net/13/8955/2013/acp-13-8955-2013.html

Abstract. The Uintah Basin in northeastern Utah, a region of intense oil and gas extraction, experienced ozone (O_3) concentrations above levels harmful to human health for multiple days during the winters of 2009–2010 and 2010–2011. These wintertime O_3 pollution episodes occur during cold, stable periods when the ground is snow-covered, and have been linked to emissions from the oil and gas extraction process. The Uintah Basin Winter Ozone Study (UBWOS) was a field intensive in early 2012, whose goal was to address current uncertainties in the chemical and physical processes that drive wintertime O_3 production in regions of oil and gas development. Although elevated O_3 concentrations were not observed during the winter of 2011–2012, the comprehensive set of observations tests our understanding of O_3 photochemistry in this unusual emissions environment. A box model, constrained to the observations and using the near-explicit Master Chemical Mechanism (MCM) v3.2 chemistry scheme, has been used to investigate the sensitivities of O_3 production during UBWOS 2012. Simulations identify the O_3 production photochemistry to be highly radical limited (with a radical production rate significantly smaller than the NO_x emission rate). Production of OH from O_3 photolysis (through reaction of $O(^1D)$ with water vapor) contributed only 170 pptv day^{-1}, 8% of the total primary radical source on average (primary radicals being those produced from non-radical precursors). Other radical sources, including the photolysis of formaldehyde (HCHO, 52%), nitrous acid (HONO, 26%), and nitryl chloride ($ClNO_2$, 13%) were larger. O_3 production was also found to be highly sensitive to aromatic volatile organic compound (VOC) concentrations, due to radical amplification reactions in the oxidation scheme of these species. Radical production was shown to be small in comparison to the emissions of nitrogen oxides (NO_x), such that NO_x acted as the primary radical sink. Consequently, the system was highly VOC sensitive, despite the much larger mixing ratio of total non-methane hydrocarbons (230 ppbv (2080 ppbC), 6 week average) relative to NO_x (5.6 ppbv average). However, the importance of radical sources which are themselves derived from NO_x emissions and chemistry, such as $ClNO_2$ and HONO, make the response of the system to changes in NO_x emissions uncertain. Model simulations attempting to reproduce conditions expected during snow-covered cold-pool conditions show a significant increase in O_3 production, although calculated concentrations do not achieve the highest seen during the 2010–2011 O_3 pollution events in the Uintah Basin. These box model simulations provide useful insight into the chemistry controlling winter O_3 production in regions of oil and gas extraction.

March 19, 2013. [*Category:* Waste / Fluids]

Spatial and temporal correlation of water quality parameters of produced waters from devonian-age shale following hydraulic fracturing.

- Barbot, Elise; Vidic, Natasa S.; Gregory, Kelvin B.; Vidic, Radisav D.
- In: *Environmental Science & Technology*, Issue 6, pages 2562-2569.
- http://www.ncbi.nlm.nih.gov/pubmed/23425120

Abstract: The exponential increase in fossil energy production from Devonian-age shale in the Northeastern United States has highlighted the management challenges for produced waters from hydraulically fractured wells. Confounding these challenges is a scant availability of critical water quality parameters for this wastewater. Chemical analyses of 160 flowback and produced water samples collected from hydraulically fractured Marcellus Shale gas wells in Pennsylvania were correlated with spatial and temporal information to reveal underlying trends. Chloride was used as a reference for the comparison as its concentration varies with time of contact with the shale. Most major cations (i.e., Ca, Mg, Sr) were well-correlated with chloride concentration while barium exhibited strong influence of geographic location (i.e., higher levels in the northeast than in southwest). Comparisons against brines from adjacent formations provide insight into the origin of salinity in produced waters from Marcellus Shale. Major cations exhibited variations that cannot be explained by simple dilution of existing formation brine with the fracturing fluid, especially during the early flowback water production when the composition of the fracturing fluid and solid-liquid interactions influence the quality of the produced water. Water quality analysis in this study may help guide water management strategies for development of unconventional gas resources.

March 16, 2013. [*Category:* Economics]

Unconventional gas – A review of regional and global resource estimates.

- McGlade, Christophe; Speirs, Jamie; Sorrell, Steve.
- In: *Energy*, Vol. 55, June 15, 2013, pages 571-584.
- http://www.sciencedirect.com/science/article/pii/S0360544213000790

Abstract: It is increasingly claimed that the world is entering a 'golden age of gas', with the exploitation of unconventional resources expected to transform gas markets around the world. But the future development of these resources is subject to multiple uncertainties, particularly with regard to the size and recoverability of the physical resource. This paper assesses the currently available evidence on the size of unconventional gas resources at both the regional and global level. Focussing in particular on shale gas, it first explores the meaning and appropriate interpretation of the various terms and definitions used in resource estimation and then summarises and compares the different regional and global estimates that have been produced to date. It shows how these estimates have increased over time and highlights their variability, the wide range of uncertainty and the inadequate treatment of this uncertainty by most studies. The paper also addresses coal bed methane and tight gas and identifies those estimates that appear to be most robust for each region. The paper concludes that unconventional gas could represent 40% of the remaining technically recoverable resource of natural gas, but the level of uncertainty is extremely high and the economically recoverable resource could be substantially smaller.

March 15, 2013. [*Category:* Waste / Fluids]

Wastewater management and Marcellus Shale gas development: Trends, drivers, and planning implications.

- Rahm, Brian G.; Bates, Josephine T.; Bertoia, Lara R.; Galford, Amy E.; Yoxtheimer, David A.; Riha, Susan J.
- In: *Journal of Environmental Management*, Vol. 120, pages 105-113.
- http://www.sciencedirect.com/science/article/pii/S0301479713001175

Abstract: Extraction of natural gas from tight shale formations has been made possible by recent technological advances, including hydraulic fracturing with horizontal drilling. Global shale gas development is seen as a potential energy and geopolitical "game-changer." However, widespread concern exists with respect to possible environmental consequences of this development, particularly impacts on water resources. In the United States, where the most shale gas extraction has occurred, the Marcellus Shale is now the largest natural gas producing play. To date, over 6,000,000 m^3 of wastewater has been generated in the process of extracting natural gas from this shale in the state of Pennsylvania (PA) alone. Here we examine wastewater management practices and trends for this shale play through analysis of industry-reported, publicly available data collected from the Pennsylvania Department of Environmental Protection Oil and Gas Reporting Website. We also analyze the tracking and transport of shale gas liquid waste streams originating in PA using a combination of web-based and GIS approaches. From 2008 to 2011 wastewater reuse increased, POTW use decreased, and data tracking became more complete, while the average distance traveled by wastewater decreased by over 30%. Likely factors influencing these trends include state regulations and policies, along with low natural gas prices. Regional differences in wastewater management are influenced by industrial treatment capacity, as well as proximity to injection disposal capacity. Using lessons from the Marcellus Shale, we suggest that nations, states, and regulatory agencies facing new unconventional shale development recognize that pace and scale of well drilling leads to commensurate wastewater management challenges. We also suggest they implement wastewater reporting and tracking systems, articulate a policy for adapting management to evolving data and development patterns, assess local and regional wastewater treatment infrastructure in terms of capacity and capability, promote well-regulated on-site treatment technologies, and review and update wastewater management regulations and policies.

March 15, 2013. [*Category:* Economics]

Fuel Prices, Emission Standards, and Generation Costs for Coal vs Natural Gas Power Plants.

- Pratson, Lincoln F.; Haerer, Drew; Patiño-Echeverri, Dalia.
- In: *Environmental Science & Technology*, Vol. 47, Issue 9, pages 4926-4933.
- http://dx.doi.org/10.1021/es4001642

Abstract: Low natural gas prices and stricter, federal emission regulations are promoting a shift away from coal power plants and toward natural gas plants as the lowest-cost means of generating electricity in the United States. By estimating the cost of electricity generation (COE) for 304 coal and 358 natural gas plants, we show that the economic viability of 9% of current coal capacity is challenged by low natural gas prices, while another 56% would be challenged by the stricter emission regulations. Under the current regulations, coal plants would again become the dominant least-cost generation option should the ratio of average natural gas to coal prices (NG2CP) rise to 1.8 (it was 1.42 in February 2012). If the more stringent emission standards are enforced, however, natural gas plants would remain cost competitive with a majority of coal plants for NG2CPs up to 4.3.

March 14, 2013. [*Categories:* Waste / Fluids, Water Quality]

Assessment of effluent contaminants from three facilities discharging Marcellus Shale wastewater to surface waters in Pennsylvania.

- Ferrar, Kyle J.; Michanowicz, Drew R.; Christen, Charles L.; Mulcahy, Ned; Malone, Samantha L; Sharma, Ravi K.
- In: *Environmental Science & Technology*, Vol. 47, Issue 7, pages 3472-3481.
- Attachment Details

Abstract: Unconventional natural gas development in Pennsylvania has created a new wastewater stream. In an effort to stop the discharge of Marcellus Shale unconventional natural gas development wastewaters into surface waters, on May 19, 2011 the Pennsylvania Department of Environmental Protection (PADEP) requested drilling companies stop disposing their wastewater through wastewater treatment plants (WWTPs). This research includes a chemical analysis of effluents discharged from three WWTPs before and after the aforementioned request. The WWTPs sampled included two municipal, publicly owned treatment works and a commercially operated industrial wastewater treatment plant. Analyte concentrations were quanitified and then compared to water quality criteria, including U.S. Environmental Protection Agency MCLs and "human health criteria." Certain analytes including barium, strontium, bromides, chlorides, total dissolved solids, and benzene were measured in the effluent at concentrations above criteria. Analyte concentrations measured in effluent samples before and after the PADEP's request were compared for each facility. Analyte concentrations in the effluents decreased in the majority of samples after the PADEP's request ($p < .05$). This research provides preliminary evidence that these and similar WWTPs may not be able to provide sufficient treatment for this wastewater stream, and more thorough monitoring is recommended.

March 12, 2013. [*Category:* Community]

There's no real choice but to sign: neoliberalization and normalization of hydraulic fracturing on Pennsylvania farmland.

- Malin, Stephanie.
- In: *Journal of Environmental Studies and Sciences*, Vol. 4, Issue 1, March 2014, pages 17-27.
- http://link.springer.com/article/10.1007/s13412-013-0115-2

Abstract: Finewood and Stroup (J Contemp Water Res Educ 147(1), 72–79, *2012*) observe that as hydraulic fracturing for natural gas spreads across the USA, neoliberal ideologies normalize fracking's potential dangers, including impacts to water and more general environmental quality. Theoretical observations like these must be tested empirically. I do so here, analyzing data from extensive fieldwork in Pennsylvania's Bradford, Susquehanna, and Washington counties. Drawing on comparative mixed method data from fieldwork in northeastern Pennsylvania's 'Endless Mountains' region and the Pittsburgh area, I compare how small-scale farmers perceive and sometimes enact elements of market-based, neoliberal rationality when assessing hydrofracking's community, environmental, and economic outcomes. This paper explores why this matters sociologically, given small-scale farmers' roles as land-use decision-makers, stewards of related natural resource development, and marginalized producers with limited access to market shares and subsidies. In counties like Bradford and Washington, impacts of fracking small-scale farmers have been under-studied. To address that gap, I examine impacts on farmers operating around natural gas development and within neoliberal economic structures. Analyzing extensive interview and ethnographic data, the following research questions are addressed: (1) Among small-scale farmers impacted by hydraulic fracturing, what evidence exists that neoliberal logic helps farmers normalize fracking? and (2) How does normalization interact with decisions to sign natural gas leases? My findings indicate that many farmers utilize neoliberal logic when assessing impacts of hydraulic fracturing and shale gas development, particularly as rapid energy development relates to their land-use decisions. Neoliberal normalization of hydraulic fracturing emerges most saliently regarding environmental outcomes and economic development. I connect this to small-scale farmers' economic vulnerability and the limited agency in dictating land use near their farms.

March 11, 2013. [*Category:* Air Quality]

Regional air quality impacts of increased natural gas production and use in Texas.

- Pacsi, Adam P.; Alhajeri, Nawaf S.; Zavala-Araiza, Daniel; Webster, Mort D.; Allen, David T.
- In: *Environmental Science & Technology*, Vol. 47, Issue 7, pages 3521-3527.
- http://www.ncbi.nlm.nih.gov/pubmed/23441728

Abstract: Natural gas use in electricity generation in Texas was estimated, for gas prices ranging from $1.89 to $7.74 per MMBTU, using an optimal power flow model. Hourly estimates of electricity generation, for individual electricity generation units, from the model were used to estimate spatially resolved hourly emissions from electricity generation. Emissions from natural gas production activities in the Barnett Shale region were also estimated, with emissions scaled up or down to match demand in electricity generation as natural gas prices changed. As natural gas use increased, emissions decreased from electricity generation and increased from natural gas production. Overall, NOx and SO2 emissions decreased, while VOC emissions increased as natural gas use increased. To assess the effects of these changes in emissions on ozone and particulate matter concentrations, spatially and temporally resolved emissions were used in a month-long photochemical modeling episode. Over the month-long photochemical modeling episode, decreases in natural gas prices typical of those experienced from 2006 to 2012 led to net regional decreases in ozone (0.2-0.7 ppb) and fine particulate matter (PM) (0.1-0.7 $\mu g/m^3$). Changes in PM were predominantly due to changes in regional PM sulfate formation. Changes in regional PM and ozone formation are primarily due to decreases in emissions from electricity generation. Increases in emissions from increased natural gas production were offset by decreasing emissions from electricity generation for all the scenarios considered.

February 20, 2013. [*Category:* General (Comment / Review)]

Energy: A reality check on the shale revolution.

- Hughes, J. David.
- In: *Nature*, Vol. 494, Issue 7437, pages 307-308.
- http://www.nature.com/nature/journal/v494/n7437/full/494307a.html

Extract: The ‘shale revolution’ – the extraction of gas and oil from previously inaccessible reservoirs – has been declared an energy game changer. It is offsetting declines in conventional oil and gas production, with shale gas being heralded as a transition fuel to a low-carbon future, and shale oil as being capable of reinstating the United States as the largest oil producer in the world, eliminating the need for foreign imports … The claims do not stand up to scrutiny. In a report published this week by the Post Carbon Institute in Santa Rosa, California, I analyse 30 shale-gas and 21 tight-oil fields (or ‘plays’) in the United States, and reveal that the shale revolution will be hard to maintain.

February 12, 2013. [*Category:* General (Comment / Review)]

Focus on the development of shale gas in China—Based on SWOT analysis.

- Xingang, Zhao; Jiaoli, Kang; Bei, Lan.
- In: *Renewable and Sustainable Energy Reviews*, Vol. 21, May 2013, pages 603-613.
- http://www.sciencedirect.com/science/article/pii/S1364032112007496

Abstract: As an unconventional natural gas with the advantages of great resource potential and low carbon emissions, shale gas has currently aroused a new round of development and utilization worldwide. China's shale gas resource is enormous and has huge potential for exploitation. However, due to the late start of exploration and development, it has not yet realized industrialization. By using the SWOT analysis method, this paper studies the internal and external development environment of Chinese shale gas, then explores shale gas development status of China from four dimensions including strengths, weaknesses, opportunities and threats. Finally, according to the combinations of SWOT matrix analysis, the paper formulates four kinds of different development strategies to provide certain references to the development of China's shale gas industry.

February 8, 2013. [*Category:* Waste / Fluids]

Generation, transport, and disposal of wastewater associated with Marcellus Shale gas development.

- Lutz, Brian D.; Lewis, Aurana N.; Doyle, Martin W.
- In: *Water Resources Research*, Vol. 49, Issue 2, pages 647-656.
- http://onlinelibrary.wiley.com/doi/10.1002/wrcr.20096/abstract

Abstract: Hydraulic fracturing has made vast quantities of natural gas from shale available, reshaping the energy landscape of the United States. Extracting shale gas, however, generates large, unavoidable volumes of wastewater, which to date lacks accurate quantification. For the Marcellus shale, by far the largest shale gas resource in the United States, we quantify gas and wastewater production using data from 2189 wells located throughout Pennsylvania. Contrary to current perceptions, Marcellus wells produce significantly less wastewater per unit gas recovered (approximately 35%) compared to conventional natural gas wells. Further, well operators classified only 32.3% of wastewater from Marcellus wells as flowback from hydraulic fracturing; most wastewater was classified as brine, generated over multiple years. Despite producing less wastewater per unit gas, developing the Marcellus shale has increased the total wastewater generated in the region by approximately 570% since 2004, overwhelming current wastewater disposal infrastructure capacity.

February 4, 2013. [*Category:* Economics]

Economic appraisal of shale gas plays in Continental Europe.

- Weijermars, Ruud.
- In: *Applied Energy*, Vol. 106, June 2013, pages 100-115.
- http://www.sciencedirect.com/science/article/pii/S0306261913000342

Abstract: This study evaluates the economic feasibility of five emergent shale gas plays on the European Continent. Each play is assessed using a uniform field development plan with 100 wells drilled at a rate of 10 wells/year in the first decade. The gas production from the realized wells is monitored over a 25 year life cycle. Discounted cash flow models are used to establish for each shale field the estimated ultimate recovery (EUR) that must be realized, using current technology cost, to achieve a profit. Our analyses of internal rates of return (IRR) and net present values (NPVs) indicate that the Polish and Austrian shale plays are the more robust, and appear profitable when the strict P90 assessment criterion is applied. In contrast, the Posidonia (Germany), Alum (Sweden) and a Turkish shale play assessed all have negative discounted cumulative cash flows for P90 wells, which puts these plays below the hurdle rate. The IRR for P90 wells is about 5% for all three plays, which suggests that a 10% improvement of the IRR by sweet spot targeting may lift these shale plays above the hurdle rate. Well productivity estimates will become better constrained over time as geological uncertainty is reduced and as technology improves during the progressive development of the shale gas fields.

January 31, 2013. [*Category:* Air Quality, Economics]

Estimation of regional air-quality damages from Marcellus Shale natural gas extraction in Pennsylvania.

- Litovitz, Aviva; Curtright, Aimee; Abramzon, Shmuel; Burger, Nicholas; Samaras, Constantine.
- In: *Environmental Research Letters*, Vol. 8, Issue 1.
- http://iopscience.iop.org/1748-9326/8/1/014017

Abstract: This letter provides a first-order estimate of conventional air pollutant emissions, and the monetary value of the associated environmental and health damages, from the extraction of unconventional shale gas in Pennsylvania. Region-wide estimated damages ranged from $7.2 to $32 million dollars for 2011. The emissions from Pennsylvania shale gas extraction represented only a few per cent of total statewide emissions, and the resulting statewide damages were less than those estimated for each of the state's largest coal-based power plants. On the other hand, in counties where activities are concentrated, NOx emissions from all shale gas activities were 20–40 times higher than allowable for a single minor source, despite the fact that individual new gas industry facilities generally fall below the major source threshold for NOx. Most emissions are related to ongoing activities, i.e., gas production and compression, which can be expected to persist beyond initial development and which are largely unrelated to the unconventional nature of the resource. Regulatory agencies and the shale gas industry, in developing regulations and best practices, should consider air emissions from these long-term activities, especially if development occurs in more populated areas of the state where per-ton emissions damages are significantly higher.

January 22, 2013. [*Category:* Ecology]

Hydraulic Fracturing and Brook Trout Habitat in the Marcellus Shale Region: Potential Impacts and Research Needs.

- Weltman-Fahs, Maya; Taylor, Jason M.

- In: *Fisheries*, Vol. 38, Issue 1, pages 4-15.
- http://www.tandfonline.com/doi/abs/10.1080/03632415.2013.750112

Abstract: Expansion of natural gas drilling into the Marcellus Shale formation is an emerging threat to the conservation and restoration of native brook trout (Salvelinus fontinalis) populations. Improved drilling and extraction technologies (horizontal drilling and hydraulic fracturing) have led to rapid and extensive natural gas development in areas overlying the Marcellus Shale. The expansion of hydraulic fracturing poses multiple threats to surface waters, which can be tied to key ecological attributes that limit brook trout populations. Here, we expand current conceptual models to identify three potential pathways of risk between surface water threats associated with increased natural gas development and life history attributes of brook trout: hydrological, physical, and chemical. Our goal is to highlight research needs for fisheries scientists and work in conjunction with resource managers to influence the development of strategies that will preserve brook trout habitat and address Marcellus Shale gas development threats to eastern North America's only native stream salmonid.

January 18, 2013. [*Category:* Community]

The Relationship between Marcellus Shale Gas Development in Pennsylvania and Local Perceptions of Risk and Opportunity.

- Schafft, Kai A.; Borlu, Yetkin; Glenna, Leland.
- In: *Rural Sociology*, Vol. 78, Issue 2, pages 143-166.
- http://onlinelibrary.wiley.com/doi/10.1111/ruso.12004/abstract

Abstract: Recent advances in gas and oil drilling technology have led to dramatic boomtown development in many rural areas that have endured extended periods of economic decline. In Pennsylvania's Marcellus gas fields, the recent development of unconventional shale gas resources has not been without controversy. It has been variously framed as a major opportunity for economic revitalization at the local and regional levels and energy independence at the national level, but also as a significant environmental risk, with uncertain and uneven economic benefits. We use data from a survey conducted in 309 school districts located within Pennsylvania's Marcellus Shale region to study the ways local stakeholders perceive both risk and opportunity associated with gas extraction from Marcellus Shale. Our analyses indicate that there is a strong positive association between perceptions of risk and opportunity associated with gas extraction. Further, the intensity of perception of both risk and opportunity is directly associated with the amount of local drilling, suggesting the complexity of local contexts within which local stakeholders evaluate rapid boomtown-associated community change. In total, these findings complicate the framing of unconventional gas extraction in the Marcellus Shale region, and indeed boomtown growth overall, as fundamentally polarizing issues.

January 18, 2013. [*Category:* General (Comment / Review)]

Gas fracking: can we safely squeeze the rocks?

- Peduzzi, P.; Harding, R.
- In: *Environmental Development*, Vol. 6, April 2013, pages 86-99.
- http://www.sciencedirect.com/science/article/pii/S2211464512001480

Extract: Hydrological fracturing techniques have made accessible vast unconventional gas reserves. However, observed impacts on the environment and human health raise legitimate public concerns. The potential climate benefits of coal-to-gas substitution are both less clear and more limited than initially claimed. The question of whether to allow or ban gas fracking needs to be carefully assessed by relevant authorities. A review of current related policies and regulations is critically needed.

January 16, 2013. [*Category:* Air Quality]

Reply to comment on "Hydrocarbon emissions characterization in the Colorado Front Range—A pilot study" by Michael A. Levi.

- Pétron, Gabrielle; Frost, Gregory J.; Trainer, Michael K.; Miller, Benjamin R.; Dlugokencky, Edward J.; Tans, Pieter.

- In: *Journal of Geophysical Research*, Vol. 118, Issue 1, pages 236-242.
- http://onlinelibrary.wiley.com/doi/10.1029/2012JD018487/abstract

Abstract: The Comment by Levi (2012) on our paper, Pétron et al. (2012), presents a different interpretation of the atmospheric data and inventory estimates we used to derive our conclusions about methane emissions from oil and natural gas development in the Denver-Julesburg Basin (DJB) in Weld County, Colorado. Levi's (2012) Comment brings up new issues that point to the need for additional information. We maintain the value of the results derived in Pétron et al. (2012), particularly that vented and fugitive methane emissions from Weld County's fossil fuel exploration and production in 2008 were likely larger and more uncertain than values reported by emission inventories. Our findings rely on the interpretation of high-quality atmospheric observations using existing inventory data provided by the industry and regulatory agencies and on reasonable assumptions about the average vented raw gas composition. However, Levi (2012) has caused us to extend our analysis and to better characterize the uncertainties associated with his and with our approaches. In this Reply, we examine some critical limitations of the Pétron et al. (2012) and Levi (2012) interpretations of the atmospheric data using simple, two-source emission models that incorporate inventory data sets of unknown reliability. We present new evidence that the regulatory estimates of flashing emission and regulatory modeled composition profiles for a limited number of condensate tanks, the starting point for the calculations of Pétron et al. (2012) and Levi (2012), probably do not represent the true range of these parameters for the thousands of such sources across the DJB in 2008. The results of Levi (2012) suggest that leakage in Weld County in 2008 was biased toward dry gas wells, which disagrees with current inventories of venting and fugitive emissions in U.S. oil and gas fields, including the DJB. Most importantly, the indirect flux derivations undertaken by Levi (2012) and Pétron et al. (2012) highlight two inherent shortcomings common to most emissions inventories: their reliance on the extrapolation of very limited information and the difficulty in carrying out a full uncertainty analysis of such datasets. We agree with Levi (2012) that there is an urgent need to statistically document the composition profiles and magnitudes of significant sources in oil- and gas-producing fields. Observations-based methods with established uncertainties and that are completely independent of inventory information could directly quantify emission strengths and compositions of both point and aggregated area sources, providing an objective assessment of inventory methodology and estimates.

January 16, 2013. [*Category:* Water Quality]

Potential Contaminant Pathways from Hydraulically Fractured Shale to Aquifers.

- Cohen, Harvey A.; Parratt, Toomas; Andrews, Charles B.
- In: *Groundwater*, Vol. 51, Issue 3, pages 317-319.
- http://onlinelibrary.wiley.com/doi/10.1111/gwat.12015/abstract

January 14, 2013. [*Category:* Air Quality]

Source Signature of Volatile Organic Compounds from Oil and Natural Gas Operations in Northeastern Colorado.

- Gilman, J. B.; Lerner, B. M.; Kuster, W. C.; de Gouw, J. A.
- In: *Environmental Science & Technology*, Vol. 47, Issue 3, pages 1297-1305.
- http://dx.doi.org/10.1021/es304119a

Abstract: An extensive set of volatile organic compounds (VOCs) was measured at the Boulder Atmospheric Observatory (BAO) in winter 2011 in order to investigate the composition and influence of VOC emissions from oil and natural gas (O&NG) operations in northeastern Colorado. BAO is 30 km north of Denver and is in the southwestern section of Wattenberg Field, one of Colorado's most productive O&NG fields. We compare VOC concentrations at BAO to those of other U.S. cities and summertime measurements at two additional sites in northeastern Colorado, as well as the composition of raw natural gas from Wattenberg Field. These comparisons show that (i) the VOC source signature associated with O&NG operations can be clearly differentiated from urban sources dominated by vehicular exhaust, and (ii) VOCs emitted from O&NG operations are evident at all three measurement sites in northeastern Colorado. At BAO, the reactivity of VOCs with the hydroxyl radical (OH) was dominated by C_2–C_6 alkanes due to their remarkably large abundances (e.g., mean propane = 27.2 ppbv). Through statistical regression analysis, we estimate that on average 55 ± 18% of the VOC–OH reactivity was attributable to emissions from O&NG operations indicating that these emissions are a significant source of ozone precursors.

January 11, 2013. [*Category:* General (Comment / Review)]

Production data analysis of unconventional gas wells: Review of theory and best practices.

- Clarkson, C. R.
- In: *International Journal of Coal Geology*, Vol. 109-110, pages 101-146.
- http://www.sciencedirect.com/science/article/pii/S0166516213000050

Abstract: Unconventional gas reservoirs, including coalbed methane (CBM), tight gas (TG) and shale gas (SG), have become a significant source of hydrocarbon supply in North America, and interest in these resource plays has been generated globally. Despite a growing exploitation history, there is still much to be learned about fluid storage and transport properties of these reservoirs. A key task of petroleum engineers and geoscientists is to use historical production (reservoir fluid production rate histories, and cumulative production) for the purposes of 1) reservoir and well stimulation characterization and 2) production forecasting for reserve estimation and development planning. Both of these subtasks fall within the domain of quantitative production data analysis (PDA). PDA can be performed analytically, where physical models are applied to historical production and flowing pressure data to first extract information about the reservoir (i.e. hydrocarbon-in-place, permeability-thickness product) and stimulation (i.e. skin or hydraulic fracture properties) and then generate a forecast using a model that has been "calibrated" to the dynamic data (i.e. rates and pressures). Analytical production data analysis methods, often referred to as rate-transient analysis (RTA), utilize concepts analogous to pressure-transient analysis (PTA) for their implementation, and hence have a firm grounding in the physics of fluid storage and flow. Empirical methods, such as decline curve analysis, rely on empirical curve fits to historical production data, and projections to the future. These methods do not rigorously account for dynamic changes in well operating conditions (i.e. flowing pressures), or reservoir or fluid property changes. Quantitative PDA is now routinely applied for conventional reservoirs, where the physics of fluid storage and flow are relatively well-understood. RTA has evolved extensively over the past four decades, and empirical methods are now applied with constraints and "rules of thumb" developed by researchers with some confidence. For unconventional reservoirs, these techniques continue to evolve according to our improved understanding of the physics of fluid storage and flow. In this article, the latest techniques for quantitative PDA including type-curve analysis, straight-line (flow-regime) analysis, analytical and numerical simulation and empirical methods are briefly reviewed, specifically addressing their adaptation for CBM and SG reservoirs. Simulated and field examples are provided to demonstrate application. It is hoped that this article will serve as practical guide to production analysis for unconventional reservoirs as well as reveal the latest advances in these techniques.

January 3, 2013. [*Category:* Regulation]

An Analysis of Unconventional Gas Well Reporting under Pennsylvania's Act 13 of 2012.

- Gehman, Joel; Mastroianni, Diego; Grant, Angela; Etzion, Dror.
- In: *Environmental Practice*, Vol. 14, Issue 4, pages 262-277 (December 2012).
- http://journals.cambridge.org/action/displayAbstract?fromPage=online&aid=8789198&fileId=S1466046612000373

Abstract: In response to growing concerns about the impact of shale gas development, Pennsylvania's Act 13 of 2012 established an unconventional gas well fee and required the state's Department of Environmental Protection (DEP) to report on the number of such wells. In this article, we analyze the extent to which the DEP complied with its reporting requirements under Act 13. Using publicly available data, we find that the DEP likely omitted between 15,300 and 25,100 unconventional gas wells from its Act 13 report. Left uncorrected, we estimate that Pennsylvania's state, county, and municipal governments could forfeit fees of $205–$303 million in 2012 and up to $0.75–$1.85 billion cumulatively over the expected life of these wells. Rather than an isolated incident, evidence suggests that information management is a systemic and recurring problem within the DEP and its predecessor agencies. We propose the implementation of a relational database and geographic information system as a way for the DEP to fulfill its Act 13 obligations.

January 1, 2013. [*Category:* Health]

Using Ethnography to Monitor the Community Health Implications of Onshore Unconventional Oil and Gas Developments: Examples from Pennsylvania's Marcellus Shale.

- Perry, Simona L.
- In: *NEW SOLUTIONS: A Journal of Environmental and Occupational Health Policy*, Vol. 23, Issue 1, pages 33-53.
- http://baywood.metapress.com/openurl.asp?genre=article&id=doi:10.2190/NS.23.1.d

Abstract: The ethnographer's toolbox has within it a variety of methods for describing and analyzing the everyday lives of human beings that can be useful to public health practitioners and policymakers. These methods can be employed to uncover information on some of the harder-to-monitor psychological, sociocultural, and environmental factors that may lead to chronic stress in individuals and communities. In addition, because most ethnographic research studies involve deep and long-term engagement with local communities, the information collected by ethnographic researchers can be useful in tracking long- and short-term changes in overall well-being and health. Set within an environmental justice framework, this article uses examples from ongoing ethnographic fieldwork in the Marcellus Shale gas fields of Pennsylvania to describe and justify using an ethnographic approach to monitor the psychological and sociocultural determinants of community health as they relate to unconventional oil and gas development projects in the United States.

January 1, 2013. [*Category:* Economics]

The Economic Impact of Shale Gas Development on State and Local Economies: Benefits, Costs, and Uncertainties.

- Barth, Jannette M.
- In: *NEW SOLUTIONS: A Journal of Environmental and Occupational Health Policy*, Vol. 23, Issue 1, pages 85-101.
- http://baywood.metapress.com/openurl.asp?genre=article&id=doi:10.2190/NS.23.1.f

Abstract: It is often assumed that natural gas exploration and development in the Marcellus Shale will bring great economic prosperity to state and local economies. Policymakers need accurate economic information on which to base decisions regarding permitting and regulation of shale gas extraction. This paper provides a summary review of research findings on the economic impacts of extractive industries, with an emphasis on peer-reviewed studies. The conclusions from the studies are varied and imply that further research, on a case-by-case basis, is necessary before definitive conclusions can be made regarding both short- and long-term implications for state and local economies.

January 1, 2013. [*Category:* Health]

Public Health and High Volume Hydraulic Fracturing.

- Korfmacher, Katrina Smith; Jones, Walter A.; Malone, Samantha L.; Vinci, Leon F.
- In: *NEW SOLUTIONS: A Journal of Environmental and Occupational Health Policy*, Vol. 23, Issue 1, pages 13-31.
- http://baywood.metapress.com/openurl.asp?genre=article&id=doi:10.2190/NS.23.1.c

Abstract: High-volume horizontal hydraulic fracturing (HVHF) in unconventional gas reserves has vastly increased the potential for domestic natural gas production. HVHF has been promoted as a way to decrease dependence on foreign energy sources, replace dirtier energy sources like coal, and generate economic development. At the same time, activities related to expanded HVHF pose potential risks including ground- and surface water contamination, climate change, air pollution, and effects on worker health. HVHF has been largely approached as an issue of energy economics and environmental regulation, but it also has significant implications for public health. We argue that public health provides an important perspective on policymaking in this arena. The American Public Health Association (APHA) recently adopted a policy position for involvement of public health professionals in this issue. Building on that foundation, this commentary lays out a set of five perspectives that guide how public health can contribute to this conversation.

January 1, 2013. [*Category:* Regulation]

Historical Analysis of Oil and Gas Well Plugging in New York: Is the Regulatory System Working?

- Bishop, Ronald E.
- In: *NEW SOLUTIONS: A Journal of Environmental and Occupational Health Policy*, Vol. 23, Issue 1, pages 103-116.
- http://baywood.metapress.com/openurl.asp?genre=article&id=doi:10.2190/NS.23.1.g & http://baywood.metapress.com/media/e2eygjquvndvwxvrlh87/contributions/b/0/4/7/b047j34r87552325.pdf

Abstract: The aim of this work was to evaluate New York State's regulatory program for plugging inactive oil and gas wells. Analysis of reports from the Division of Mineral Resources, Department of Environmental Conservation, reveals that three-fourths of the state's abandoned oil and gas wells were never plugged. Inadequate enforcement efforts have resulted in steady increases of unplugged oil and gas wells abandoned since 1992. Further, no program exists or is proposed to monitor abandoned wells which were plugged. These results strongly suggest that comprehensive reform and increased agency resources would be required to effectively regulate conventional oil and gas development in New York. Industrial expansion into shale oil and gas development should be postponed to avoid adding stress to an already compromised regulatory system.

January 1, 2013. [*Category:* Health]

Investigating Links between Shale Gas Development and Health Impacts Through a Community Survey Project in Pennsylvania.

- Steinzor, Nadia; Subra, Wilma; Sumi, Lisa.
- In: *NEW SOLUTIONS: A Journal of Environmental and Occupational Health Policy*, Vol. 23, Issue 1, pages 55-83.
- http://baywood.metapress.com/openurl.asp?genre=article&id=doi:10.2190/NS.23.1.e

Abstract: Across the United States, the race for new energy sources is picking up speed and reaching more places, with natural gas in the lead. While the toxic and polluting qualities of substances used and produced in shale gas development and the general health effects of exposure are well established, scientific evidence of causal links has been limited, creating an urgent need to understand health impacts. Self-reported survey research documenting the symptoms experienced by people living in proximity to gas facilities, coupled with environmental testing, can elucidate plausible links that warrant both response and further investigation. This method, recently applied to the gas development areas of Pennsylvania, indicates the need for a range of policy and research efforts to safeguard public health.

January 1, 2013. [*Category:* Economics]

Estimating Willingness to Pay for River Amenities and Safety Measures Associated with Shale Gas Extraction.

- Bernstein, Paula; Kinnaman, Thomas C.; Wu, Mengqi.
- In: *Eastern Economic Journal*, Vol. 39, Issue 1, pages 28-44.
- http://www.jstor.org/stable/23524238

Abstract: This research was funded by the Susquehanna Heartland Coalition for Environmental Studies (SHCES), an organization that "exists to promote collaboration in research, provide environmental education, improve water quality, and address other environmental concerns related to the Susquehanna River Watershed." All statements and conclusions expressed in this manuscript do not represent the views of SHCES or those of Bucknell University. Neither SHCES nor Bucknell influenced the writing of this document or assumed any editing authority. This paper utilizes a Contingent Valuation Method survey of a random sample of residents to estimate that households are willing to pay an average of US$12.00 per month for public projects designed to improve river access and US$10.46 per month for additional safety measures that would eliminate risks to local watersheds from drilling for natural gas from underground shale formations. These estimates can be compared with the costs of providing each of these two amenities to help foster the formation of efficient policy decisions.

January 1, 2013. [*Category:* General (Comment / Review)]

Science and Politics of Shale Gas Extraction.

- Bamberger, Michelle; Oswald, Robert E.
- In: *NEW SOLUTIONS: A Journal of Environmental and Occupational Health Policy*, Vol. 23, Issue 1, pages 7-12.
- http://baywood.metapress.com/openurl.asp?genre=article&id=doi:10.2190/NS.23.1.b

Extract (page 10): The question of whether industrialized gas drilling has affected our food supply is an important unresolved issue. One of the reasons for our lack of information about this issue is that farming is by definition a decentralized process without detailed public recordkeeping. Madelon Finkel and collaborators have used what data are available to study the changes in the dairy industry in Pennsylvania, comparing those counties with extensive gas drilling to those with little or none. Using data from the United States Department of Agriculture's National Agricultural Statistics Service and the Pennsylvania Department of Environmental Protection, the authors showed that both milk production and numbers of dairy cows began decreasing in 1996, but that larger decreases were seen between 2007 and 2011 in those counties with intensive gas drilling compared to those with little drilling. Although causal relationships are difficult to establish in studies such as this, the paper emphasizes the importance of considering the effects on the dairy industry when hydrocarbon extraction impacts large portions of a particular region of the country (e.g., the Marcellus and Utica Shales in the northeast United States).

January 1, 2013. [*Category:* General (Comment / Review)]

Insights on Unconventional Natural Gas Development from Shale: An Interview with Anthony R. Ingraffea.

- Law, Adam; Hays, Jake.
- In: *NEW SOLUTIONS: A Journal of Environmental and Occupational Health Policy*, Vol. 23, Issue 1, pages 203-208.
- http://baywood.metapress.com/openurl.asp?genre=article&id=doi:10.2190/NS.23.1.l

Abstract: Adam Law, M.D., interviewed Anthony R. Ingraffea, Ph.D., P.E., as part of a series of interviews funded by the Heinz Endowment. Dr. Ingraffea is the Dwight C. Baum Professor of Engineering at Cornell University, and has taught structural mechanics, finite element methods, and fracture mechanics at Cornell for 33 years. He discusses issues related to hydraulic fracturing, including inherent risks, spatial intensity, and the importance of a multi-disciplinary organization in establishing a chain of evidence.

January 1, 2013. [*Category:* Health]

Navigating Medical Issues in Shale Territory.

- Saberi, Pouné
- In: *NEW SOLUTIONS: A Journal of Environmental and Occupational Health Policy*, Vol. 23, Issue 1, pages 209-221.
- http://baywood.metapress.com/openurl.asp?genre=article&id=doi:10.2190/NS.23.1.m

Abstract: The introduction of natural gas drilling with high-volume hydraulic fracturing to Pennsylvania and neighboring states since 2004 has been accompanied by numerous reports of varied symptoms and illnesses by those living near these operations. Pollutants with established toxic effects in humans may be introduced into the environment at various points during gas extraction and processing. Some community residents, as well as employees of the natural gas industry, believe that their health has deteriorated as a result of these operations and have sought medical care from local practitioners, who may have limited access to immediate toxicological consultations. This article reviews taking an environmental exposure history in the context of natural gas activities, underscoring the importance of thorough and guided history-taking in the discovery of environmental exposure clusters. It also highlights the critical need for funding, research, and peer-reviewed studies to help generate the body of evidence that is needed by practitioners.

January 1, 2013. [*Category:* Water Quality]

Community-Based Risk Assessment of Water Contamination from High-Volume Horizontal Hydraulic Fracturing.

- Penningroth, Stephen M.; Yarrow, Matthew M.; Figueroa, Abner X.; Bowen, Rebecca J.; Delgado, Soraya.
- In: *New Solutions: A Journal of Environmental and Occupational Health Policy*, Vol. 23, Issue 1, pages 137-166.
- http://baywood.metapress.com/openurl.asp?genre=article&id=doi:10.2190/NS.23.1.i

Abstract: The risk of contaminating surface and groundwater as a result of shale gas extraction using high-volume horizontal hydraulic fracturing (fracking) has not been assessed using conventional risk assessment methodologies. Baseline (pre-fracking) data on relevant water quality indicators, needed for meaningful risk assessment, are largely lacking. To fill this gap, the nonprofit Community Science Institute (CSI) partners with community volunteers who perform regular sampling of more than 50 streams in the Marcellus and Utica Shale regions of upstate New York; samples are analyzed for parameters associated with HVHHF. Similar baseline data on regional groundwater comes from CSI's testing of private drinking water wells. Analytic results for groundwater (with permission) and surface water are made publicly available in an interactive, searchable database. Baseline concentrations of potential contaminants from shale gas operations are found to be low, suggesting that early community-based monitoring is an effective foundation for assessing later contamination due to fracking.

January 1, 2013. [*Category:* General (Comment / Review)]

Challenges of Unconventional Shale Gas Development: So What's the Rush.

- Goldstein, Bernard; Bjerke, Elizabeth Ferrell; Kriesky, Jill.
- In: *Notre Dame Journal of Law, Ethics & Public Policy*, Vol. 27, Issue 1, pages 149-186.
- http://scholarship.law.nd.edu/ndjlepp/vol27/iss1/7

Excerpts: Exploitation of previously inaccessible shale gas deposits is beginning to have a major impact on energy utilization in the United States. U.S. shale gas production increased from 1.0 trillion cubic feet in 2006 to 4.8 trillion cubic feet in 2010. Shale gas accounted for 23% of U.S. natural gas production in 2010 and is projected to increase to 49% of production by 2035. Similar growth is predicted in many other countries, with China believed to have the largest shale gas reserves.

The advancing technology for shale gas extraction from previously inaccessible sites has resulted from research and development funded by the U.S. Department of Energy (DOE) and by the individual companies, and is being adopted globally in the many countries which have shale gas reserves. Increased natural gas production in the U.S. is projected to cause significant job growth and to have positive national security implications. Natural gas production is also viewed as environmentally advantageous, primarily because it replaces coal in power plants, thereby reducing emissions of sulfur oxides, particulates, and mercury. The greater efficiency of burning natural gas in power plants results in less carbon dioxide emissions than does coal, but the value of unconventional shale gas development (UGD) in avoiding climate change is unclear as methane is itself a potent greenhouse gas and the extent to which it will leak into the atmosphere during the drilling and distribution process is under debate. Also of concern is the extent to which the plentiful availability of natural gas will slow down movement toward a low-carbon world. Both major U.S. political parties support shale gas development.

Stepping back from this predominantly positive picture, we ask what might be the appropriate speed to extract the nation's shale gas. We suggest considering the risks and benefits of unconventional shale gas extraction in much the same way that we would consider the risks and benefits of the marketing of a new chemical agent or a new drug in which costs and benefits are carefully considered prior to approval. The time element provides an additional reason to proceed slowly with respect to shale gas. Shale gas is a limited resource. The supply of natural gas in identified tight shale deposits in the U.S. will last perhaps two to five decades before it runs out. It is not a new surgical technology or wonder drug that once deployed will always be available, nor is it a newly developed chemical product with socially valuable uses that may continue for an indefinite time. We all recognize that it is tragic for people to die just before the cure for their disease becomes available. But will it be a tragedy if the window for exploitation of shale gas is delayed by a few years and simply extends that much longer?

We approach the subject by providing overviews of three different areas which are among those for which we believe more consideration of short-term issues would help maximize the benefits of UGD: direct health and environmental risks related to toxicology and safety issues; indirect effects on communities, including social disruption and attendant health impacts; and inefficiencies due to lack of clarity in the laws pertinent to the potential adverse consequences of shale gas drilling on the environment—particularly at the local level. For all three we will be describing paths forward. Our focus will be on the state of Pennsylvania, which has aggressively exploited its tight shale gas deposits. We begin by providing an overview of UGD and proceed to describe the confusion generated by industry's success in steering the debate to focus on the wrong questions. We also briefly consider the precautionary principle and sustainability in relation to shale gas development. We conclude by briefly comparing the current situation with UGD to the approach to drugs and medical devices under the Food, Drug, and Cosmetic Act (FDCA), and to new chemicals under the Toxic Substances Control Act (TSCA).

January 1, 2013. [*Category:* Waste / Fluids]

Analysis of Reserve Pit Sludge from Unconventional Natural Gas Hydraulic Fracturing and Drilling Operations for the Presence of Technologically Enhanced Naturally Occurring Radioactive Material (TENORM).

- Rich, Alisa L.; Crosby, Ernest C.
- In: *New Solutions: A Journal of Environmental and Occupational Health Policy*, Vol. 23, Number 1, pages 117-135 (special fracking issue).
- http://baywood.metapress.com/openurl.asp?genre=article&id=doi:10.2190/NS.23.1.h

Abstract: Soil and water (sludge) obtained from reserve pits used in unconventional natural gas mining was analyzed for the presence of technologically enhanced naturally occurring radioactive material (TENORM). Samples were analyzed for total gamma, alpha, and beta radiation, and specific radionuclides: beryllium, potassium, scandium, cobalt, cesium, thallium, lead-210 and -214, bismuth-212 and -214, radium-226 and -228, thorium, uranium, and strontium-89 and -90. Laboratory analysis confirmed elevated beta readings recorded at 1329 ± 311 pCi/g. Specific radionuclides present in an active reserve pit and the soil of a leveled, vacated reserve pit included ^{232}Thorium decay series (^{228}Ra, ^{228}Th, ^{208}Tl), and ^{226}Radium decay series (^{214}Pb, ^{214}Bi, ^{210}Pb) radionuclides. The potential for impact of TENORM to the environment, occupational workers, and the general public is presented with potential health effects of individual radionuclides. Current oversight, exemption of TENORM in federal and state regulations, and complexity in reporting are discussed.

January 2013. [*Category:* Economics]

Marcellus Shale Drilling's Impact on the Dairy Industry in Pennsylvania: A Descriptive Report.

- Finkel, Madelon L.; Selegean, Jane; Hays, Jake; Kondamudi, Nitin.
- In: *New Solutions: A Journal of Environmental and Occupational Health Policy: NS*, Vol. 23, Issue 1, pages 189-201.
- http://baywood.metapress.com/app/home/contribution.asp?referrer=parent&backto=issue,11,13;journal,9,95;linkingpublicationresults,1:300327,1

Abstract: Unconventional natural gas drilling in Pennsylvania has accelerated over the past five years, and is unlikely to abate soon. Dairy farming is a large component of Pennsylvania's agricultural economy. This study compares milk production, number of cows, and production per cow in counties with significant unconventional drilling activity to that in neighboring counties with less unconventional drilling activity, from 1996 through 2011. Milk production and milk cows decreased in most counties since 1996, with larger decreases occurring from 2007 through 2011 (when unconventional drilling increased substantially) in five counties with the most wells drilled compared to six adjacent counties with fewer than 100 wells drilled. While this descriptive study cannot draw a causal association between well drilling and decline in cows or milk production, given the importance of Pennsylvania's dairy industry and the projected increase in unconventional natural gas drilling, further research to prevent unintended economic and public health consequences is imperative.

December 13, 2012. [*Category:* General (Comment / Review)]

Environmental Reviews and Case Studies: Addressing the Societal Costs of Unconventional Oil and Gas Exploration and Production: A Framework for Evaluating Short-Term, Future, and Cumulative Risks and Uncertainties of Hydrofracking.

- Perry, Simona L.
- In: *Environmental Practice*, Vol. 14, Issue 4, pages 352-365.
- http://journals.cambridge.org/action/displayAbstract?fromPage=online&aid=8789189&fileId=S1466046612000336

Abstract: This article proposes a framework for addressing societal costs—psychological, social, community, and human health risks and uncertainties—associated with natural gas extraction and production from tight shale, tight sand, or coal-bed methane formations that use hydraulic fracturing processes. The US Environmental Protection Agency's 2011–14 study of hydraulic fracturing and the risks posed to drinking-water resources is used as a case study of how such a framework could be applied. This report also discusses some of the current regulatory and institutional barriers that make incorporation of societal costs into science-based and proactive decisions regarding unconventional oil and gas exploration and production in the United States more difficult and recommends some general steps for getting past those barriers.

December 12, 2012. [*Category:* Waste / Fluids]

Oil and Gas Produced Water Management and Surface Drinking Water Sources in Pennsylvania.

- Wilson, Jessica M.; VanBriesen, Jeanne M.
- In: *Environmental Practice*, Vol. 14, Issue 4, pages 288-300.
- http://journals.cambridge.org/action/displayAbstract?fromPage=online&aid=8789213

Abstract: Produced water from oil and gas development requires management to avoid negative public health effects, particularly those associated with dissolved solids and bromide in drinking water. Rapidly expanding drilling in the Marcellus Shale in Pennsylvania has significantly increased the volume of produced water that must be managed. Produced water management may include treatment followed by surface water discharge, such as at publically owned wastewater treatment plants (POTWs) or centralized brine treatment plants (CWTs). The use of POTWs and CWTs that discharge partially treated produced water has the potential to increase salt loads to surface waters significantly. These loads may cause unacceptably high concentrations of dissolved solids or bromide in source waters, particularly when rivers are at low-flow conditions. The present study evaluates produced water management in Pennsylvania from 2006 through 2011 to determine whether surface water discharges were sufficient to cause salt or bromide loads that would negatively affect drinking water sources. The increase in produced water that occurred in 2008 in Pennsylvania was accompanied by an increase in use of CWTs and POTWs that were exempt from discharge limits on dissolved solids. Estimates of salt loads associated with produced water and with discharges from CWTs and POTWs in 2008 and 2009 indicate that more than 50% of the total dissolved solids in the produced water generated in those years were released to surface water systems. Especially during the low-flow conditions of 2008 and 2009, these loads would be expected to affect drinking water.

December 10, 2012. [*Category:* Water Quality]

Reply to Engelder: Potential for fluid migration from the Marcellus Formation remains possible.

- Warner, Nathaniel R.; Jackson, Robert B.; Darrah, Thomas H.; Osborn, Stephen G.; Down, Adrian; Zhao, Kaiguang; White, Alissa; Vengosh, Avner.
- In: *Proceedings of the National Academy of Sciences*, Vol. 109, Issue 52, page E3626.
- http://www.pnas.org/content/109/52/E3626

Extract: Engelder's letter argues that the sequestration of hydraulic fracturing fluids (HFFs) and brines by imbibition and capillary binding seals the Marcellus Formation and precludes the flow of fluids into overlying formations. This apparently conflicts with our study suggesting that natural connectivity exists between the Marcellus Formation and shallow aquifers in northeastern Pennsylvania.

First, considerable data show that the Marcellus Formation is not "dry," as Engelder suggests. Data from many Marcellus Formation shale-gas wells show that produced water is highly saline [total dissolved solids (TDS) exceeding 250,000 mg/L]. These concentrations are ∼10-fold the salinity of seawater and include elevated Br/Cl and Ca/Cl ratios, a combination that indicates residual evaporated …

December 10, 2012. [*Categories:* Waste / Fluids, Water Quality]

Capillary tension and imbibition sequester frack fluid in Marcellus gas shale.

- Engelder, Terry.
- In: *Proceedings of the National Academy of Sciences*, Vol. 109, Issue 52, page 3625.
- http://www.pnas.org/content/109/52/E3625

Full Text: In a recent issue of PNAS, Warner et al. (1) interpreted local ground water chemistry in the Appalachian Basin as a signal for cross-formational pathways where natural migration of brine from the deep formations may be ongoing today. The implication of this paper is that the Marcellus is leaking now naturally, without any human assistance, and that if water-based fluid is injected into these cross-formational pathways, that leakage, which is already "contaminating" the aquifers with salt, could be made much worse.

During large-scale tectonic events more than 250 million years ago, deep-basin brine migrated into fractures of the Marcellus (2). Despite brine penetration during tectonics, the Marcellus pore space has so little free brine that water saturation is ∼23 ± 10% (1 SD) based on regional wireline analysis, calibrated to core, for >340 wells. Such low water saturation leads to capillary binding that will not allow entrained brine to leak upward naturally into shallow groundwater thousands of feet higher in the stratigraphic section.

This brine bound within the Marcellus by capillary tension serves as the tight seal over very large Oriskany gas storage fields in New York and Pennsylvania. The Marcellus maintains an initial pressure head of >0.7 psi/ft. Such high gas pressure means that even if natural fractures within the Marcellus contain brine, they remain sealed.

Further, natural gas is buoyant, and therefore far more mobile and likely to migrate than deep-basin brine. The gas in the Marcellus today is highly overpressured (>0.85 psi/ft in places), as can happen when trapped firmly by a capillary seal. Evidence that gas is not leaking upward at a meaningful rate comes from the difference in isotope geochemistry of Marcellus gas and that from the Upper Devonian section in this area of the basin. If gas were leaking even a little over the past 200 million years, it would now be all gone.

Introducing 104 m3 of fracking fluid per horizontal well seems sizable, but only less than half of it returns after drilling, and this half is gradually salinized by what little free brine from the Marcellus comes in contact with the frack fluid. Drawing brine into a Marcellus well from the Onondaga Limestone below can cause extreme salinization in flow-back. Where does the rest of the frack fluid go if not returned to the surface during flow-back and production? With natural fractures commonly 1 m apart, imbibition of water by capillary forces driving just 5 cm of matrix penetration could sequester the remaining charge of fracking fluid in a matrix porosity of about 1%, only a fraction of the porosity in gas shale.† Not only is the Marcellus unlikely to leak natural brine through capillary seals, but imbibition ensures that fluids left in the Marcellus will be sequestered permanently.

For those concerned that stimulation by hydraulic fracturing could reopen deep-seated fractures and then move either gas or liquid up thousands of feet on a human time scale, the operation of capillary tension causing imbibition in the Marcellus makes this unlikely.

December 7, 2012. [*Category:* Waste/Fluids]

Production and Disposal of Waste Materials from Gas and Oil Extraction from the Marcellus Shale Play in Pennsylvania.

- Maloney, Kelly O.; Yoxtheimer, David A.
- In: *Environmental Practice*, Vol. 14, Issue 4, pages 278-287.
- http://journals.cambridge.org/article_S146604661200035X

Abstract: The increasing world demand for energy has led to an increase in the exploration and extraction of natural gas, condensate, and oil from unconventional organic-rich shale plays. However, little is known about the quantity, transport, and disposal method of wastes produced during the extraction process. We examined the quantity of waste produced by gas extraction activities from the Marcellus Shale play in Pennsylvania for 2011. The main types of wastes included drilling cuttings and fluids from vertical and horizontal drilling and fluids generated from hydraulic fracturing [i.e., flowback and brine (formation) water]. Most reported drill cuttings (98.4%) were disposed of in landfills, and there was a high amount of interstate (49.2%) and interbasin (36.7%) transport. Drilling fluids were largely reused (70.7%), with little interstate (8.5%) and interbasin (5.8%) transport. Reported flowback water was mostly reused (89.8%) or disposed of in brine or industrial waste treatment plants (8.0%) and largely remained within Pennsylvania (interstate transport was 3.1%) with little interbasin transport (2.9%). Brine water was most often reused (55.7%), followed by disposal in injection wells (26.6%), and then disposed of in brine or industrial waste treatment plants (13.8%). Of the major types of fluid waste, brine water was most often transported to other states (28.2%) and to other basins (9.8%). In 2011, 71.5% of the reported brine water, drilling fluids, and flowback was recycled: 73.1% in the first half and 69.7% in the second half of 2011. Disposal of waste to municipal sewage treatment plants decreased nearly 100% from the first half to second half of 2011. When standardized against the total amount of gas produced, all reported wastes, except flowback sands, were less in the second half than the first half of 2011. Disposal of wastes into injection disposal wells increased 129.2% from the first half to the second half of 2011; other disposal methods decreased. Some issues with data were uncovered during the analytical process (e.g., correct geospatial location of disposal sites and the proper reporting of end use of waste) that obfuscated the analyses; correcting these issues will help future analyses.

December 4, 2012. [*Category:* Regulation]

Regulation of Water Pollution from Hydraulic Fracturing in Horizontally-Drilled Wells in the Marcellus Shale Region, USA.

- Hatzenbuhler, Heather; Centner, Terence J.
- In: *Water*, Vol. 4, Issue 4, pages 983-994.
- http://www.mdpi.com/2073-4441/4/4/983

Abstract: Hydraulic fracturing is an industrial process used to extract fossil fuel reserves that lie deep underground. With the introduction of horizontal drilling, new commercial sources of energy have become available. Wells are drilled and injected with large quantities of water mixed with specially selected chemicals at high pressures that allow petroleum reserves to flow to the surface. While the increased economic activities and the outputs of domestic energy are welcomed, there is growing concern over negative environmental impacts from horizontal drilling in shale formations. The potential for water contamination, land destruction, air pollution, and geologic disruption has raised concerns about the merits of production activities used during extraction. This paper looks at the impacts of horizontal drilling using hydraulic fracturing on water supplies and takes a comprehensive look at legislative and regulatory approaches to mitigate environmental risks in the Marcellus shale region. The overview identifies shortcomings associated with regulatory controls by local and state governments and offers two policy suggestions to better protect waters of the region.

December 3, 2012. [*Category:* General (Comment / Review)]

Global Prospects for the Development of Unconventional Gas.

- Bocora, Jan.
- In: *Procedia – Social and Behavioral Sciences*, Vol. 65, December 3, 2012, pages 436-442.
- http://www.sciencedirect.com/science/article/pii/S1877042812051300

Abstract: The fast and large-scale development of unconventional natural gas in North America created a new geopolitical and economic situation in the world. Discovery of large deposits of shale gas triggered a quiet revolution on the local market. Unconventional gas in its various forms has also been found in other parts of the world, giving an opportunity for many countries to lower their import dependence and strengthen their energy security. The rise of unconventional forms of oil and gas and a fast shift from the traditional producers to plentiful domestic resources could present the beginning of a new era in global energy affairs. But the extraction of these resources has also been marked by different attitudes of political elites, business representatives and the public, mostly because of their economic and environmental impacts. In this paper, we will focus on the global perspective of the development of unconventional gas based on the assessment of relevant risks and implications on a global scale.

November 27, 2012. [*Category:* General (Comment / Review)]

Energy (in)security in Poland the case of shale gas.

- Johnson, Corey; Boersma, Tim.
- In: *Energy Policy*, Vol. 53, February 2013, pages 389-399.
- http://www.sciencedirect.com/science/article/pii/S0301421512009536

Abstract: The large scale extraction of natural gas from shale rock layers in North America using hydraulic fracturing, or "fracking", has prompted geologists, economists and politicians in various parts of the world to ask whether there are new reserves of this precious resource to be found under their soils. It has also raised a host of questions about the potential environmental impacts of extracting it. Drawing on research on both sides of the Atlantic, this paper assesses the most pressing issues for research and policy makers related to shale gas extraction. The paper first provides a survey of environmental and economic issues related to shale gas. It then turns to a case study of Poland, whose policy makers have been among the most fervent proponents of shale gas development in the European Union. We examine the status of shale gas extraction in that country and what the barriers are to overcome before commercial extraction can in fact take place, if at all.

November 27, 2012. [*Category:* Economics]

Quantifying the health and environmental benefits of wind power to natural gas.

- McCubbin, Donald; Sovacool, Benjamin K.
- In: *Energy Policy*, Vol. 53, February 2013, pages 429-441.
- http://www.sciencedirect.com/science/article/pii/S030142151200969X

Abstract: How tangible are the costs of natural gas compared to the benefits of one of the fastest growing sources of electricity – wind energy – in the United States? To answer this question, this article calculates the benefits of wind energy derived from two locations: the 580 MW wind farm at Altamont Pass, CA, and the 22 MW wind farm in Sawtooth, ID. Both wind farms have environmental and economic benefits that should be considered when evaluating the comparative costs of natural gas and wind energy. Though there are uncertainties within the data collected, for the period 2012–2031, the turbines at Altamont Pass will likely avoid anywhere from $560 million to $4.38 billion in human health and climate related externalities, and the turbines at Sawtooth will likely avoid $18 million to $104 million of human health and climate-related externalities. Translating these negative externalities into a cost per kWh of electricity, we estimate that Altamont will avoid costs of 1.8–11.8 cents/kWh and Sawtooth will avoid costs of 1.5–8.2 cents/kWh.

November 27, 2012. [*Category:* General (Comment / Review)]

Shale gas vs. coal: Policy implications from environmental impact comparisons of shale gas, conventional gas, and coal on air, water, and land in the United States.

- Jenner, Steffen; Lamadrid, Alberto J.
- In: *Energy Policy*, Vol. 53, pages 442-453.
- http://www.sciencedirect.com/science/article/pii/S0301421512009755

Abstract: The aim of this paper is to examine the major environmental impacts of shale gas, conventional gas and coal on air, water, and land in the United States. These factors decisively affect the quality of life (public health and safety) as well as local and global environmental protection. Comparing various lifecycle assessments, this paper will suggest that a shift from coal to shale gas would benefit public health, the safety of workers, local environmental protection, water consumption, and the land surface. Most likely, shale gas also comes with a smaller GHG footprint than coal. However, shale gas extraction can affect water safety. This paper also discusses related aspects that exemplify how shale gas can be more beneficial in the short and long term. First, there are technical solutions readily available to fix the most crucial problems of shale gas extraction, such as methane leakages and other geo-hazards. Second, shale gas is best equipped to smoothen the transition to an age of renewable energy. Finally, this paper will recommend hybrid policy regulations.

November 26, 2012. [*Category:* Climate]

Shale gas production: potential versus actual greenhouse gas emissions.

- O'Sullivan, Francis; Paltsev, Sergey.
- In: *Environmental Research Letters*, Vol. 7, Issue 4, page 044030.
- http://iopscience.iop.org/1748-9326/7/4/044030

Abstract: Estimates of greenhouse gas (GHG) emissions from shale gas production and use are controversial. Here we assess the level of GHG emissions from shale gas well hydraulic fracturing operations in the United States during 2010. Data from each of the approximately 4000 horizontal shale gas wells brought online that year are used to show that about 900 Gg CH4 of potential fugitive emissions were generated by these operations, or 228 Mg CH4 per well—a figure inappropriately used in analyses of the GHG impact of shale gas. In fact, along with simply venting gas produced during the completion of shale gas wells, two additional techniques are widely used to handle these potential emissions: gas flaring and reduced emission 'green' completions. The use of flaring and reduced emission completions reduce the levels of actual fugitive emissions from shale well completion operations to about 216 Gg CH4, or 50 Mg CH4 per well, a release substantially lower than several widely quoted estimates. Although fugitive emissions from the overall natural gas sector are a proper concern, it is incorrect to suggest that shale gas-related hydraulic fracturing has substantially altered the overall GHG intensity of natural gas production.

November 26, 2012. [*Category:* Ecology]

Toxicity of sediments potentially contaminated by coal mining and natural gas extraction to unionid mussels and commonly tested benthic invertebrates.

- Wang, Ning; Ingersoll, Christopher G.; Kunz, James L.; Brumbaugh, William G.; Kane, Cindy M.; Evans, R. Brian; Alexander, Steven; Walker, Craig; Bakaletz, Steve.
- In: *Environmental Toxicology and Chemistry*, Vol. 32, Issue 1, pages 207-221.
- http://onlinelibrary.wiley.com/doi/10.1002/etc.2032/abstract

Abstract: Sediment toxicity tests were conducted to assess potential effects of contaminants associated with coal mining or natural gas extraction activities in the upper Tennessee River basin and eastern Cumberland River basin in the United States. Test species included two unionid mussels (rainbow mussel, *Villosa iris*, and wavy-rayed lampmussel, *Lampsilis fasciola*, 28-d exposures), and the commonly tested amphipod, *Hyalella azteca* (28-d exposure) and midge, *Chironomus dilutus* (10-d exposure). Sediments were collected from seven test sites with mussel communities classified as impacted and in proximity to coal mining or gas extraction activities, and from five reference sites with mussel communities classified as not impacted and no or limited coal mining or gas extraction activities. Additional samples were collected from six test sites potentially with high concentrations of polycyclic aromatic hydrocarbons (PAHs) and from a test site contaminated by a coal ash spill. Mean survival, length, or biomass of one or more test species was reduced in 10 of 14 test samples (71%) from impacted areas relative to the response of organisms in the five reference samples. A higher proportion of samples was classified as toxic to mussels (63% for rainbow mussels, 50% for wavy-rayed lampmussels) compared with amphipods (38%) or midge (38%). Concentrations of total recoverable metals and total PAHs in sediments did not exceed effects-based probable effect concentrations (PECs). However, the survival, length, or biomasses of the mussels were reduced significantly with increasing PEC quotients for metals and for total PAHs, or with increasing sum equilibrium-partitioning sediment benchmark toxic units for PAHs. The growth of the rainbow mussel also significantly decreased with increasing concentrations of a major anion (chloride) and major cations (calcium and magnesium) in sediment pore water. Results of the present study indicated that (1) the findings from laboratory tests were generally consistent with the field observations of impacts on mussel populations; (2) total recoverable metals, PAHs, or major ions, or all three in sediments might have contributed to the sediment toxicity; (3) the mussels were more sensitive to the contaminants in sediments than the commonly tested amphipod and midge; and (4) a sediment toxicity benchmark of 1.0 based on PECs may not be protective of mussels.

November 19, 2012. [*Category:* Climate]

Mapping urban pipeline leaks: Methane leaks across Boston.

- Phillips, Nathan G.; Ackley, Robert; Crosson, Eric R.; Down, Adrian; Hutyra, Lucy R.; Brondfield, Max; Karr, Jonathan D.; Zhao, Kaiguang; Jackson, Robert B.
- In: *Environmental Pollution*, Vol. 173, February 2013, pages 1-4.
- http://www.sciencedirect.com/science/article/pii/S0269749112004800

Abstract: Natural gas is the largest source of anthropogenic emissions of methane (CH_4) in the United States. To assess pipeline emissions across a major city, we mapped CH_4 leaks across all 785 road miles in the city of Boston using a cavity-ring-down mobile CH_4 analyzer. We identified 3356 CH_4 leaks with concentrations exceeding up to 15 times the global background level. Separately, we measured $\delta^{13}CH_4$ isotopic signatures from a subset of these leaks. The $\delta^{13}CH_4$ signatures (mean = −42.8‰ ± 1.3‰ s.e.; n = 32) strongly indicate a fossil fuel source rather than a biogenic source for most of the leaks; natural gas sampled across the city had average $\delta^{13}CH_4$ values of −36.8‰ (±0.7‰ s.e., n = 10), whereas CH_4 collected from landfill sites, wetlands, and sewer systems had $\delta^{13}CH_4$ signatures ~20‰ lighter (μ = −57.8‰, ±1.6‰ s.e., n = 8). Repairing leaky natural gas distribution systems will reduce greenhouse gas emissions, increase consumer health and safety, and save money.

November 6, 2012. [*Category:* Air Quality]

Comment on “Hydrocarbon emissions characterization in the Colorado Front Range: A pilot study” by Gabrielle Pétron et al.

- Levi, Michael A.
- In: *Journal of Geophysical Research: Atmospheres*, Vol. 117, Issue D21.
- http://onlinelibrary.wiley.com/doi/10.1029/2012JD017686/abstract

Abstract: Pétron et al. (2012) have recently observed and analyzed alkane concentrations in air in Colorado’s Weld County and used them to estimate the volume of methane vented from oil and gas operations in the Denver-Julesburg Basin. They conclude that “the emissions of the species we measured are most likely underestimated in current inventories”, often by large factors. However, their estimates of methane venting, and hence of other alkane emissions, rely on unfounded assumptions about the composition of vented natural gas. We show that relaxing those assumptions results in much greater uncertainty. We then exploit previously unused observations reported in Pétron et al. (2012) to constrain methane emissions without making assumptions about the composition of vented gas. This results in a new set of estimates that are consistent with current inventories but inconsistent with the estimates in Pétron et al. (2012). The analysis also demonstrates the value of the mobile air sampling method employed in Pétron et al. (2012).

November 2, 2012. [*Category:* General (Comment / Review)]

Emerging Shale Gas Revolution in China.

- Chang, Yunhua; Liu, Xuejun; Christie, Peter.
- In: *Environmental Science & Technology*, Vol. 46, Issue 22, pages 12281-12282.
- http://pubs.acs.org/doi/abs/10.1021/es3040939

November 1, 2012. [*Category:* Health]

Impacts of Gas Drilling on Human and Animal Health.

- Bamberger, Michelle; Oswald, Robert E.
- In: *NEW SOLUTIONS: A Journal of Environmental and Occupational Health Policy*, Vol. 22, Issue 1, pages 51-77.
- http://baywood.metapress.com/openurl.asp?genre=article&id=doi:10.2190/NS.22.1.e

Abstract: Environmental concerns surrounding drilling for gas are intense due to expansion of shale gas drilling operations. Controversy surrounding the impact of drilling on air and water quality has pitted industry and leaseholders against individuals and groups concerned with environmental protection and public health. Because animals often are exposed continually to air, soil, and groundwater and have more frequent reproductive cycles, animals can be used as sentinels to monitor impacts to human health. This study involved interviews with animal owners who live near gas drilling operations. The findings illustrate which aspects of the drilling process may lead to health problems and suggest modifications that would lessen but not eliminate impacts. Complete evidence regarding health impacts of gas drilling cannot be obtained due to incomplete testing and disclosure of chemicals, and nondisclosure agreements. Without rigorous scientific studies, the gas drilling boom sweeping the world will remain an uncontrolled health experiment on an enormous scale.

October 31, 2012. [*Category:* Ecology]

Does Spatial Resolution Matter? A Multi-scale Comparison of Object-based and Pixel-based Methods for Detecting Change Associated with Gas Well Drilling Operations.

- Baker, BenjaminA.; Warner, TimothyA.; Conley, Jamison F.; McNeil, Brenden E.;

- In: *International Journal of Remote Sensing*, Vol. 34, Issue 5, pages 1633-1651.
- http://dx.doi.org/10.1080/01431161.2012.724540

Abstract: An implicit assumption of the geographic object-based image analysis GEOBIA literature is that GEOBIA is more accurate than pixel-based methods for high spatial resolution image classification, but that the benefits of using GEOBIA are likely to be lower when moderate resolution data are employed. This study investigates this assumption within the context of a case study of mapping forest clearings associated with drilling for natural gas. The forest clearings varied from 0.2 to 9.2 ha, with an average size of 0.9 ha. National Aerial Imagery Program data from 2004 to 2010, with 1 m pixel size, were resampled through pixel aggregation to generate imagery with 2, 5, 15, and 30 m pixel sizes. The imagery for each date and at each of the five spatial resolutions was classified into Forest and Non-forest classes, using both maximum likelihood and GEOBIA. Change maps were generated through overlay of the classified images. Accuracy evaluation was carried out using a random sampling approach. The 1 m GEOBIA classification was found to be significantly more accurate than the GEOBIA and per-pixel classifications with either 15 or 30 m resolution. However, at any one particular pixel size e.g. 1 m, the pixel-based classification was not statistically different from the GEOBIA classification. In addition, for the specific class of forest clearings, accuracy varied with the spatial resolution of the imagery. As the pixel size coarsened from 1 to 30 m, accuracy for the per-pixel method increased from 59% to 80%, but decreased from 71% to 58% for the GEOBIA classification. In summary, for studying the impact of forest clearing associated with gas extraction, GEOBIA is more accurate than pixel-based methods, but only at the very finest resolution of 1 m. For coarser spatial resolutions, per-pixel methods are not statistically different from GEOBIA.

October 25, 2012. [*Category:* Waste / Fluids]

Geochemical evaluation of flowback brine from Marcellus gas wells in Pennsylvania, USA.

- Haluszczak, Lara O.; Rose, Arthur W.; Kump, Lee R.
- In: *Applied Geochemistry*, Vol. 28, January 2013, pages 55-61.
- http://www.sciencedirect.com/science/article/pii/S0883292712002752

Abstract: Large quantities of highly saline brine flow from gas wells in the Marcellus Formation after hydraulic stimulation ("fracking"). This study assesses the composition of these flowback waters from the Marcellus shale in Pennsylvania, USA. Concentrations of most inorganic components of flowback water (Cl, Br, Na, K, Ca, Mg, Sr, Ba, Ra, Fe, Mn, total dissolved solids, and others) increase with time from a well after hydraulic stimulation. Based on results in several datasets reported here, the greatest concentration of Cl^- in flowback water is 151,000 mg/L. For total Ra (combined 226Ra and 228Ra) in flowback, the highest level reported is 6540 pCi/L. Flowback waters from hydraulic fracturing of Marcellus wells resemble brines produced from conventional gas wells that tap into other Paleozoic formations in the region. The Br/Cl ratio and other parameters indicate that both types of brine formed by the evaporation of seawater followed by dolomitization, sulfate reduction and subsurface mixing with seawater and/or freshwater. Trends and relationships in brine composition indicate that (1) increased salt concentration in flowback is not mainly caused by dissolution of salt or other minerals in rock units, (2) the flowback waters represent a mixture of injection waters with highly concentrated in situ brines similar to those in the other formations, and (3) these waters contain concentrations of Ra and Ba that are commonly hundreds of times the US drinking water standards.

October 18, 2012. [*Category:* General (Comment / Review)]

Legislative Interference with the Patient–Physician Relationship.

- Weinberger, Steven E.; Lawrence, Hal C.; Henley, Douglas E.; Alden, Errol R.; Hoyt, David B.
- In: *New England Journal of Medicine*, Vol. 367, Issue 16, pages 1557-1559.
- http://www.nejm.org/doi/full/10.1056/NEJMsb1209858

Extract: Increasingly in recent years, legislators in the United States have been overstepping the proper limits of their role in the health care of Americans to dictate the nature and content of patients' interactions with their physicians. Some recent laws and proposed legislation inappropriately infringe on clinical practice and patient–physician relationships, crossing traditional boundaries and intruding into the realm of medical professionalism. We, the executive staff leadership of five professional societies that represent the majority of U.S. physicians providing clinical care — the American Academy of Family Physicians, the American Academy of Pediatrics, the American College of Obstetricians and Gynecologists, the American College of Physicians, and the American College of Surgeons — find this trend alarming and believe that legislators should abide by principles that put patients' best interests first. Critical to achieving this goal is respect for the importance of scientific evidence, patient autonomy, and the patient–physician relationship.

October, 2012. [*Category:* Health]

Occupational silica exposure in hydraulic fracturing.

- Chalupka, Stephanie.
- In: *Workplace Health Safety*, Vol. 69, Issue 10, page 460.
- http://www.ncbi.nlm.nih.gov/pubmed/23054167

Abstract: Workers may be exposed to dust containing high levels of respirable crystalline silica during hydraulic fracturing.

September 24, 2012. [*Category:* Water Quality]

Potential Contaminant Pathways from Hydraulically Fractured Shale Aquifers.

- Saiers, James E.; Barth, Erica.
- In: *Groundwater*, Vol. 50, Issue 6, pages 826-828.
- http://onlinelibrary.wiley.com/doi/10.1111/j.1745-6584.2012.00990.x/abstract

Extract: In a recent article, T. Myers used MODFLOW to examine the impacts of hydraulic fracturing of the Marcellus Shale ("the Marcellus") on groundwater flow patterns. Myers' model includes a layer representing the Marcellus, a 1500-m overburden of sandstone and one high permeability "fracture" connecting the Marcellus directly to the surface. Myers conducts steady-state and transient groundwater flow simulations for scenarios without and with injection into a horizontal well (to approximate conditions during hydraulic stimulation of the shale layer), and he examines the sensitivity of the model calculations to changes in hydraulic conductivity of the shale and overlying sandstone. His results suggest the flow system would reach a new equilibrium in 3 to 6 years following hydraulic fracturing, and he conclude .. that the hydrologic stress of hydraulic fracturing could allow for advective transport of frac fluids and formation water to drinking-water aquifers in less than 10 years (Myers 2012).

September 4, 2012. [*Category:* Community]

Landowner attitudes toward natural gas and wind farm development in northern Pennsylvania.

- Jacquet, Jeffrey B.
- In: *Energy Policy*, Vol. 50, November 2012, pages 677-688.
- http://www.sciencedirect.com/science/article/pii/S0301421512006702

Abstract: The US has undergone a recent boom in the development of onshore wind farm and natural gas energy projects and contentious debates over the construction of these projects are common in communities across the US. A survey of landowners in a region of Northern Pennsylvania (N=1028) undergoing simultaneous development of both wind and natural gas development shows that landowners are generally much more polarized and negative towards gas development than wind farm development, and that attitudes toward natural gas development is highly dependent on environmental attitudes and industry leasing, development, or employment experience. Landowner proximity to the development explains a small amount of the variation in attitudes towards wind energy. Recommendations for energy policy and future research are discussed.

September, 2012. [*Category:* Health]

Preserving health in the Marcellus region.

- McDermott-Levy, Ruth; Kaktins, Nina.
- In: *The Pennsylvania Nurse,* Vol. 67, Issue 3, pages 4-10.
- http://www.ncbi.nlm.nih.gov/pubmed/23155825

Abstract: Community health nurses (CHNs) have an opportunity and responsibility to address potential environmental health issues related to shale drilling, even in the face of scientific uncertainty. Potential health impacts to air and water quality related to shale drilling are addressed within the context of the CHNs role of educator, case finder, advocate and researcher. Since 2005, an estimated 5,500 unconventional natural gas wells have been drilled in Pennsylvania's Marcellus Shale (Pennsylvania Department of Environmental Protection [PA DEP], n.d.), resulting in tremendous controversy throughout the state regarding impacts to human health and the environment. Although there are numerous anecdotal reports of illnesses in humans and animals living in drilling areas, there is a notable lack of peer-reviewed research on the impacts. Research efforts are underway to study these issues, including a proposed retrospective study of hospital and clinic data by Geisinger Health System's Weis Center for Research (Begos, 2012). However, CHNs have the opportunity and the responsibility to help address potential environmental health issues related to shale drilling, even in the face of scientific uncertainty. This responsibility is highlighted by the American Nurses Association's (ANA) (2003, p. 2) adoption of the Precautionary Principle, which states that "when an activity raises threats of harm to human health or the environment, precautionary measures should be taken even if some cause and effect relationships are not fully established scientifically." CHN practice includes the promotion and preservation of health, and the prevention of disease, as well as assisting people in their response to illness (Maurer & Smith, 2009). In Pennsylvania's Marcellus Shale regions, CHNs must assume the critical nursing roles of educator, case finder, advocate and researcher when addressing the health needs in shale drilling communities. Unfortunately, CHNs practicing within these regions may feel unprepared to take on these roles related to unconventional gas extraction. The following discusses these CHN roles in the context of environmental health impacts of shale drilling on air and water quality.

September, 2012. [*Category:* Waste / Fluids]

Effect of biogas generation on radon emissions from landfills receiving radium-bearing waste from shale gas development.

- Walter, Gary R.; Benke, Roland R.; Pickett, David A.

- In: *Journal of the Air & Waste Management Association (1995)*, Vol. 65, Issue 9, pages 1040-1049.
- http://www.ncbi.nlm.nih.gov/pubmed/23019818

Abstract: Dramatic increases in the development of oil and natural gas from shale formations will result in large quantities of drill cuttings, flowback water, and produced water. These organic-rich shale gas formations often contain elevated concentrations of naturally occurring radioactive materials (NORM), such as uranium, thorium, and radium. Production of oil and gas from these formations will also lead to the development of technologically enhanced NORM (TENORM) in production equipment. Disposal of these potentially radium-bearing materials in municipal solid waste (MSW) landfills could release radon to the atmosphere. Risk analyses of disposal of radium-bearing TENORM in MSW landfills sponsored by the Department of Energy did not consider the effect of landfill gas (LFG) generation or LFG control systems on radon emissions. Simulation of radon emissions from landfills with LFG generation indicates that LFG generation can significantly increase radon emissions relative to emissions without LFG generation, where the radon emissions are largely controlled by vapor-phase diffusion. Although the operation of LFG control systems at landfills with radon source materials can result in point-source atmospheric radon plumes, the LFG control systems tend to reduce overall radon emissions by reducing advective gas flow through the landfill surface, and increasing the radon residence time in the subsurface, thus allowing more time for radon to decay. In some of the disposal scenarios considered, the radon flux from the landfill and off-site atmospheric activities exceed levels that would be allowed for radon emissions from uranium mill tailings. Implications: Increased development of hydrocarbons from organic-rich shale formations has raised public concern that wastes from these activities containing naturally occurring radioactive materials, particularly radium, may be disposed in municipal solid waste landfills and endanger public health by releasing radon to the atmosphere. This paper analyses the processes by which radon may be emitted from a landfill to the atmosphere. The analyses indicate that landfill gas generation can significantly increase radon emissions, but that the actual level of radon emissions depend on the place of the waste, construction of the landfill cover, and nature of the landfill gas control system.

August 19, 2012. [*Category:* Waste / Fluids]

Chemical characteristics of Marcellus Shale flowback water in Pennsylvania.

- Barbot, Elise; Vidic, Radisav D.
- In: *Abstracts of Papers American Chemical Society*, Vol. 244, 26 pages.
- http://acselb-529643017.us-west-2.elb.amazonaws.com/chem/244nm/program/view.php

Abstract: The flowback water collected after hydraulic fracturing in the Marcellus Shale is characterized by high level of Cl, Na, Mg, Ba, and Sr when compared with flowback waters from other shale gas plays in the US. Samples were collected at various times from four wells located in SW Pennsylvania. Publically available flowback water quality data were added to this dataset and compared to other formation brines, either from adjacent geologic formations or collected as produced water by the oil and gas industry in the state. Data analysis highlights the particularities of flowback water from the Marcellus Shale and gives insight into the origin of the salinity in this water. This study also summarizes the variations of flowback water composition with time and location across Pennsylvania. The emphasis is on barium concentration variations across Pennsylvania as it impacts the flowback water treatment requirements before its reuse as a fracturing fluid.

August 15, 2012. [*Category:* Water Quality]

Experimental Evidence for Self-Limiting Reactive Flow through a Fractured Cement Core: Implications for Time-Dependent Wellbore Leakage.

- Huerta, Nicolas J.; Hesse, Marc A.; Bryant, Steven L.; Strazisar, Brian R.; Lopano, Christina L.
- In: Environmental Science & Technology, Vol. 47, Issue 1, pages 269-275.
- http://dx.doi.org/10.1021/es3013003

Abstract: We present a set of reactive transport experiments in cement fractures. The experiments simulate coupling between flow and reaction when acidic, CO2-rich fluids flow along a leaky wellbore. An analog dilute acid with a pH between 2.0 and 3.15 was injected at constant rate between 0.3 and 9.4 cm/s into a fractured cement core. Pressure differential across the core and effluent pH were measured to track flow path evolution, which was analyzed with electron microscopy after injection. In many experiments reaction was restricted within relatively narrow, tortuous channels along the fracture surface. The observations are consistent with coupling between flow and dissolution/precipitation. Injected acid reacts along the fracture surface to leach calcium from cement phases. Ahead of the reaction front, high pH pore fluid mixes with calcium-rich water and induces mineral precipitation. Increases in the pressure differential for most experiments indicate that precipitation can be sufficient to restrict flow. Experimental data from this study combined with published field evidence for mineral precipitation along cemented annuli suggests that leakage of CO2-rich fluids along a wellbore may seal the leakage pathway if the initial aperture is small and residence time allows mobilization and precipitation of minerals along the fracture.

August 10, 2012. [*Category:* Regulation]

The significance of regulation and land use patterns on natural gas resource estimates in the Marcellus shale.

- Blohm, Andrew; Peichel, Jeremy; Smith, Caroline; Kougentakis, Alexandra.
- In: *Energy Policy*, Vol. 50, November 2012, pages 358-369.
- http://www.sciencedirect.com/science/article/pii/S030142151200612X

Abstract: Recent advancements in natural gas extraction (e.g. hydraulic fracturing) have significantly increased natural gas reserves in the United States. Estimates of the technically recoverable natural gas (TRR) in the Marcellus range between 141 trillion cubic feet (TCF) and 489 TCF. However, TRR estimation does not incorporate existing policies, regulations, or land use. We find that approximately 48% of the Marcellus in New York and Pennsylvania is inaccessible given land use patterns and current policy. In New York, approximately 83% of the Marcellus is inaccessible; while in Pennsylvania about 32% of the Marcellus is off limits to drilling. The New York portion of the Marcellus is estimated to have a TRR of between 19.9 TCF and 68.9 TCF. We estimate that 79% of the resource is inaccessible, which results in an accessible resource estimate of between 4.2 TCF and 14.4 TCF. In Pennsylvania, the shale gas TRR is estimated at 86.6–300 TCF. However, we estimate that 31% of the resource is inaccessible, which results in an accessible resource estimate of between 60.0 TCF and 208 TCF.

August 6, 2012. [*Category:* Seismicity]

Two-year survey comparing earthquake activity and injection-well locations in the Barnett Shale, Texas.

- Frohlich, Cliff.
- In: *Proceedings of the National Academy of Sciences of the United States of America*, Vol. 109, Issue 35, pages 13934-13938.
- http://www.ncbi.nlm.nih.gov/pubmed/22869701

Abstract: Between November 2009 and September 2011, temporary seismographs deployed under the EarthScope USArray program were situated on a 70-km grid covering the Barnett Shale in Texas, recording data that allowed sensing and locating regional earthquakes with magnitudes 1.5 and larger. I analyzed these data and located 67 earthquakes, more than eight times as many as reported by the National Earthquake Information Center. All 24 of the most reliably located epicenters occurred in eight groups within 3.2 km of one or more injection wells. These included wells near Dallas-Fort Worth and Cleburne, Texas, where earthquakes near injection wells were reported by the media in 2008 and 2009, as well as wells in six other locations, including several where no earthquakes have been reported previously. This suggests injection-triggered earthquakes are more common than is generally recognized. All the wells nearest to the earthquake groups reported maximum monthly injection rates exceeding 150,000 barrels of water per month (24,000 m^3/mo) since October 2006. However, while 9 of 27 such wells in Johnson County were near earthquakes, elsewhere no earthquakes occurred near wells with similar injection rates. A plausible hypothesis to explain these observations is that injection only triggers earthquakes if injected fluids reach and relieve friction on a suitably oriented, nearby fault that is experiencing regional tectonic stress. Testing this hypothesis would require identifying geographic regions where there is interpreted subsurface structure information available to determine whether there are faults near seismically active and seismically quiescent injection wells.

August 1, 2012. [*Categories:* Air Quality, Climate]

On the Sources of Methane to the Los Angeles Atmosphere.

- Wennberg, Paul O.; Mui, Wilton; Wunch, Debra; Kort, Eric A.; Blake, Donald R.; Atlas, Elliot L.; Santoni, Gregory W.; Wofsy, Steven C.; Diskin, Glenn S.; Jeong, Seongeun; Fischer, Marc L.
- In: *Environmental Science & Technology*, Vol. 46, Issue 17, pages 9282-9289.
- http://dx.doi.org/10.1021/es301138y

Abstract: We use historical and new atmospheric trace gas observations to refine the estimated source of methane (CH_4) emitted into California's South Coast Air Basin (the larger Los Angeles metropolitan region). Referenced to the California Air Resources Board (CARB) CO emissions inventory, total CH_4 emissions are 0.44 ± 0.15 Tg each year. To investigate the possible contribution of fossil fuel emissions, we use ambient air observations of methane (CH_4), ethane (C_2H_6), and carbon monoxide (CO), together with measured C_2H_6 to CH_4 enhancement ratios in the Los Angeles natural gas supply. The observed atmospheric C_2H_6 to CH_4 ratio during the ARCTAS (2008) and CalNex (2010) aircraft campaigns is similar to the ratio of these gases in the natural gas supplied to the basin during both these campaigns. Thus, at the upper limit (assuming that the only major source of atmospheric C_2H_6 is fugitive emissions from the natural gas infrastructure) these data are consistent with the attribution of most (0.39 ± 0.15 Tg yr^{-1}) of the excess CH_4 in the basin to uncombusted losses from the natural gas system (approximately 2.5–6% of natural gas delivered to basin customers). However, there are other sources of C_2H_6 in the region. In particular, emissions of C_2H_6 (and CH_4) from natural gas seeps as well as those associated with petroleum production, both of which are poorly known, will reduce the inferred contribution of the natural gas infrastructure to the total CH_4 emissions, potentially significantly. This study highlights both the value and challenges associated with the use of ethane as a tracer for fugitive emissions from the natural gas production and distribution system.

August, 2012. [*Category:* Air Quality]

The potential near-source ozone impacts of upstream oil and gas industry emissions.

- Olaguer, Eduardo P.

- In: *Journal of the Air & Waste Management Association*, Vol. 62, Issue 8, pages 966-977.
- http://www.ncbi.nlm.nih.gov/pubmed/22916444

Abstract: Increased drilling in urban areas overlying shale formations and its potential impact on human health through decreased air quality make it important to estimate the contribution of oil and gas activities to photochemical smog. Flares and compressor engines used in natural gas operations, for example, are large sources not only of NOx but also offormaldehyde, a hazardous air pollutant and powerful ozone precursor We used a neighborhood scale (200 m horizontal resolution) three-dimensional (3D) air dispersion model with an appropriate chemical mechanism to simulate ozone formation in the vicinity ofa hypothetical natural gas processing facility, based on accepted estimates of both regular and nonroutine emissions. The model predicts that, under average midday conditions in June, regular emissions mostly associated with compressor engines may increase ambient ozone in the Barnett Shale by more than 3 ppb beginning at about 2 km downwind of the facility, assuming there are no other major sources of ozone precursors. Flare volumes of 100,000 cubic meters per hour ofnatural gas over a period of 2 hr can also add over 3 ppb to peak 1-hr ozone somewhatfurther (>8 km) downwind, once dilution overcomes ozone titration and inhibition by large flare emissions of NOx. The additional peak ozone from the hypothetical flare can briefly exceed 10 ppb about 16 km downwind. The enhancements of ambient ozone predicted by the model are significant, given that ozone control strategy widths are of the order of a few parts per billion. Degrading the horizontal resolution of the model to 1 km spuriously enhances the simulated ozone increases by reducing the effectiveness of ozone inhibition and titration due to artificial plume dilution.

July 18, 2012. [*Category:* Waste / Fluids]

Forward osmosis treatment of drilling mud and fracturing wastewater from oil and gas operations.

- Hickenbottom, Kerri L.; Hancock, Nathan T.; Hutchings, Nathan R.; Appleton, Eric W.; Beaudry, Edward G.; Xu, Pei; Cath, Tzahi Y.
- In: *Desalination*, Vol. 312, March 2013, pages 60-66.
- http://www.sciencedirect.com/science/article/pii/S0011916412003086

Abstract: To produce large volumes of newly discovered unconventional gas, hydraulic fracturing of wells is commonly practiced in basins where shale gas and coal bed methane are extracted. Hydraulic fracturing of wells during oil and gas (O&G) exploration consumes large volumes of fresh water and generates larger volumes of contaminated wastewater. In this study, a novel application of forward osmosis (FO) was tested for treatment and reclamation of water from drilling waste to facilitate beneficial water reuse. By using FO, two major benefits were achieved: both the volume of the waste stream and the need for a fresh water source were greatly reduced. Results indicate that FO can achieve high rejection of organic and inorganic contaminants, membrane fouling was reversible, and that the process was able to effectively recover more than 80% of the water from the drilling waste. Osmotic backwashing was demonstrated to be an effective membrane cleaning technique; successfully removing fouling and restoring water flux.

July 10, 2012. [*Category:* Waste / Fluids]

Fracture stimulation fundamentals.

- Britt, Larry.
- In: *Journal of Natural Gas and Engineering*, Vol. 8, September 2012, pages 34-51.
- http://www.sciencedirect.com/science/article/pii/S187551001200087X

Abstract: This article highlights the multi-disciplinary nature of multiple fractured horizontal wells in unconventional oil and gas reservoirs. The drilling, geomechanics, reservoir, completion, fracture stimulation, and field execution/operations disciplines must all do their jobs effectively in order to achieve success. Failure in any one discipline likely means project failure. The critical importance of multi-disciplinary success is clearest when you look at the competing objectives of horizontal well fracturing. All of the disciplines can and should work together to develop a horizontal well(s) project objective based on economics, deliverability, and/or estimated ultimate recovery; however, the geomechanics of the project will have a strong impact on whether the project objectives are achieved. The geomechanics need to be considered with respect to the stress state and its impact on hoop stresses and breakdown pressures (critically important to the drilling, completion, and fracture stimulation disciplines). Fracture interference must be considered to determine its impact on fracture width and treating pressure (critically important to the completions, fracture stimulation, and operational disciplines). In addition, the geomechanical effects on the fracture stimulation design and ultimately fracture geometry must be considered when stimulating a transverse horizontal well. From a fracture design perspective, material sourcing of the fracturing fluid (gel or treated water) is primarily a geomechanical issue in unconventional reservoirs, as is the type, size, and concentration of the proppant to be used. Even the designed fluid and proppant volumes should be based on the unconventional reservoir's rock and geomechanical considerations. This article will review some of the multidisciplinary inputs and objectives for multiple fractured transverse horizontal wells in unconventional oil and gas reservoirs. The paper will establish horizontal well fracturing design fundamentals and objectives that include determination of reservoir permeability, geomechanical parameters such as the in-situ stress state, the geomechanical basis of fracture design, and material sourcing. More importantly, this paper shows how rock and geomechanical considerations including fluid and proppant type and volumes can be utilized to design fracture stimulations in unconventional oil and gas reservoirs.

July 7, 2012. [*Category:* Waste / Fluids]

Total arsenic and selenium analysis in Marcellus shale, high-salinity water, and hydrofracture flowback wastewater.

- Balaba, Ronald S.; Smart, Ronald B.
- In: *Chemosphere*, Vol. 89, Issue 11, November 2012, pages 1437-1442.
- http://www.ncbi.nlm.nih.gov/pubmed/22776255

Abstract: Trace levels of arsenic and selenium can be toxic to living organisms yet their quantitation in high ionic strength or high salinity aqueous media is difficult due to the matrix interferences which can either suppress or enhance the analyte signal. A modified thiol cotton fiber (TCF) method employing lower flow rates and centrifugation has been used to remove the analyte from complex aqueous media and minimize the matrix interferences. This method has been tested using a USGS (SGR-1b) certified reference shale. It has been used to analyze Marcellus shale samples following microwave digestion as well as spiked samples of high salinity water (HSW) and flow back wastewater (WRF6) obtained from an actual gas well drilling operation. Quantitation of arsenic and selenium is carried out by graphite furnace atomic spectroscopy (GFAAS). Extraction of arsenic and selenium from Marcellus shale exposed to HSW and WRF6 for varying lengths of time is also reported.

July 2, 2012. [*Category:* Water Usage]

Fracking vs Faucets: Balancing Energy Needs and Water Sustainability at Urban Frontiers.

- Fry, Matthew; Hoeinghaus, David J.; Ponette-González, Alexandra G.; Thompson, Ruthanne; La Point, Thomas W.
- In: *Environmental Science & Technology*, Vol. 46, Issue 14, pages 7444-7445.
- http://dx.doi.org/10.1021/es302472y

Extract: Newly accessible shale deposits have dramatically increased global gas reserves and are touted as a bridge to a clean energy future. For example, in the U.S., where shale gas is projected to comprise 49% of national natural gas production by 2035, proponents argue that shale gas production can provide energy independence, create employment, and stimulate regional economies. Amidst this optimism, however, are growing concerns about the effects of shale gas extraction, and, in particular, hydraulic fracturing or “fracking”, on water resources—concerns that are magnified in urban areas where human populations and extractive operations overlap. We believe that water conflicts arising from expansion of the U.S. shale gas industry foreshadow developments in other countries with cities situated over large shale-gas deposits, including Diyarbakir, Turkey; Ahmedabad, India; and Chongqing, China.

July 2, 2012. [*Categories:* Air Quality, General (Comment / Review), Regulation]

The Future of Fracking: New Rules Target Air Emissions for Cleaner Natural Gas Production.

- Weinhold, Bob.
- In: *Environmental Health Perspectives*, Vol. 120, Issue 7, pages a272-a279.
- http://www.ncbi.nlm.nih.gov/pmc/articles/PMC3404676/

Extract: Natural gas is lauded as a cleaner-burning fuel than either coal or oil, but getting the fuel out of the ground can be a dirty process, especially given the widespread adoption of the technology known as hydraulic fracturing ("fracking"). Concerns about toxic air emissions from previously unregulated fracking sites led to the U.S. Environmental Protection Agency (EPA) announcement on 18 April 2012 of new and updated air pollution regulations for these facilities and certain other elements of oil and natural gas production and transmission. Compliance with the new regulations is expected to result in major reductions in emissions of methane and volatile organic compounds (VOCs), particularly from new fracked natural gas wells.

The rules were a hot topic nationally, drawing more than 156,000 comments after the proposed version was released in mid-2011. Under the final rules, companies have until January 2015 to fully phase in the control measures needed; by comparison, the initial proposal called for a 60-day phase-in for many major requirements. The EPA says about half of all new wells already use the equipment needed to capture the targeted emissions.

July 1, 2012. [*Categories:* Climate, General (Comment / Review)]

A commentary on "The greenhouse-gas footprint of natural gas in shale formations" by R.W. Howarth, R. Santoro, and Anthony Ingraffea.

- Cathles, Lawrence M.; Brown, Larry; Taam, Milton; Hunter, Andrew.
- In: *Climatic Change*, Vol. 113, Issue 2, pages 525-535.
- http://link.springer.com/article/10.1007/s10584-011-0333-0

Abstract: Natural gas is widely considered to be an environmentally cleaner fuel than coal because it does not produce detrimental by-products such as sulfur, mercury, ash and particulates and because it provides twice the energy per unit of weight with half the carbon footprint during combustion. These points are not in dispute. However, in their recent publication in Climatic Change Letters, Howarth et al. (2011) report that their life-cycle evaluation of shale gas drilling suggests that shale gas has a larger GHG footprint than coal and that this larger footprint "undercuts the logic of its use as a bridging fuel over the coming decades". We argue here that their analysis is seriously flawed in that they significantly overestimate the fugitive emissions associated with unconventional gas extraction, undervalue the contribution of "green technologies" to reducing those emissions to a level approaching that of conventional gas, base their comparison between gas and coal on heat rather than electricity generation (almost the sole use of coal), and assume a time interval over which to compute the relative climate impact of gas compared to coal that does not capture the contrast between the long residence time of CO2 and the short residence time of methane in the atmosphere. High leakage rates, a short methane GWP, and comparison in terms of heat content are the inappropriate bases upon which Howarth et al. ground their claim that gas could be twice as bad as coal in its greenhouse impact. Using more reasonable leakage rates and bases of comparison, shale gas has a GHG footprint that is half and perhaps a third that of coal.

June 26, 2012. [*Category:* Community]

Development, Land Use, and Collective Trauma: The Marcellus Shale Gas Boom in Rural Pennsylvania.

- Perry, Simona L.
- In: *Culture, Agriculture, Food and Environment*, Vol. 34, Issue 1, pages 81-92.
- http://onlinelibrary.wiley.com/doi/10.1111/j.2153-9561.2012.01066.x/abstract

Abstract: This article describes a place and people undergoing rapid transition using some of the preliminary findings from two years of ongoing ethnographic field work. Through exploring what ethnographic evidence is revealing concerning the impacts of Marcellus shale gas development in Bradford County, in Northeastern Pennsylvania, I illustrate the ways that rapid social and economic change processes are impacting daily lives and community dynamics in one traditionally agricultural and rural place. I provide a broad overview of the social history and current social dynamics in order to understand the significance of the short-term changes agricultural landowners and other local residents have witnessed and experienced. I discuss some of the most significant short-term changes in quality of life as seen by a small group of agricultural landowners, in relation to the cultural significance of place, home, and family, and what this tells us about the sociocultural and psychological impacts of rapid energy development. Finally, I comment on what my ethnographic data show so far with regard to the short- and long-term individual and collective impacts being experienced in this one community.

June 19, 2012. [*Category:* Climate]

Assessing the greenhouse impact of natural gas.

- Cathles, L.M.
- In: *Geochemistry, Geophysics, Geosystems*, Vol. 13, Issue 6, pages 1-18.
- http://energyindepth.org/wp-content/uploads/2012/07/Cathles-Assessing-greenhouse-impact-natgas-June2012.pdf

Abstract: The global warming impact of substituting natural gas for coal and oil is currently in debate. We address this question here by comparing the reduction of greenhouse warming that would result from substituting gas for coal and some oil to the reduction which could be achieved by instead substituting zero carbon energy sources. We show that substitution of natural gas reduces global warming by 40% of that which could be attained by the substitution of zero carbon energy sources. At methane leakage rates that are $1% of production, which is similar to today's probable leakage rate of $1.5% of production, the 40% benefit is realized as gas substitution occurs. For short transitions the leakage rate must be more than 10 to 15% of production for gas substitution not to reduce warming, and for longer transitions the leakage must be much greater. But even if the leakage was so high that the substitution was not of immediate benefit, the 40%-of-zero-carbon benefit would be realized shortly after methane emissions ceased because methane is removed quickly from the atmosphere whereas CO2 is not. The benefits of substitution are unaffected by heat exchange to the ocean. CO2 emissions are the key to anthropogenic climate change, and substituting gas reduces them by 40% of that possible by conversion to zero carbon energy sources. Gas substitution also reduces the rate at which zero carbon energy sources must eventually be introduced.

June 19, 2012. [*Category:* Health]

Environmental pathways of potential impacts to human health from oil and gas development in northeast British Columbia, Canada.

- Krzyzanowski, Judi.
- In: *Environmental Reviews*, Vol. 20, Issue 2, pages 122-134.
- http://www.nrcresearchpress.com/doi/abs/10.1139/a2012-005#.VO3d_0JDbKE

Abstract: Concerns have arisen recently as to whether the upstream oil and gas (UOG) sector — responsible for exploration, production, and some processing of raw fossil fuels — is negatively impacting human (and environmental) health in northeast British Columbia (NEBC). The region has experienced increased rates of cancers and other illnesses that have been linked to the contaminants and stressors associated with UOG. Contaminants reach human receptors through environmental pathways, namely air, soil, water, and food. Each contaminant or stressor has specific sources, transport, exposure mechanisms, and biochemistry; and each can impact health both directly and indirectly. Of particular concern are airborne sulphur and nitrogen oxides, hazardous volatile organic compounds, hydrogen sulphide, ozone, noise, and radiation; as well as soil- or water-borne hydrocarbons, heavy metals, and radiation — some of which can also impact human health through food pathways. It has been determined that UOG is negatively impacting human health in NEBC; however, further information, such as environmental monitoring, is required before the actual health risks and impacts posed by UOG can be quantified.

May 24, 2012. [*Category:* Waste/Fluids]

Bacterial Communities Associated with Production Facilities of Two Newly Drilled Thermogenic Natural Gas Wells in the Barnett Shale (Texas, USA).

- Davis, James P.; Struchtemeyer, Christopher G.; Elshahed, Mostafa S.
- In: *Microbial Biology*, Vol. 64, Issue 4, pages 942-954.
- http://link.springer.com/article/10.1007/s00248-012-0073-3

Abstract: We monitored the bacterial communities in the gas–water separator and water storage tank of two newly drilled natural gas wells in the Barnett Shale in north central Texas, using a 16S rRNA gene pyrosequencing approach over a period of 6 months. Overall, the communities were composed mainly of moderately halophilic and halotolerant members of the phyla Firmicutes and Proteobacteria (classes Beta-, Gamma-, and Epsilonproteobacteria) in both wells at all sampling times and locations. Many of the observed lineages were encountered in prior investigations of microbial communities from various fossil fluid formations and production facilities. In all of the samples, multiple H_2S-producing lineages were encountered; belonging to the sulfate- and sulfur-reducing class Deltaproteobacteria, order Clostridiales, and phylum *Synergistetes*, as well as the thiosulfate-reducing order Halanaerobiales. The bacterial communities from the separator and tank samples bore little resemblance to the bacterial communities in the drilling mud and hydraulic-fracture waters that were used to drill these wells, suggesting the in situ development of the unique bacterial communities in such well components was in response to the prevalent geochemical conditions present. Conversely, comparison of the bacterial communities on temporal and spatial scales suggested the establishment of a core microbial community in each sampled location. The results provide the first overview of bacterial dynamics and colonization patterns in newly drilled, thermogenic natural gas wells and highlights patterns of spatial and temporal variability observed in bacterial communities in natural gas production facilities.

May 19, 2012. [*Category:* Economics]

Gas versus oil prices the impact of shale gas.

- Asche, Frank; Oglend, Atle; Osmundsen, Petter.
- In: *Energy Policy*, Vol. 47, August 2012, pages 117-124.
- http://www.sciencedirect.com/science/article/pii/S0301421512003382

Abstract: What significance will developments in shale gas production have for European gas prices? Some commentators paint a gloomy picture of the future gas markets. But most forecasts for the oil market are positive. Consequently, a view appears to prevail that price trends will differ sharply between oil and gas markets. This article looks at developments in US shale gas production and discusses their impact on the movement of European gas prices. The relationship between oil and gas prices over time is also analysed.

May 15, 2012. [*Category:* Health]

Effect of Gas Flaring on Lung Function among Residents in Gas Flaring Community in Delta State, Nigeria.

- Ovuakporaye, SI; Ojieh, AE; Ejebe, DE; Mordi, JC.
- In: *Research Journal of Environmental and Earth Sciences*, Vol. 4, Issue 5, pages 525-528.
- http://maxwellsci.com/print/rjees/v4-524-528.pdf

Abstract: The study determined the impact of gas flaring on lung function by specifically evaluating changes in Peak Expiratory Flow Rate (PEFR) of residents in Ugberikoko, a gas flaring community. Participants for the study were drawn from the representative group in the gas flaring community in Delta State, Nigeria and values obtained were compared with those from non gas flaring community (Irhodo). Peak Expiratory Flow Rate (PEFR) was measured and used to assess lung function of the selected participants (n = 400) each for both. The peak expiratory flow rate was determined using the (Wright peak flow metre as a spirometric device) results obtained for children, young adults and older adults from the gas flaring community are 270.05±3.30 (13-17 years), 222.17±6.03 (18-30 years) and 245.00±8.66 (41-50 years), respectively. Age-matched values from nongas flaring community are 432.05±5.57 (13-17 years), 420.75±16.22 (18-30 years) and 428.57±19.41 (41-50 years). Differences in matched values were significant (p<0.05). The findings showed that residents in gas flaring community had reduced peak expiratory flow rate.

May 15, 2012. [*Category:* Economics]

The Interdependence of Electricity and Natural Gas: Current Factors and Future Prospects.

- Hibbard, Paul J.; Schatzki, Todd.
- In: *The Electricity Journal*, Vol. 25, Issue 4, May 2012, pages 6-17.
- http://www.sciencedirect.com/science/article/pii/S1040619012000899

Abstract: The growing interdependence of the nation’s electricity and natural gas systems presents challenges to the reliable and efficient operation of both systems. Shale gas developments, retirement of aging fossil units, and increases in variable renewable generation are likely to increase the prominence of natural-gas-fired generation and interdependence risks. The authors review factors at the intersection of electricity and natural gas markets and operations, and present ways to address the risks.

May 10, 2012. [*Category:* Water Quality]

Geochemical evidence for possible natural migration of Marcellus Formation brine to shallow aquifers in Pennsylvania.

- Warner, Nathaniel R.; Jackson, Robert B.; Darrah, Thomas H.; Osborn, Stephen G.; Down, Adrian; Zhao, Kaiguang; White, Alissa; Vengosh, Avner.
- In: *Proceedings of the National Academy of Sciences*, Vol. 109, Issue 30, pages 11961-11966.
- http://www.pnas.org/content/early/2012/07/03/1121181109

Abstract: The debate surrounding the safety of shale gas development in the Appalachian Basin has generated increased awareness of drinking water quality in rural communities. Concerns include the potential for migration of stray gas, metal-rich formation brines, and hydraulic fracturing and/or flowback fluids to drinking water aquifers. A critical question common to these environmental risks is the hydraulic connectivity between the shale gas formations and the overlying shallow drinking water aquifers. We present geochemical evidence from northeastern Pennsylvania showing that pathways, unrelated to recent drilling activities, exist in some locations between deep underlying formations and shallow drinking water aquifers. Integration of chemical data (Br, Cl, Na, Ba, Sr, and Li) and isotopic ratios (87Sr/86Sr, 2H/H, 18O/16O, and 228Ra/226Ra) from this and previous studies in 426 shallow groundwater samples and 83 northern Appalachian brine samples suggest that mixing relationships between shallow ground water and a deep formation brine causes groundwater salinization in some locations. The strong geochemical fingerprint in the salinized (Cl > 20 mg/L) groundwater sampled from the Alluvium, Catskill, and Lock Haven aquifers suggests possible migration of Marcellus brine through naturally occurring pathways. The occurrences of saline water do not correlate with the location of shale-gas wells and are consistent with reported data before rapid shale-gas development in the region; however, the presence of these fluids suggests conductive pathways and specific geostructural and/or hydrodynamic regimes in northeastern Pennsylvania that are at increased risk for contamination of shallow drinking water resources, particularly by fugitive gases, because of natural hydraulic connections to deeper formations.

April 30, 2012. [*Category:* Climate]

Life Cycle Carbon Footprint of Shale Gas: Review of Evidence and Implications.

- Weber, Christopher L.; Clavin, Christopher.

- In: *Environmental Science & Technology*, Vol. 46, Issue 11, pages 5688-5695.
- http://dx.doi.org/10.1021/es300375n

Abstract: The recent increase in the production of natural gas from shale deposits has significantly changed energy outlooks in both the US and world. Shale gas may have important climate benefits if it displaces more carbon-intensive oil or coal, but recent attention has discussed the potential for upstream methane emissions to counteract this reduced combustion greenhouse gas emissions. We examine six recent studies to produce a Monte Carlo uncertainty analysis of the carbon footprint of both shale and conventional natural gas production. The results show that the most likely upstream carbon footprints of these types of natural gas production are largely similar, with overlapping 95% uncertainty ranges of 11.0 - 21.0 g CO2e/MJLHV for shale gas and 12.4 - 19.5 g CO2e/MJLHV for conventional gas. However, because this upstream footprint represents less than 25% of the total carbon footprint of gas, the efficiency of producing heat, electricity, transportation services, or other function is of equal or greater importance when identifying emission reduction opportunities. Better data are needed to reduce the uncertainty in natural gas's carbon footprint, but understanding system-level climate impacts of shale gas, through shifts in national and global energy markets, may be more important and requires more detailed energy and economic systems assessments.

April 30, 2012. [*Category:* Climate]

Greenwashing gas: Might a 'transition fuel' label legitimize carbon-intensive natural gas development?

- Stephenson, Eleanor; Doukas, Alexander; Shaw, Karena.
- In: *Energy Policy*, Vol. 46, July 2012, pages 452-459.
- http://www.sciencedirect.com/science/article/pii/S0301421512003102

Abstract: Natural gas is widely considered to be the crucial "bridging fuel" in the transition to the low-carbon energy systems necessary to mitigate climate change. This paper develops a case study of the shale gas industry in British Columbia (BC), Canada to evaluate this assumption. We find that the transition fuel argument for gas development in BC is unsubstantiated by the best available evidence. Emissions factors for shale gas and LNG remain poorly characterized and contested in the academic literature, and context-specific factors have significant impacts on the lifecycle emissions of shale gas but have not been evaluated. Moreover, while the province has attempted to frame natural gas development within its ambitious climate change policy, this framing misrepresents substantive policy on gas production. The "transition fuel" and "climate solution" labels applied to development by the BC provincial government risk legitimizing carbon-intensive gas development. We argue that policy makers in BC and beyond should abandon the "transition fuel" characterization of natural gas. Instead, decision making about natural gas development should proceed through transparent engagement with the best available evidence to ensure that natural gas lives up to its best potential in supporting a transition to a low-carbon energy system.

April 27, 2012. [*Category:* Waste / Fluids]

Four-compartment partition model of hazardous components in hydraulic fracturing fluid additives.

- Aminto, Alison; Olson, Mira Stone.
- In: *Journal of Natural Gas Science and Engineering*, Vol. 7, July 2012, pages 16-21.
- http://www.sciencedirect.com/science/article/pii/S1875510012000327

Abstract: Mass balance principles were applied to a four-compartment partition model for 12 different hazardous components of hydraulic fracturing fluid additives used in 47 completed natural gas wells in the Marcellus Shale. Spill scenarios were modeled as if 1000 gallons of diluted additive were discharged into a surface water body or onto soil. Resulting concentrations were ranked according to magnitude, providing a relative comparison of quantities to be expected in each compartment. Highest mass concentrations in the water, soil and biota compartments were due to sodium hydroxide, 4,4-dimethyl oxazolidine, and hydrochloric acid. 4,4-dimethyl oxazolidine ranked highest in the air compartment.

April 26, 2012. [*Category:* Waste / Fluids]

A critical assessment of the efficacy of biocides used during the hydraulic fracturing process in shale natural gas wells.

- Struchtemeyer, Christopher G.; Morrison, Michael D.; Elshahed, Mostafa S.
- In: *Journal of International Biodeterioration & Biodegradation*, Vol. 71, pages 15-21.
- http://www.sciencedirect.com/science/article/pii/S096483051200073X

Abstract: We examined the efficacy of multiple biocides that are commonly used to control sulfate-reducing bacteria in fracturing fluids in shale natural gas formations. Seven biocides (tetrakis [hydroxymethyl] phosphonium sulfate, sodium hypochlorite, didecyldimethylammonium chloride, tri-n-butyl tetradecyl phosphonium chloride, glutaraldehyde, a glutaraldehyde and alkyldimethylbenzylammonium chloride blend, and a glutaraldehyde alkyldimethylethylbenzylammonium chloride blend) were examined. Minimum inhibitory concentrations (MIC) were determined using planktonic cells and biofilms of Desulfovibrio desulfuricans strain G20 and a sulfate-reducing enrichment culture that was obtained from a Barnett Shale frac pond. All biocides had higher MIC values for biofilms compared to planktonic cells from these two cultures. Higher concentrations of all biocides, except didecyldimethylammonium chloride, were required to kill planktonic cells of G20 that were exposed to humic acid. These results clearly indicate that biofilm formation by sulfate-reducing bacteria, as well as organic loading rates, negatively impact the efficacy of biocides. This work provides valuable information concerning the effects of biofilm formation and organic loading on biocide MIC values. These MIC data can be used as a guide for the control of microbial growth in future frac jobs, which should result in fewer incidences of sulfide production and corrosion in shale natural gas wells.

April 24, 2012. [*Category:* Water Quality]

Hydraulic fractures: How far can they go?

- Davies, Richard J.; Mathias, Simon A.; Moss, Jennifer; Hustoft, Steinar; Newport, Leo.
- In: *Marine and Petroleum Geology*, Vol. 37, Issue 1, pages 1-6.
- http://www.sciencedirect.com/science/article/pii/S0264817212000852

Abstract: The maximum reported height of an upward propagating hydraulic fracture from several thousand fracturing operations in the Marcellus, Barnett, Woodford, Eagle Ford and Niobrara shale (USA) is ~588 m. Of the 1170 natural hydraulic fracture pipes imaged with three-dimensional seismic data offshore of West Africa and mid-Norway it is ~1106 m. Based on these empirical data, the probability of a stimulated and natural hydraulic fracture extending vertically >350 m is ~1% and ~33% respectively. Constraining the probability of stimulating unusually tall hydraulic fractures in sedimentary rocks is extremely important as an evidence base for decisions on the safe vertical separation between the depth of stimulation and rock strata not intended for penetration.

April 24, 2012. [*Category:* Community]

Fracking and the Neoliberalization of the Hydro-Social Cycle in Pennsylvania's Marcellus Shale.

- Finewood, Michael H.; Stroup, Laura J.
- In: *Journal of Contemporary Water Research & Education*, Vol. 147, Issue 1, pages 72-79.
- http://onlinelibrary.wiley.com/doi/10.1111/j.1936-704X.2012.03104.x/abstract

Abstract: Oil and gas firms are utilizing a controversial drilling technique, hydraulic fracturing, or fracking, to access unconventional natural gas reserves in Pennsylvania's Marcellus Shale. The potential impacts of fracking are creating sharp tensions between stakeholders over the costs and benefits of drilling within their communities. In particular, much contention has emerged over water resources as the process both uses and degrades billions of gallons of water. This paper takes a critical look at the way multi-scale neoliberal discourses obfuscate comprehensive understandings of fracking's effect on water resources. We turn to the neoliberal environments literature as a way to situate the economic logic that normalizes the impacts of fracking on resources, particularly in the absence of an effective regulatory framework. We argue that neoliberal pro-fracking arguments are (re)defining the relationship among people, the environment, and institutions, which in turn normalizes the impacts on communities and the resources on which they depend.

April 17, 2012. [*Category:* Water Quality]

Potential Contaminant Pathways from Hydraulically Fractured Shale to Aquifers.

- Myers, Tom.
- In: *Groundwater*, Vol. 50, Issue 6, pages 872-882.
- http://onlinelibrary.wiley.com/doi/10.1111/j.1745-6584.2012.00933.x/abstract

Abstract: Hydraulic fracturing of deep shale beds to develop natural gas has caused concern regarding the potential for various forms of water pollution. Two potential pathways—advective transport through bulk media and preferential flow through fractures—could allow the transport of contaminants from the fractured shale to aquifers. There is substantial geologic evidence that natural vertical flow drives contaminants, mostly brine, to near the surface from deep evaporite sources. Interpretative modeling shows that advective transport could require up to tens of thousands of years to move contaminants to the surface, but also that fracking the shale could reduce that transport time to tens or hundreds of years. Conductive faults or fracture zones, as found throughout the Marcellus shale region, could reduce the travel time further. Injection of up to 15,000,000 L of fluid into the shale generates high pressure at the well, which decreases with distance from the well and with time after injection as the fluid advects through the shale. The advection displaces native fluids, mostly brine, and fractures the bulk media widening existing fractures. Simulated pressure returns to pre-injection levels in about 300 d. The overall system requires from 3 to 6 years to reach a new equilibrium reflecting the significant changes caused by fracking the shale, which could allow advective transport to aquifers in less than 10 years. The rapid expansion of hydraulic fracturing requires that monitoring systems be employed to track the movement of contaminants and that gas wells have a reasonable offset from faults.

April 15, 2012. [*Category:* Waste / Fluids]

Radioactive elements in natural gas: a case study on distribution of gaseous ^{222} radon and its origin mechanism.

- Luo, Haohan; Tang, Dazhen; Yan, Qituan; He, Wei; Xu, Hao.
- In: *Natural Hazards*, Vol. 63, Issue 2, pages 647-657.
- http://link.springer.com/article/10.1007/s11069-012-0171-z

Abstract: As natural gas becomes increasingly important in our daily life, studies have been carried out on trace elements such as mercury and arsenic within it. Other than those, the existence of radioactive gaseous radon from the combustion of natural gas indoors can cause severe diseases and damages to body organs, putting a hazardous impact on human health. At the same time, the radon can also corrode gas production and transportation equipment. A review of the literature on radon concentrations in natural gas produced from gas reservoirs in China and other countries have been studied. Radon is a decay product from 238U, which is closely related to the accumulation and migration of organic matter during diagenesis. Gas recovered from reservoirs with higher than average natural 238U contains higher than average levels of 222Rn. Massive fault systems and fracture zones appear to play a significant role in radon concentrations in natural gas.

April 5, 2012. [*Category:* General (Comment / Review)]

Shale gas and hydrofracturing.

- Schnoor, Jerald L.
- In: *Environmental Science & Technology*, Vol. 46, Issue 9, page 4686.
- http://pubs.acs.org/doi/full/10.1021/es3011767

Extract: The greatest energy story of the 21st century (so far) is the incredible ability to extract gas and oil from tight shale deposits in the U.S. and throughout the world. Advances in horizontal drilling technology and hydrofracturing allow natural gas to escape from shale formations following high pressure treatment, i.e. “fracking” with sand, water and chemicals. Something like 1000 trillion cubic feet of “new” gas could be produced in North America alone by such technology, enough gas for several decades

April 1, 2012. [*Categories:* Climate, General (Comment / Review)]

Is Shale Gas Good for Climate Change?

- Schrag, Daniel P.
- In: *Daedalus*, Vol. 141, Issue 2, pages 72-80.
- http://www.jstor.org/stable/23240280

Abstract: Shale gas is a new energy resource that has shifted the dominant paradigm on U.S. hydrocarbon resources. Some have argued that shale gas will play an important role in reducing greenhouse gas emissions by displacing coal used for electricity, serving as a moderate-carbon "bridge fuel." Others have questioned whether methane emissions from shale gas extraction lead to higher greenhouse gas emissions overall. I argue that the main impact of shale gas on climate change is neither the reduced emissions from fuel substitution nor the greenhouse gas footprint of natural gas itself, but rather the competition between abundant, low-cost gas and low-carbon technologies, including renewables and carbon capture and storage. This might be remedied if the gas industry joins forces with environmental groups, providing a counterbalance to the coal lobby, and ultimately eliminating the conventional use of coal in the United States.

March 25, 2012. [*Category:* Ecology]

Early Trends in Landcover Change and Forest Fragmentation Due to Shale-Gas Development in Pennsylvania: A Potential Outcome for the Northcentral Appalachians.

- Drohan, P. J.; Brittingham, M.; Bishop, J.; Yoder, K.

- In: *Environmental Management*, Vol. 49, Issue 5, pages 1061-1075.
- http://link.springer.com/article/10.1007/s00267-012-9841-6

Abstract: Worldwide shale-gas development has the potential to cause substantial landscape disturbance. The northeastern U.S., specifically the Allegheny Plateau in Pennsylvania, West Virginia, Ohio, and Kentucky, is experiencing rapid exploration. Using Pennsylvania as a proxy for regional development across the Plateau, we examine land cover change due to shale-gas exploration, with emphasis on forest fragmentation. Pennsylvania's shale-gas development is greatest on private land, and is dominated by pads with 1–2 wells; less than 10 % of pads have five wells or more. Approximately 45–62 % of pads occur on agricultural land and 38–54 % in forest land (many in core forest on private land). Development of permits granted as of June 3, 2011, would convert at least 644–1072 ha of agricultural land and 536–894 ha of forest land. Agricultural land conversion suggests that drilling is somewhat competing with food production. Accounting for existing pads and development of all permits would result in at least 649 km of new road, which, along with pipelines, would fragment forest cover. The Susquehanna River basin (feeding the Chesapeake Bay), is most developed, with 885 pads (26 % in core forest); permit data suggests the basin will experience continued heavy development. The intensity of core forest disturbance, where many headwater streams occur, suggests that such streams should become a focus of aquatic monitoring. Given the intense development on private lands, we believe a regional strategy is needed to help guide infrastructure development, so that habitat loss, farmland conversion, and the risk to waterways are better managed.

March 22, 2012. [*Categories:* Air Quality, Health]

Human health risk assessment of air emissions from development of unconventional natural gas resources.

- McKenzie, Lisa M.; Witter, Roxana Z.; Newman, Lee S.; Adgate, John L.
- In: *Science of the Total Environment*, Vol. 424, May 1, 2012, pages 79-87.
- http://www.sciencedirect.com/science/article/pii/S0048969712001933

Abstract: BACKGROUND: Technological advances (e.g. directional drilling, hydraulic fracturing), have led to increases in unconventional natural gas development (NGD), raising questions about health impacts. OBJECTIVES: We estimated health risks for exposures to air emissions from a NGD project in Garfield County, Colorado with the objective of supporting risk prevention recommendations in a health impact assessment (HIA). METHODS: We used EPA guidance to estimate chronic and subchronic non-cancer hazard indices and cancer risks from exposure to hydrocarbons for two populations: (1) residents living >½ mile from wells and (2) residents living ≤ ½ mile from wells. RESULTS: Residents living ≤ ½ mile from wells are at greater risk for health effects from NGD than are residents living >½ mile from wells. Subchronic exposures to air pollutants during well completion activities present the greatest potential for health effects. The subchronic non-cancer hazard index (HI) of 5 for residents ≤ ½ mile from wells was driven primarily by exposure to trimethylbenzenes, xylenes, and aliphatic hydrocarbons. Chronic HIs were 1 and 0.4. for residents ≤ ½ mile from wells and >½ mile from wells, respectively. Cumulative cancer risks were 10 in a million and 6 in a million for residents living ≤ ½ mile and >½ mile from wells, respectively, with benzene as the major contributor to the risk. CONCLUSIONS: Risk assessment can be used in HIAs to direct health risk prevention strategies. Risk management approaches should focus on reducing exposures to emissions during well completions. These preliminary results indicate that health effects resulting from air emissions during unconventional NGD warrant further study. Prospective studies should focus on health effects associated with air pollution.

March 2, 2012. [*Category:* Water Usage]

Water Use for Shale-Gas Production in Texas, US.

- Nicot, Jean-Philippe; Scanlon, Bridget R.
- In: *Environmental Science & Technology*, Vol. 46, Issue 6, pages 3580-3586.
- http://pubs.acs.org/doi/abs/10.1021/es204602t

Abstract: Shale-gas production using hydraulic fracturing of mostly horizontal wells has led to considerable controversy over water-resource and environmental impacts. The study objective was to quantify net water use for shale-gas production using data from Texas, which is the dominant producer of shale gas in the U.S. with a focus on three major plays: the Barnett Shale (∼15 000 wells, mid-2011), Texas-Haynesville Shale (390 wells), and Eagle Ford Shale (1040 wells). Past water use was estimated from well-completion data, and future water use was extrapolated from past water use constrained by shale-gas resources. Cumulative water use in the Barnett totaled 145 Mm^3 (2000–mid-2011). Annual water use represents ∼9% of water use in Dallas (population 1.3 million). Water use in younger (2008–mid-2011) plays, although less (6.5 Mm^3 Texas-Haynesville, 18 Mm^3 Eagle Ford), is increasing rapidly. Water use for shale gas is <1% of statewide water withdrawals; however, local impacts vary with water availability and competing demands. Projections of cumulative net water use during the next 50 years in all shale plays total ∼4350 Mm^3, peaking at 145 Mm^3 in the mid-2020s and decreasing to 23 Mm^3 in 2060. Current freshwater use may shift to brackish water to reduce competition with other users.

March 1, 2012. [*Category:* General (Comment / Review)]

An unconventional mindset for shale gas surface facilities.

- Guarnone, M.; Rossi, F.; Negri, E.; Grassi, C.; Genazzi, D.; Zennaro, R.
- In: *Journal of Natural Gas Science and Engineering*, Vol. 6, pages 14-23 (May, 2012).
- http://www.sciencedirect.com/science/article/pii/S1875510012000030

Abstract: Following the "gas revolution" occurring in the USA, where shale gas is contributing to abundant and low-priced domestic gas production, many companies and countries all around the world are considering investing in this type of gas source. Key elements of shale gas production include the extensive drilling campaign, the need for hydraulic fracturing (with its implication on the whole water supply/handling cycle) and the realisation of a continuously growing network of geographically scattered production facilities and flowlines, which accompany gas from wellheads to the final customers. Exporting shale gas experience from the USA to new promising basins will not simply mean customising subsurface technologies (such as drilling & completion or hydraulic fracturing) to a geologically different area; it will especially imply adopting an unconventional mindset for surface facilities. First of all, there may not be a context as fertile as in the USA in terms of existing infrastructures (pipelines, treatment plants) or abundance of local contractors/providers, therefore an efficient engineering and fast-response procurement and construction chain will be more crucial for life-cycle-cost minimization than it is for conventional gas production. Moreover, standardized and repeatable production facilities will likely be the most economically viable way to handle gas flow from hundreds or thousands of wells, designed in parallel with step-by-step territorial studies to locate those facilities considering geographical, infrastructural and legislative constraints and opportunities. Finally, the passage from exploration to extensive commercial production will likely require a proper appraisal campaign through a pilot development, especially in new areas, with the objective to "long-test" shale gas wells performances and optimize full-development approaches in an environmentally friendly way.

March, 2012. [*Category:* Water Quality]

Factors affecting the variability of stray gas concentration and composition in groundwater.

- Gorody, Anthony W.
- In: *Environmental Geosciences*, Vol. 19, Issue 1, pages 17-31.
- http://archives.datapages.com/data/deg/2012/eg0112/EG11013/EG11013.htm?doi=10.1306%2Feg.12081111013

Abstract: Identifying the source of stray gas in drinking water supplies principally relies on comparing the gas composition in affected water supplies with gas samples collected in shows while drilling, produced gases, casing head gases, pipeline gases, and other potential point sources. However, transport dynamics of free and dissolved gas migration in groundwater aquifers can modify both the concentration and the composition of point source stray gases flowing to aquifers and occurring in the groundwater environment. Accordingly, baseline and forensic investigations related to stray gas sources need to address the effects of mixing, dilution, and oxidation reactions in the context of regional and local hydrology. Understanding and interpreting such effects are best addressed by collecting and analyzing multiple samples from baseline groundwater investigations, potential point sources, and impacted water resources.

Several case studies presented here illustrate examples of the natural variability in gas composition and concentration data evident when multiple samples are collected from produced gases, casing head gases, and baseline groundwater investigations. Results show that analyses of single samples from either potential contaminant point sources or groundwater and surface water resources may not always be sufficient to document site-specific baseline conditions. Results also demonstrate the need to consistently sample and analyze a variety of baseline groundwater and gas composition screening parameters. A multidisciplinary approach is the best practice for differentiating among the effects of fluid and gas mixing, dilution, and natural attenuation.

February 21, 2012. [*Categories:* Air Quality, Climate]

Hydrocarbon emissions characterization in the Colorado Front Range: A pilot study.

- Pétron, Gabrielle; Frost, Gregory; Miller, Benjamin R.; Hirsch, Adam I.; Montzka, Stephen A.; Karion, Anna; Trainer, Michael; Sweeney, Colm; Andrews, Arlyn E.; Miller, Lloyd; Kofler, Jonathan; Bar-Ilan, Amnon; Dlugokencky, Ed J.; Patrick, Laura; Moore, Charles T.; Ryerson, Thomas B.; Siso, Carolina; Kolodzey, William; Lang, Patricia M.; Conway, Thomas; Novelli, Paul; Masarie, Kenneth; Hall, Bradley; Guenther, Douglas; Kitzis, Duane; Miller, John; Welsh, David; Wolfe, Dan; Neff, William; Tans, Pieter.
- In: *Journal of Geophysical Research*, Vol. 117, Issue D4, D04304 (19 pages).
- http://onlinelibrary.wiley.com/doi/10.1029/2011JD016360/abstract & http://www.readcube.com/articles/10.1029/2011JD016360?

Abstract: The multispecies analysis of daily air samples collected at the NOAA Boulder Atmospheric Observatory (BAO) in Weld County in northeastern Colorado since 2007 shows highly correlated alkane enhancements caused by a regionally distributed mix of sources in the Denver-Julesburg Basin. To further characterize the emissions of methane and non-methane hydrocarbons (propane, n-butane, i-pentane, n-pentane and benzene) around BAO, a pilot study involving automobile-based surveys was carried out during the summer of 2008. A mix of venting emissions (leaks) of raw natural gas and flashing emissions from condensate storage tanks can explain the alkane ratios we observe in air masses impacted by oil and gas operations in northeastern Colorado. Using the WRAP Phase III inventory of total volatile organic compound (VOC) emissions from oil and gas exploration, production and processing, together with flashing and venting emission speciation profiles provided by State agencies or the oil and gas industry, we derive a range of bottom-up speciated emissions for Weld County in 2008. We use the observed ambient molar ratios and flashing and venting emissions data to calculate top-down scenarios for the amount of natural gas leaked to the atmosphere and the associated methane and non-methane emissions. Our analysis suggests that the emissions of the species we measured are most likely underestimated in current inventories and that the uncertainties attached to these estimates can be as high as a factor of two.

February 21, 2012. [*Category:* Climate]

Potential Restrictions for CO2 Sequestration Sites Due to Shale and Tight Gas Production.

- Elliot, T. R.; Celia, M. A.
- In: *Environmental Science & Technology*, Vol. 46, Issue 7, pages 4223-4227.
- http://pubs.acs.org/doi/abs/10.1021/es2040015

Abstract: Carbon capture and geological sequestration is the only available technology that both allows continued use of fossil fuels in the power sector and reduces significantly the associated CO2 emissions. Geological sequestration requires a deep permeable geological formation into which captured CO2 can be injected, and an overlying impermeable formation, called a caprock, that keeps the buoyant CO2 within the injection formation. Shale formations typically have very low permeability and are considered to be good caprock formations. Production of natural gas from shale and other tight formations involves fracturing the shale with the explicit objective to greatly increase the permeability of the shale. As such, shale gas production is in direct conflict with the use of shale formations as a caprock barrier to CO2 migration. We have examined the locations in the United States where deep saline aquifers, suitable for CO2 sequestration, exist, as well as the locations of gas production from shale and other tight formations. While estimated sequestration capacity for CO2 sequestration in deep saline aquifers is large, up to 80% of that capacity has areal overlap with potential shale-gas production regions and, therefore, could be adversely affected by shale and tight gas production. Analysis of stationary sources of CO2 shows a similar effect: about two-thirds of the total emissions from these sources are located within 20 miles of a deep saline aquifer, but shale and tight gas production could affect up to 85% of these sources. These analyses indicate that colocation of deep saline aquifers with shale and tight gas production could significantly affect the sequestration capacity for CCS operations. This suggests that a more comprehensive management strategy for subsurface resource utilization should be developed.

February 16, 2012. [*Category:* Ecology]

Status of Fish and Macroinvertebrate Communities in a Watershed Experiencing High Rates of Fossil Fuel Extraction: Tenmile Creek, a Major Monongahela River Tributary.

- Kimmel, William G.; Argent, David G.

- In: *Water, Air, & Soil Pollution*, Vol. 223, Issue 7, pages 4647-4657.
- http://link.springer.com/article/10.1007/s11270-012-1076-x

Abstract: Over the summer and fall seasons, 2006–2010, we surveyed the fish and macroinvertebrate communities of the Tenmile Creek basin in southwestern Pennsylvania, an area undergoing accelerated extraction of energy resources—historically coal and more recently natural gas associated with the Marcellus formation. Tenmile Creek, its major South Fork (SF), and numerous tributaries drain a basin of 875 km^2. The drainage network is characterized as warm-water, low-gradient, and net alkaline. The purpose was to provide synoptic baseline data on water quality and the resident aquatic communities in terms of species richness, stress tolerance, and trophic structure. Overall, we sampled 20 stations on the 2 main branches and 1 on each of the 12 tributaries. We collected 26,375 fishes representing nine families and 54 species/hybrids along with 989 macroinvertebrates from 25 separate taxa. The parameter which defines water quality here is specific conductance which ranges from natural background levels of about 400 μS/cm on the minimally impaired Tenmile mainstem to 4,500 μS/cm on its SF. Diverse fish and macroinvertebrate communities were documented at levels of specific conductance exceeding 1,000 μS/cm, well above the 300 μS/cm criterion to protect aquatic life proposed by the US Environmental Protection Agency for streams in the Central Appalachian Region. South Fork fish communities exhibit impairment at levels of specific conductance approaching the maximum observed here.

February 16, 2012. [Category: Climate]

Greenhouse gases, climate change and the transition from coal to low-carbon electricity.

- Myhrvold, N. P.; Caldeira, K.
- In: *Environmental Research Letters*, Vol. 7, Issue 1.
- http://iopscience.iop.org/1748-9326/7/1/014019

Abstract: A transition from the global system of coal-based electricity generation to low-greenhouse-gas-emission energy technologies is required to mitigate climate change in the long term. The use of current infrastructure to build this new low-emission system necessitates additional emissions of greenhouse gases, and the coal-based infrastructure will continue to emit substantial amounts of greenhouse gases as it is phased out. Furthermore, ocean thermal inertia delays the climate benefits of emissions reductions. By constructing a quantitative model of energy system transitions that includes life-cycle emissions and the central physics of greenhouse warming, we estimate the global warming expected to occur as a result of build-outs of new energy technologies ranging from 100 GWe to 10 TWe in size and 1–100 yr in duration. We show that rapid deployment of low-emission energy systems can do little to diminish the climate impacts in the first half of this century. Conservation, wind, solar, nuclear power, and possibly carbon capture and storage appear to be able to achieve substantial climate benefits in the second half of this century; however, natural gas cannot.

February 13, 2012. [*Category:* Climate]

Greater focus needed on methane leakage from natural gas infrastructure.

- Alvarez, Ramón A.; Pacala, Stephen W.; Winebrake, James J.; Chameides, William L.; Hamburg, Steven P.
- In: *Proceedings of the National Academy of Sciences*, Vol. 109, Issue 17, pages 6435-6440.
- http://www.pnas.org/content/early/2012/04/02/1202407109

Abstract: Natural gas is seen by many as the future of American energy: a fuel that can provide energy independence and reduce greenhouse gas emissions in the process. However, there has also been confusion about the climate implications of increased use of natural gas for electric power and transportation. We propose and illustrate the use of technology warming potentials as a robust and transparent way to compare the cumulative radiative forcing created by alternative technologies fueled by natural gas and oil or coal by using the best available estimates of greenhouse gas emissions from each fuel cycle (i.e., production, transportation and use). We find that a shift to compressed natural gas vehicles from gasoline or diesel vehicles leads to greater radiative forcing of the climate for 80 or 280 yr, respectively, before beginning to produce benefits. Compressed natural gas vehicles could produce climate benefits on all time frames if the well-to-wheels CH4 leakage were capped at a level 45–70% below current estimates. By contrast, using natural gas instead of coal for electric power plants can reduce radiative forcing immediately, and reducing CH4 losses from the production and transportation of natural gas would produce even greater benefits. There is a need for the natural gas industry and science community to help obtain better emissions data and for increased efforts to reduce methane leakage in order to minimize the climate footprint of natural gas.

February 9, 2012. [*Category:* Climate]

Implications of the Recent Reductions in Natural Gas Prices for Emissions of CO2 from the US Power Sector.

- Lu, Xi; Salovaara, Jackson; McElroy, Michael B.

- In: *Environmental Science & Technology*, Vol. 46, Issue 5, pages 3014-3021.
- http://pubs.acs.org/doi/abs/10.1021/es203750k

Abstract: CO_2 emissions from the US power sector decreased by 8.76% in 2009 relative to 2008 contributing to a decrease over this period of 6.59% in overall US emissions of greenhouse gases. An econometric model, tuned to data reported for regional generation of US electricity, is used to diagnose factors responsible for the 2009 decrease. More than half of the reduction is attributed to a shift from generation of power using coal to gas driven by a recent decrease in gas prices in response to the increase in production from shale. An important result of the model is that, when the cost differential for generation using gas rather than coal falls below 2–3 cents/kWh, less efficient coal fired plants are displaced by more efficient natural gas combined cycle (NGCC) generation alternatives. Costs for generation using NGCC decreased by close to 4 cents/kWh in 2009 relative to 2008 ensuring that generation of electricity using gas was competitive with coal in 2009 in contrast to the situation in 2008 when gas prices were much higher. A modest price on carbon could contribute to additional switching from coal to gas with further savings in CO_2 emissions.

February 1, 2012. [*Category:* Climate]

Venting and leaking of methane from shale gas development: response to Cathles et al.

- Howarth, Robert W.; Santoro, Renee; Ingraffea, Anthony.
- In: *Climatic Change*, Vol. 113, Issue 2, pages 537-549.
- http://link.springer.com/article/10.1007/s10584-012-0401-0

Abstract: In April 2011, we published the first comprehensive analysis of greenhouse gas (GHG) emissions from shale gas obtained by hydraulic fracturing, with a focus on methane emissions. Our analysis was challenged by Cathles et al. (2012). Here, we respond to those criticisms. We stand by our approach and findings. The latest EPA estimate for methane emissions from shale gas falls within the range of our estimates but not those of Cathles et al. which are substantially lower. Cathles et al. believe the focus should be just on electricity generation, and the global warming potential of methane should be considered only on a 100-year time scale. Our analysis covered both electricity (30% of US usage) and heat generation (the largest usage), and we evaluated both 20- and 100-year integrated time frames for methane. Both time frames are important, but the decadal scale is critical, given the urgent need to avoid climate-system tipping points. Using all available information and the latest climate science, we conclude that for most uses, the GHG footprint of shale gas is greater than that of other fossil fuels on time scales of up to 100 years. When used to generate electricity, the shale-gas footprint is still significantly greater than that of coal at decadal time scales but is less at the century scale. We reiterate our conclusion from our April 2011 paper that shale gas is not a suitable bridge fuel for the 21st Century.

January 28, 2012. [*Category:* Ecology]

Human-mediated shifts in animal habitat use: Sequential changes in pronghorn use of a natural gas field in Greater Yellowstone.

- Beckmann, Jon P.; Murray, Kim; Seidler, Renee G.; Berger, Joel.
- In: *Biological Conservation*, Vol. 147, Issue 1, pages 222-223.
- http://www.sciencedirect.com/science/article/pii/S0006320712000043

Abstract: To manage America's 991,479 km2 (245 million acres) of public BLM lands for such mixed uses as natural resource extraction, wildlife, and recreation requires knowledge about effects of habitat alterations. Two of North America's largest natural gas fields occur in the southern region of the Greater Yellowstone Ecosystem (Wyoming), an area that contains >100,000 wintering ungulates. During a 5-year period (2005–2009), we concentrated on patterns of habitat selection of pronghorn (Antilocapra americana) to understand how winter weather and increasing habitat loss due to gas field development impact habitat selection. Since this population is held below a food ceiling (i.e., carrying capacity) by human harvest, we expected few habitat constraints on animal movements – hence we examined fine-scale habitat use in relationship to progressive energy footprints. We used mixed-effects resource selection function models on 125 GPS-collared female pronghorn, and analyzed a comprehensive set of factors that included habitat (e.g., slope, plant cover type) and variables examining the impact of gas field infrastructure and human activity (e.g., distance to nearest road and well pad, amount of habitat loss due to conversion to a road or well pad) inside gas fields. Our RSF models demonstrate: (1) a fivefold sequential decrease in habitat patches predicted to be of high use and (2) sequential fine-scale abandonment by pronghorn of areas with the greatest habitat loss and greatest industrial footprint. The ability to detect behavioral impacts may be a better sentinel and earlier warning for burgeoning impacts of resource extraction on wildlife populations than studies focused solely on demography. Nevertheless disentangling cause and effect through the use of behavior warrants further investigation.

January 10, 2012. [*Categories:* General (Comment / Review), Health]

Missing from the Table: Role of the Environmental Public Health Community in Governmental Advisory Commissions Related to Marcellus Shale Drilling.

- Goldstein, Bernard D.; Kriesky, Jill; Pavliakova, Barbara.
- In: *Environmental Health Perspectives*, Vol. 120, Issue 4, pages 483-486.
- http://www.ncbi.nlm.nih.gov/pmc/articles/PMC3339470/

Abstract:

Background

The Marcellus Shale is a vast natural gas field underlying parts of Pennsylvania, New York, West Virginia, Virginia, and Maryland. Rapid development of this field has been enabled by advances in hydrofracking techniques that include injection of chemical and physical agents deep underground. Response to public concern about potential adverse environmental and health impacts has led to the formation of state and national advisory committees.

Objectives

We review the extent to which advisory committees formed in 2011 by President Obama and governors of the states of Maryland and Pennsylvania contain individuals with expertise pertinent to human environmental public health. We also analyze the extent to which human health issues are of concern to the public by reviewing presentations at the public meeting of the Secretary of Energy Advisory Board (SEAB) Natural Gas Subcommittee formed by the U.S. President's directive.

Results

At a public hearing held by the SEAB Natural Gas Subcommittee 62.7% of those not in favor of drilling mentioned health issues. Although public health is specified to be a concern in the executive orders forming these three advisory committees, we could identify no individuals with health expertise among the 52 members of the Pennsylvania Governor's Marcellus Shale Advisory Commission, the Maryland Marcellus Shale Safe Drilling Initiative Advisory Commission, or the SEAB Natural Gas Subcommittee.

Conclusions

Despite recognition of the environmental public health concerns related to drilling in the Marcellus Shale, neither state nor national advisory committees selected to respond to these concerns contained recognizable environmental public health expertise.

January 9, 2012. [*Categories:* Water Usage, Water Quality]

Toward strategic management of shale gas development: Regional, collective impacts on water resources.

- Rahm, Brian G.; Riha, Susan J.
- In: *Environmental Science & Technology*, Vol. 17, March 2012, pages 12-23.
- http://www.sciencedirect.com/science/article/pii/S1462901111001948

Abstract: Shale gas resources are relatively plentiful in the United States and in many countries and regions around the world. Development of these resources is moving ahead amidst concerns regarding environmental risks, especially to water resources. The complex nature of this distributed extractive industry, combined with limited impact data, makes establishing possible effects and designing appropriate regulatory responses challenging. Here we move beyond the project level impact assessment approach to use regional collective impact analysis in order to assess a subset of potential water management policy options. Specifically, we examine hypothetical water withdrawals for hydraulic fracturing and the subsequent treatment of wastewater that could be returned or produced from future active shale gas wells in the currently undeveloped Susquehanna River Basin region of New York. Our results indicate that proposed water withdrawal management strategies may not provide greater environmental protection than simpler approaches. We suggest a strategy that maximizes protectiveness while reducing regulatory complexity. For wastewater treatment, we show that the Susquehanna River Basin region of New York State has limited capacity to treat wastewater using extant municipal infrastructure. We suggest that modest private investment in industrial treatment facilities can achieve treatment goals without putting public systems at risk. We conclude that regulation of deterministic water resource impacts of shale gas extraction should be approached on a regional, collective basis, and suggest that water resource management objectives can be met by balancing the need for development with environmental considerations and regulatory constraints.

January 9, 2012. [*Category:* Economics]

Haynesville shale play economic analysis.

- Kaiser, Mark J.
- In: *Journal of Petroleum Science and Engineering*, Volumes 82-83, February – March 2012, pages 75-89.
- http://www.sciencedirect.com/science/article/pii/S0920410512000034

Abstract: Unconventional gas resources in the U.S. are abundant, but their development is capital intensive and subject to technologic risk, geologic uncertainty, and gas price volatility. In the Haynesville shale, wells are characterized by high initial production rates and rapid decline, and it is the tradeoff between these conditions and high investment that define the profitability of the play. The purpose of this paper is to examine the economic viability and sustainability of the Haynesville shale play. We characterize the operating envelope under which Haynesville wells are economic and describe the profit space based on a technical review of production and cost characteristics in the region. We explore two-variable factor models using type curves and construct before and after tax functional relationships. The majority of Haynesville wells fail to break-even on a full-cycle basis at prevailing gas prices. For $6/Mcf gas, average producers are expected to generate pre-tax returns between 1 and 11.5% for 1 to $0.5/Mcf operating expenses and $7.5 million capital expenditure. P10 wells are expected to generate a pre-tax return of 52 to 25% for $7.5 to $10 million capital expenditures and post-tax returns of 40 to 20%. We show that gas prices in the first year of production are an important determinant of well profitability.

January 1, 2012. [*Category:* General (Comment / Review)]

Unconventional Bridges over Troubled Water - Lessons to Be Learned from the Canadian Oil Sands as the United States Moves to Develop the Natural Gas of the Marcellus Shale Play.

- Jefferies, Cameron.
- In: *Energy Law Journal*, Vol. 33, Issue 1, page 75.
- http://www.questia.com/library/journal/1P3-2673424501/unconventional-bridges-over-troubled-water-lessons

Synopsis: As North America's energy demands grow in the face of diminishing conventional fossil fuel resources, unconventional oil and gas figures to play an increasingly important role. This article assesses two important unconventional fossil fuel deposits, namely the oil sands located in Alberta, Canada and the Marcellus Shale gas located in America's Appalachian region as well as the importance of properly crafted regulatory regimes that safeguard another critical natural resource - fresh water. Development of unconventional fossil fuels requires considerable quantities of fresh water for extraction and produces substantial quantities of contaminated wastewater as a byproduct. This analysis addresses the importance of unconventional fossil fuels, compares the two resources in terms of extraction and water impact, highlights the weaknesses in the regulatory regimes in Alberta and the Marcellus Shale states, and proposes federal intervention and/or regional management as a possible solution, as justified by traditional theories of regulation (i.e., the externalization of pollution and race to the bottom theory). Commercial oil sands extraction has been ongoing for at least forty years and, above all, the Canadian experience demonstrates the importance of properly considered regulation and regional monitoring prior to accelerated development in the Marcellus Shale gas play.

December 29, 2011. [*Category:* General (Comment / Review)]

Modeling the implications of expanded US shale gas production.

- Medlock III, Kenneth Barry.
- In: *Energy Strategy Reviews*, Vol. 1, Issue 1, March 2012, pages 33-41.
- http://www.sciencedirect.com/science/article/pii/S2211467X11000071

Abstract: Conventional thinking just ten years ago was that the United States would become a major importer of liquefied natural gas. Yet, today the discussion has shifted to one of export potential, largely driven by the rapid development of shale gas resources. This has had dramatic implications not only for the US, but also for the rest of the world. In particular, the outlook for several gas exporting countries has been substantially altered. Namely, while the US has certainly from an energy security standpoint, Russia, Iran, Venezuela and Qatar have seen their projected fortunes reduced. Development of shale gas has effectively increased the global elasticity of supply and could substantially reduce overall dependence on exports from these critical countries.

December 28, 2011. [*Category:* Water Quality]

Water pollution risk associated with natural gas extraction from the Marcellus Shale.

- Rozell, Daniel J.; Reaven, Sheldon J.
- In: *Risk Analysis*, Vol. 32, Issue 8, August 2012, pages 1382-1393.
- http://www.ncbi.nlm.nih.gov/pubmed/22211399

Abstract: In recent years, shale gas formations have become economically viable through the use of horizontal drilling and hydraulic fracturing. These techniques carry potential environmental risk due to their high water use and substantial risk for water pollution. Using probability bounds analysis, we assessed the likelihood of water contamination from natural gas extraction in the Marcellus Shale. Probability bounds analysis is well suited when data are sparse and parameters highly uncertain. The study model identified five pathways of water contamination: transportation spills, well casing leaks, leaks through fractured rock, drilling site discharge, and wastewater disposal. Probability boxes were generated for each pathway. The potential contamination risk and epistemic uncertainty associated with hydraulic fracturing wastewater disposal was several orders of magnitude larger than the other pathways. Even in a best-case scenario, it was very likely that an individual well would release at least 200 m^3 of contaminated fluids. Because the total number of wells in the Marcellus Shale region could range into the tens of thousands, this substantial potential risk suggested that additional steps be taken to reduce the potential for contaminated fluid leaks. To reduce the considerable epistemic uncertainty, more data should be collected on the ability of industrial and municipal wastewater treatment facilities to remove contaminants from used hydraulic fracturing fluid.

December 26, 2011. [*Category:* Economics]

Profitability assessment of Haynesville shale gas wells.

- Kaiser, Mark J.
- In: *Energy*, Vol. 38, Issue 1, pages 315-330.
- http://www.sciencedirect.com/science/article/pii/S0360544211007882

Abstract: The Haynesville shale in Louisiana is one of several unconventional gas plays that have been discovered in the U.S. in the past decade and promise to dramatically change the course of future energy development given its enormous resource potential. Unconventional gas resources are abundant, but their development is particularly sensitive to technologic risk, geologic uncertainty, and gas price. To produce at commercial rates, shale gas wells require horizontal drilling and hydraulic fracturing which significantly increases the capital cost. The purpose of this paper is to examine the price sensitivity of Haynesville wells and the economic viability of the play. We characterize the operating envelope under which Haynesville wells are economic and describe the profit space based on a review of production and cost characteristics. The majority of Haynesville wells fail to break-even on a full-cycle basis at prevailing gas prices. This harsh economic reality will control future activity after new entrants fulfill their drilling requirements. For $5/Mcf gas, the average Haynesville well is expected to generate a 10% return when drilling and completion costs are $7 million and operating expenditures are $1/Mcf. We explore two-variable factor models using type curves and introduce functional relations for the multiple variable case.

December 23, 2011. [*Category:* Economics]

How the technical differences between shale gas and conventional gas projects lead to a new business model being required to be successful.

- Binnion, Michael.
- In: *Marine and Petroleum Geology*, Vol. 31, Issue 1, March 2012, pages 3-7.
- http://www.sciencedirect.com/science/article/pii/S0264817211002637

Abstract: This paper will make the case that the unconventional natural gas business is not the same as the conventional natural gas business. The skills involved in finding, developing and producing discreet pools of oil and gas are not identical to those for shale gas projects. However, they are similar enough that many companies large and small have not recognized this difference and have not changed their business models. Those companies are struggling to succeed. Others have become huge successes seemingly overnight. This paper is based primarily on our experience as a junior oil and gas start-up company with three different shale gas plays, as well as my observations as President of one of the first junior companies in Canada to become involved in shale gas. Our first shale gas play was the Liard Basin Besa River shale play in northeast British Columbia in western Canada. We tried conventional approaches, with the usual business model, and failed. Worse, we had to go back to the beginning of the learning curve and start over. More recently we have applied the new technical methods in our Utica shale gas play in Quebec in eastern Canada with great technical success. However, other "orders of magnitude" factors required for success have stalled our progress as we struggle with acquiring new skills in public policy and politics. Based on these experiences, it is our belief that geology and sound science still matters now more than ever. It is our position that new skills and approaches are needed in areas that have not been the traditional strengths of our industry.

December 21, 2011. [*Category:* Economics]

The effects of a natural gas boom on employment and income in Colorado, Texas, and Wyoming.

- Weber, Jeremy G.
- In: *Energy Economics*, Vol. 34, Issue 5, pages 1580-1588.
- http://www.sciencedirect.com/science/article/pii/S0140988311002878

Abstract: Improvements in technology have made it profitable to tap unconventional gas reservoirs in relatively impermeable shale and sandstone deposits, which are spread throughout the U.S., mostly in rural areas. Proponents of gas drilling point to the activity's local economic benefits yet no empirical studies have systematically documented the magnitude or distribution of economic gains. I estimate these gains for counties in Colorado, Texas, and Wyoming, three states where natural gas production expanded substantially since the late 1990s. I find that a large increase in the value of gas production caused modest increases in employment, wage and salary income, and median household income. The results suggest that each million dollars in gas production created 2.35 jobs in the county of production, which led to an annualized increase in employment that was 1.5% of the pre-boom level for the average gas boom county. Comparisons show that ex-ante estimates of the number of jobs created by developing the Fayetteville and Marcellus shale gas formations may have been too large.

November 28, 2011. [*Category:* Water Quality]

Transport properties of unconventional gas systems.

- Amann-Hildenbrand, Alexandra; Ghanizadeh, Amin; Krooss, Bernhard M.
- In: *Marine and Petroleum Geology*, Vol. 31, Issue 1, March 2012, pages 90-99.
- http://www.sciencedirect.com/science/article/pii/S0264817211002595

Abstract: An overview is given of the mechanisms and processes (viscous flow, diffusion, sorption, desorption) affecting transport in unconventional reservoir rocks. Processes are described, terms and definitions are given, and selected literature data are presented to document the state of knowledge and the data situation on gas, water and two-phase flow in low-permeable lithotypes. Gas transport in the matrix of shales and coals is controlled by and may be restricted to diffusion. Depending on the gas type (e.g. methane or carbon dioxide), transport may be strongly affected by sorption. In many instances, high capillary threshold pressures prevent gas from moving as a continuous phase through the conducting pore network. In contrast, tight sandstone reservoir rocks allow for capillary-controlled viscous flow of a gas phase. Because in these rocks the determination of the water saturation at the prevailing flow conditions is difficult or impossible, we propose to directly use the relationship between effective gas permeability and capillary pressure for the description of two-phase (gas/water) flow in these rocks. In ongoing studies this relationship is being studied systematically for both, steady state and non-steady state saturation conditions.

November 22, 2011. [*Category:* Climate]

Life-Cycle Greenhouse Gas Emissions of Shale Gas, Natural Gas, Coal, and Petroleum.

- Burnham, Andrew; Han, Jeongwoo; Clark, Corrie E.; Wang, Michael; Dunn, Jennifer B.; Palou-Rivera, Ignasi.

- In: *Environmental Science & Technology*, Vol. 46, Issue 2, pages 619-627.
- http://dx.doi.org/10.1021/es201942m

Abstract: The technologies and practices that have enabled the recent boom in shale gas production have also brought attention to the environmental impacts of its use. It has been debated whether the fugitive methane emissions during natural gas production and transmission outweigh the lower carbon dioxide emissions during combustion when compared to coal and petroleum. Using the current state of knowledge of methane emissions from shale gas, conventional natural gas, coal, and petroleum, we estimated up-to-date life-cycle greenhouse gas emissions. In addition, we developed distribution functions for key parameters in each pathway to examine uncertainty and identify data gaps such as methane emissions from shale gas well completions and conventional natural gas liquid unloadings that need to be further addressed. Our base case results show that shale gas life-cycle emissions are 6% lower than conventional natural gas, 23% lower than gasoline, and 33% lower than coal. However, the range in values for shale and conventional gas overlap, so there is a statistical uncertainty whether shale gas emissions are indeed lower than conventional gas. Moreover, this life-cycle analysis, among other work in this area, provides insight on critical stages that the natural gas industry and government agencies can work together on to reduce the greenhouse gas footprint of natural gas.

November 15, 2011. [*Category:* Climate]

Modeling the Relative GHG Emissions of Conventional and Shale Gas Production.

- Stephenson, Trevor; Valle, Jose Eduardo; Riera-Palou, Xavier.
- In: *Environmental Science & Technology*, Vol. 45, Issue 24, pages 10757-10764.
- http://www.ncbi.nlm.nih.gov/pmc/articles/PMC3238415/

Abstract: Recent reports show growing reserves of unconventional gas are available and that there is an appetite from policy makers, industry, and others to better understand the GHG impact of exploiting reserves such as shale gas. There is little publicly available data comparing unconventional and conventional gas production. Existing studies rely on national inventories, but it is not generally possible to separate emissions from unconventional and conventional sources within these totals. Even if unconventional and conventional sites had been listed separately, it would not be possible to eliminate site-specific factors to compare gas production methods on an equal footing. To address this difficulty, the emissions of gas production have instead been modeled. In this way, parameters common to both methods of production can be held constant, while allowing those parameters which differentiate unconventional gas and conventional gas production to vary. The results are placed into the context of power generation, to give a ″well-to-wire″ (WtW) intensity. It was estimated that shale gas typically has a WtW emissions intensity about 1.8–2.4% higher than conventional gas, arising mainly from higher methane releases in well completion. Even using extreme assumptions, it was found that WtW emissions from shale gas need be no more than 15% higher than conventional gas if flaring or recovery measures are used. In all cases considered, the WtW emissions of shale gas powergen are significantly lower than those of coal.

November, 2011. [*Category:* Waste / Fluids]

Radon in Natural Gas from Marcellus Shale.

- Resnikoff, Marvin.
- In: *Ethics in Biology, Engineering and Medicine*, Vol. 2, Issue 4, pages 317-331.
- http://dl.begellhouse.com/journals/6ed509641f7324e6,2e9a7a8d16e248dd,2190f99a200e6f21.html

Abstract: A potential public health hazard associated with radon in natural gas from the Marcellus Shale formation should be investigated by regulatory agencies. Unlike present sources for natural gas, located in Texas and Louisiana, the Marcellus Shale formation is considerably closer to New York consumers and the radon concentrations at wellheads in New York and Pennsylvania are higher than the national average for natural gas wells. Using a simple Fortran program that simulates the production of radon in the well bore and transit to the well head, we calculate the wellhead concentrations of radon in natural gas from Marcellus Shale. Then accounting for the transit time to consumers, and the average dilution in homes, including smaller apartment volumes in urban areas, we determine the potential health effects of releasing radon in natural gas from unvented kitchen stoves, using Environmental Protection Agency data. While several uncertainties must be resolved, the potential health effects require investigation by regulatory agencies.

October 26, 2011. [*Category:* Economics]

The Hidden Factors That Make Wind Energy Cheaper than Natural Gas in the United States.

- McCubbin, Donald; Sovacool, Benjamin K.
- In: *The Electricity Journal*, Vol. 24, Issue 9, pages 84-95.
- http://www.sciencedirect.com/science/article/pii/S1040619011002351

Abstract: Based on an analysis comparing the 580 MW Altamont Pass wind farm in California and the 22 MW Sawtooth wind farm in Idaho with natural gas-fired generation, this article finds that wind energy provides significant and quantifiable human health, wildlife, and climate change benefits not normally considered by energy planners and utility operators. These benefits make wind energy far cheaper than natural gas.

October 25, 2011. [*Category:* Climate]

The greenhouse impact of unconventional gas for electricity generation.

- Hultman, Nathan; Rebois, Dylan; Scholten, Michael; Ramig, Christopher.
- In: *Environmental Research Letters*, Vol. 6, Issue 4, page 44008.
- http://iopscience.iop.org/1748-9326/6/4/044008

Abstract: New techniques to extract natural gas from unconventional resources have become economically competitive over the past several years, leading to a rapid and largely unanticipated expansion in natural gas production. The US Energy Information Administration projects that unconventional gas will supply nearly half of US gas production by 2035. In addition, by significantly expanding and diversifying the gas supply internationally, the exploitation of new unconventional gas resources has the potential to reshape energy policy at national and international levels—altering geopolitics and energy security, recasting the economics of energy technology investment decisions, and shifting trends in greenhouse gas (GHG) emissions. In anticipation of this expansion, one of the perceived core advantages of unconventional gas—its relatively moderate GHG impact compared to coal—has recently come under scrutiny. In this paper, we compare the GHG footprints of conventional natural gas, unconventional natural gas (i.e. shale gas that has been produced using the process of hydraulic fracturing, or ‘fracking’), and coal in a transparent and consistent way, focusing primarily on the electricity generation sector. We show that for electricity generation the GHG impacts of shale gas are 11% higher than those of conventional gas, and only 56% that of coal for standard assumptions.

October 24, 2011. [*Categories:* Climate, General (Comment / Review)]

Reducing the greenhouse gas footprint of shale gas.

- Wang, Jinsheng; Ryan, David; Anthony, Edward J.
- In: *Energy Policy*, Vol. 39, Issue 12, pages 8196-8199.
- http://www.sciencedirect.com/science/article/pii/S030142151100797X

Abstract: Shale gas is viewed by many as a global energy game-changer. However, serious concerns exist that shale gas generates more greenhouse gas emissions than does coal. In this work the related published data are reviewed and a reassessment is made. It is shown that the greenhouse gas effect of shale gas is less than that of coal over long term if the higher power generation efficiency of shale gas is taken into account. In short term, the greenhouse gas effect of shale gas can be lowered to the level of that of coal if methane emissions are kept low using existing technologies. Further reducing the greenhouse gas effect of shale gas by storing CO2 in depleted shale gas reservoirs is also discussed, with the conclusion that more CO2 than the equivalent CO2 emitted by the extracted shale gas could be stored in the reservoirs at significantly reduced cost.

October 10, 2011. [*Categories:* Economics, Regulation]

Economic Incentives and Regulatory Framework for Shale Gas Well Site Reclamation in Pennsylvania.

- Mitchell, Austin L.; Casman, Elizabeth A.
- In: *Environmental Science & Technology*, Vol. 45, Issue 22, pages 9506-9514.
- http://pubs.acs.org/doi/pdf/10.1021/es2021796

Abstract: Improperly abandoned gas wells threaten human health and safety as well as pollute the air and water. In the next 20 years, tens of thousands of new gas wells will be drilled into the Marcellus, Utica, and Upper Devonian shale formations of Pennsylvania. Pennsylvania currently requires production companies to post a bond to ensure environmental reclamation of abandoned well sites, but the size of the bond covers only a small fraction of the site reclamation costs. The economics of shale gas development favor transfer of assets from large entities to smaller ones. With the assets go the liabilities, and without a mechanism to prevent the new owners from assuming reclamation liabilities beyond their means, the economics favor default on well-plugging and site restoration obligations. Policy options and alternatives to bonding are discussed and evaluated.

October 6, 2011. [*Category:* Water Quality]

Rapid expansion of natural gas development poses a threat to surface waters.

- Entrekin, Sally; Evans-White, Michelle; Johnson, Brent; Hagenbuch, Elisabeth.
- In: *Frontiers in Ecology and the Environment*, Vol. 9, Issue 9, pages 503-511.
- http://www.esajournals.org/doi/abs/10.1890/110053

Abstract: Extraction of natural gas from hard-to-reach reservoirs has expanded around the world and poses multiple environmental threats to surface waters. Improved drilling and extraction technology used to access low permeability natural gas requires millions of liters of water and a suite of chemicals that may be toxic to aquatic biota. There is growing concern among the scientific community and the general public that rapid and extensive natural gas development in the US could lead to degradation of natural resources. Gas wells are often close to surface waters that could be impacted by elevated sediment runoff from pipelines and roads, alteration of streamflow as a result of water extraction, and contamination from introduced chemicals or the resulting wastewater. However, the data required to fully understand these potential threats are currently lacking. Scientists therefore need to study the changes in ecosystem structure and function caused by natural gas extraction and to use such data to inform sound environmental policy.

October 1, 2011. [*Category:* Climate]

Coal to gas: the influence of methane leakage.

- Wigley, Tom M. L.
- In: *Climatic Change*, Vol. 108, Issue 3, pages 601-608.
- http://link.springer.com/article/10.1007/s10584-011-0217-3

Abstract: Carbon dioxide (CO2) emissions from fossil fuel combustion may be reduced by using natural gas rather than coal to produce energy. Gas produces approximately half the amount of CO2 per unit of primary energy compared with coal. Here we consider a scenario where a fraction of coal usage is replaced by natural gas (i.e., methane, CH4) over a given time period, and where a percentage of the gas production is assumed to leak into the atmosphere. The additional CH4 from leakage adds to the radiative forcing of the climate system, offsetting the reduction in CO2 forcing that accompanies the transition from coal to gas. We also consider the effects of: methane leakage from coal mining; changes in radiative forcing due to changes in the emissions of sulfur dioxide and carbonaceous aerosols; and differences in the efficiency of electricity production between coal- and gas-fired power generation. On balance, these factors more than offset the reduction in warming due to reduced CO2 emissions. When gas replaces coal there is additional warming out to 2,050 with an assumed leakage rate of 0%, and out to 2,140 if the leakage rate is as high as 10%. The overall effects on global-mean temperature over the 21st century, however, are small.

Fall, 2011. [*Category:* Regulation]

Superfund to the rescue? Seeking potential CERCLA response authority and cost recovery liability for releases of hazardous substances resulting from hydraulic fracturing.

- Joyner, Sean H.
- In: *The Journal of Contemporary Health Law and Policy*, Vol. 28, Issue 1, pages 111-143.
- http://scholarship.law.edu/jchlp/vol28/iss1/7/

Excerpt: Water is our most vital natural resource, without which life cannot be sustained. Recognizing its importance, Congress has enacted environmental legislation in order to protect this resource for the public health and welfare. The main federal statutes concerned with the protection of this resource are the Clean Water Act ("CWA") and the Safe Drinking Water Act ("SDWA"). The SDWA in particular is concerned with the protection of underground sources of drinking water ("USDW"). However, the Energy Policy Act of 2005 amended the SDWA to exclude the practice of hydraulic fracturing ("fracking") from its statutory definition of an underground injection. This definition is somewhat ironic because fracking is the underground injection of proprietary chemicals mixed with substantial amounts of water into wells drilled deep into shale and other geologic formations to enhance the capture of natural gas. Without federal permitting requirements, the regulation of fracking is left almost exclusively to the states. Given the lack of specific federal oversight, the limited resources available to the states, the rapidly expanding scope of fracking, and the significant dangers to public health posed by fracking, there is a need for the federal government to assert a new regulatory approach to fracking using existing statutory authority.

September 20, 2011. [*Category:* Health]

Natural Gas Operations from a Public Health Perspective.

- Colborn, Theo; Kwiatkowski, Carol; Schultz, Kim; Bachran, Mary.
- In: *Human and Ecological Risk Assessment: An International Journal*, Vol. 17, Issue 5, pages 1039-1056.
- http://ourlongmont.org/wp-content/uploads/2012/10/Theo-Colborn-Peer-Reviewed-Article-on-Public-Health-Perspective-on-Natural-Gas1.pdf

Abstract: The technology to recover natural gas depends on undisclosed types and amounts of toxic chemicals. A list of 944 products containing 632 chemicals used during natural gas operations was compiled. Literature searches were conducted to determine potential health effects of the 353 chemicals identified by Chemical Abstract Service (CAS) numbers. More than 75% of the chemicals could affect the skin, eyes, and other sensory organs, and the respiratory and gastrointestinal systems. Approximately 40–50% could affect the brain/nervous system, immune and cardiovascular systems, and the kidneys; 37% could affect the endocrine system; and 25% could cause cancer and mutations. These results indicate that many chemicals used during the fracturing and drilling stages of gas operations may have long-term health effects that are not immediately expressed. In addition, an example was provided of waste evaporation pit residuals that contained numerous chemicals on the Comprehensive Environmental Response, Compensation, and Liability Act (CERCLA) and Emergency Planning and Community Right-to-Know Act (EPCRA) lists of hazardous substances. The discussion highlights the difficulty of developing effective water quality monitoring programs. To protect public health we recommend full disclosure of the contents of all products, extensive air and water monitoring, coordinated environmental/human health studies, and regulation of fracturing under the U.S. Safe Drinking Water Act.

September 16, 2011. [*Category:* General (Comment / Review)]

UK shale gas: The story so far.

- Selley, Richard C.
- In: *Marine and Petroleum Geology*, Vol. 31, Issue 1, pages 100-109.
- http://www.sciencedirect.com/science/article/pii/S0264817211002030

Abstract: The UK's first well to encounter shale gas was drilled into the Upper Jurassic Kimmeridge Clay in 1875, but its significance was not realised at the time. 25 years ago research at Imperial College applied the US shale gas paradigm to evaluate the UK's shale gas potential. Shale sequences with potential for gas production were identified in Carboniferous strata in the Midlands, and in Jurassic strata, particularly in the Weald. Without encouragement from Her Majesty's Government no exploration resulted from this initial research. Publication of the results of the project was rejected by many UK journals. It was finally published in the USA in 1987. Subsequent evaluations of UK petroleum resources by the Department of Energy and its descendants published in 2001 and 2003 omitted any mention of shale gas resources. Recent timely re-evaluations of the UK's shale gas potential have been carried out by the British Geological Survey and the Department for Energy & Climate Change. In 2008 the 13th Round of Onshore Licensing resulted in the award of several blocks for shale gas exploration, though bids were often based on a quest for both shale gas and conventional prospects. Cuadrilla Resource's Preese Hall No. 1 well drilled in 2010 was the first well drilled to specifically test for UK shale gas. The same drilling and fracturing techniques that led to the shale gas renaissance in the USA are now being applied to extracting oil from organic-rich shales that are currently in the oil window. It is interesting to speculate that oil may be produced by such techniques from the thermally mature Jurassic shales in the Wessex and Weald basins in the southern UK.

September 14, 2011. [*Category:* General (Comment / Review)]

Natural gas: Should fracking stop?

- Howarth, Robert W.; Ingraffea, Anthony; Engelder, Terry.
- In: Nature, Vol. 477, Issue 7364, pages 271-275.
- http://www.nature.com/nature/journal/v477/n7364/abs/477271a.html

Abstract: In this article, the authors discuss the positive and negative impact of natural gas fracking known as hydraulic fracturing to health and environment. Robert W. Howarth and Anthony Ingraffea say that extracting natural gas from shale increases the health and environmental risks. However, Terry Engelder argues that hydraulic fracturing is important to global economic stability in which fracking-related gas production can help alleviate global warming and reduce global greenhouse-gas emissions.

September 13, 2011. [*Category:* Water Quality]

Lack of data to support a relationship between methane contamination of drinking water wells and hydraulic fracturing.

- Saba, Tarek; Orzechowski, Mark.
- In: *Proceedings of the National Academy of Sciences*, Vol. 108, Issue 37, page E663.
- http://www.pnas.org/content/108/37/E663

Extract: Osborn et al. (1) sampled 68 water wells located in upstate New York (Genesee formation) and northeast Pennsylvania (Catskill and Lockhaven formations). The study opined that there is systematic evidence of increased concentrations of thermogenic methane in water wells near active gas extraction areas compared with water wells outside active gas extraction areas. Average methane concentrations were 19.2 and 1.1 mg L^{-1} for active and nonactive areas, respectively. By using isotope analysis, the study concluded that the thermogenic methane in the water wells is consistent with Marcellus shale gases. However, the Genesee data show that average methane concentrations in nonactive area water wells was 1.5 mg L …

September 6, 2011. [*Category:* Health]

Environmental health advocacy: an overview of natural gas drilling in northeast Pennsylvania and implications for pediatric nursing.

- Lauver, Lori S.
- In: *Journal of Pediatric Nursing*, Vol. 27, Issue 4, pages 383-389.
- http://www.ncbi.nlm.nih.gov/pubmed/22703686

Abstract: This article presents an overview of the Marcellus Shale gas well drilling project in northeast Pennsylvania and serves as a model for how nurses can evaluate such problems in their own communities. Resources to help nurses become involved in the environmental health advocacy process are made available.

August 30, 2011. [*Category:* Water Quality]

Hydraulic fracturing not responsible for methane migration.

- Samuel C. Schon.
- In: *Proceedings of the National Academy of Sciences*, Vol. 108, Issue 37, page E664.
- http://www.pnas.org/content/108/37/E664

Extract: Although Osborn et al. (1) provided important geochemical measurements of dissolved methane in a portion of the Appalachian basin, their report does not fully appreciate the geologic history of this region and misrepresents potential risks of modern drilling and completion techniques used to develop shale-gas resources. The fear that hydraulic fracturing is responsible for methane migration from the Marcellus shale into shallow groundwater is contrasted by direct observations in microseismic studies that even the longest fractures induced by the hydraulic fracturing …

August 16, 2011. [*Category:* Climate]

Uncertainty in life cycle greenhouse gas emissions from United States natural gas end-uses and its effects on policy.

- Venkatesh, Aranya; Jaramillo, Paulina; Griffin, W Michael; Matthews, H Scott.
- In: *Environmental Science & Technology*, Vol. 45, Issue 19, pages 8182-8189.
- http://pubs.acs.org/doi/abs/10.1021/es200930h

Abstract: Increasing concerns about greenhouse gas (GHG) emissions in the United States have spurred interest in alternate low carbon fuel sources, such as natural gas. Life cycle assessment (LCA) methods can be used to estimate potential emissions reductions through the use of such fuels. Some recent policies have used the results of LCAs to encourage the use of low carbon fuels to meet future energy demands in the U.S., without, however, acknowledging and addressing the uncertainty and variability prevalent in LCA. Natural gas is a particularly interesting fuel since it can be used to meet various energy demands, for example, as a transportation fuel or in power generation. Estimating the magnitudes and likelihoods of achieving emissions reductions from competing end-uses of natural gas using LCA offers one way to examine optimal strategies of natural gas resource allocation, given that its availability is likely to be limited in the future.

In this study, the uncertainty in life cycle GHG emissions of natural gas (domestic and imported) consumed in the U.S. was estimated using probabilistic modeling methods. Monte Carlo simulations are performed to obtain sample distributions representing life cycle GHG emissions from the use of 1 MJ of domestic natural gas and imported LNG. Life cycle GHG emissions per energy unit of average natural gas consumed in the U.S were found to range between −8 and 9% of the mean value of 66 g CO_2e/MJ. The probabilities of achieving emissions reductions by using natural gas for transportation and power generation, as a substitute for incumbent fuels such as gasoline, diesel, and coal were estimated. The use of natural gas for power generation instead of coal was found to have the highest and most likely emissions reductions (almost a 100% probability of achieving reductions of 60 g CO_2e/MJ of natural gas used), while there is a 10–35% probability of the emissions from natural gas being higher than the incumbent if it were used as a transportation fuel. This likelihood of an increase in GHG emissions is indicative of the potential failure of a climate policy targeting reductions in GHG emissions.

August 1, 2011. [*Categories:* General (Comment / Review), Health]

Blind Rush? Shale Gas Boom Proceeds Amid Human Health Questions.

- Schmidt, Charles W.
- In: *Environmental Health Perspectives*, Vol. 119, Issue 8, pages 348-453.
- http://www.ncbi.nlm.nih.gov/pmc/articles/PMC3237379/

Partial Commentary: In 2003 Range Resources, a natural gas company based in Fort Worth, Texas, was among the first of its competitors working on what appeared to be a promising deposit in Pennsylvania called the Marcellus Shale. Geologists had long believed the Marcellus was full of gas trapped in shale pores deep underground, like bubbles in fossilized soda. Range Resources was hoping to tap it with a method called hydraulic fracturing (or fracking for short) in which a high-volume mixture of water, sand, and chemicals is pumped into the shale under pressure. Several companies had used this approach to liberate natural gas from the Barnett Shale, a similar formation in Texas.

When Range Resources fracked the Marcellus Shale, the yields were at first modest. So the company shifted its approach; instead of drilling vertical wells straight into the shale, they drilled wells that could also turn sideways thousands of feet below the surface and then probe horizontally for miles in any direction. With horizontal drilling, the yields got steadily better, until Range Resources hit a jackpot in 2006: a gas-rich formation that might generate 50 years of profits for the company, according to spokesman Matt Pitzarella. That discovery helped confirm that the Marcellus—which cuts across portions of at least eight eastern states from New York to Tennessee—is one of the largest shale gas deposits in the world. A $400 million company in 2003, Range Resources is now valued at more than $8 billion, largely because of its Marcellus lease holdings.

Meanwhile, the combination of fracking and horizontal drilling has sent potentially recoverable amounts of natural gas nationwide soaring. The Energy Information Administration estimates that technically recoverable shale gas reserves have the potential to satisfy domestic consumption in the United States (based on 2010 figures) for more than 30 years.

But for shale gas to meet its potential, millions of Americans will have to live with drill rigs in or near their own neighborhoods. And that opens the door to a range of potential environmental health problems: pipelines and wellheads can explode, the process produces toxic air emissions, and fracking generates liquid wastes that can contaminate surface and drinking water supplies.

The fact that many gas companies—citing confidential business practices—won't readily disclose their fracking chemicals has also become a public relations issue for the industry. According to an April 2011 report for the U.S. House of Representatives Committee on Energy and Commerce, oil and gas service companies use 750 chemicals during fracking, some of them—for instance, salt, citric acid, and coffee—fairly innocuous as far as adverse human health effects are concerned, and some not. Naphthalene, xylene, toluene, ethylbenzene, and formaldehyde, for example, each used in a number of proprietary fracking solutions, are known or suspected human carcinogens. On 17 June 2011 Texas became the first state to require that drillers publicly disclose their fracking chemicals.

July 1, 2011. [*Category:* Climate]

Life cycle greenhouse gas emissions of Marcellus shale gas.

- Jiang, Mohan; Griffin, W. Michael; Hendrickson, Chris; Jaramillo, Paulina; VanBriesen, Jeanne; Venkatesh, Aranya.
- In: *Environmental Research Letters*, Vol. 6, Issue 3, 9 pages.
- http://iopscience.iop.org/1748-9326/6/3/034014

Abstract: This study estimates the life cycle greenhouse gas (GHG) emissions from the production of Marcellus shale natural gas and compares its emissions with national average US natural gas emissions produced in the year 2008, prior to any significant Marcellus shale development. We estimate that the development and completion of a typical Marcellus shale well results in roughly 5500 t of carbon dioxide equivalent emissions or about 1.8 g CO2e/MJ of gas produced, assuming conservative estimates of the production lifetime of a typical well. This represents an 11% increase in GHG emissions relative to average domestic gas (excluding combustion) and a 3% increase relative to the life cycle emissions when combustion is included. The life cycle GHG emissions of Marcellus shale natural gas are estimated to be 63–75 g CO2e/MJ of gas produced with an average of 68 g CO2e/MJ of gas produced. Marcellus shale natural gas GHG emissions are comparable to those of imported liquefied natural gas. Natural gas from the Marcellus shale has generally lower life cycle GHG emissions than coal for production of electricity in the absence of any effective carbon capture and storage processes, by 20–50% depending upon plant efficiencies and natural gas emissions variability. There is significant uncertainty in our Marcellus shale GHG emission estimates due to eventual production volumes and variability in flaring, construction and transportation.

June 3, 2011. [*Category:* General (Comment / Review)]

The Marcellus Shale: Resources and Reservations.

- Soeder, Daniel J.
- In: *EOS, Transactions American Geophysical Union*, Vol. 91, Issue 32, pages 277-278.
- http://onlinelibrary.wiley.com/doi/10.1029/2010EO320001/abstract

Abstract: The Marcellus Shale is an organic-rich, sedimentary rock formation in the Appalachian Basin of the northeastern United States that contains significant quantities of natural gas. Published estimates of the amount of gas that may be recoverable from the Marcellus Shale have been higher than 1.42 trillion cubic meters, or 50 trillion cubic feet [Engelder and Lash, 2008]. The recovery of commercial quantities of gas from a low-permeability rock like the Marcellus became economically possible with the application of directional drilling technology, which allows horizontal boreholes to penetrate kilometers of rock, combined with staged hydraulic fracturing to create permeable flow paths into the shale. Each hydraulic fracturing treatment may use more than 11 million liters of water (3 million gallons), which must then be recovered from the ground to allow gas flow [Harper, 2008].

June 1, 2011. [*Category:* Water Usage]

Water Management Challenges Associated with the Production of Shale Gas by Hydraulic Fracturing.

- Gregory, Kelvin B.; Vidic, Radisav D.; Dzombak, David A.
- In: *Elements*, Vol. 7, Issue 3, pages 181-186.
- http://elements.geoscienceworld.org/content/7/3/181

Abstract: Development of unconventional, onshore natural gas resources in deep shales is rapidly expanding to meet global energy needs. Water management has emerged as a critical issue in the development of these inland gas reservoirs, where hydraulic fracturing is used to liberate the gas. Following hydraulic fracturing, large volumes of water containing very high concentrations of total dissolved solids (TDS) return to the surface. The TDS concentration in this wastewater, also known as "flowback," can reach 5 times that of sea water. Wastewaters that contain high TDS levels are challenging and costly to treat. Economical production of shale gas resources will require creative management of flowback to ensure protection of groundwater and surface water resources. Currently, deep-well injection is the primary means of management. However, in many areas where shale gas production will be abundant, deep-well injection sites are not available. With global concerns over the quality and quantity of fresh water, novel water management strategies and treatment technologies that will enable environmentally sustainable and economically feasible natural gas extraction will be critical for the development of this vast energy source.

June, 2011. [*Category:* Ecology]

Effects of Disturbance Associated with Natural Gas Extraction on the Occurrence of Three Grassland Songbirds.

- Hamilton, Laura E.; Dale, Brenda C.; Paszkowski, Cynthia A.
- In: *Avian Conservation and Ecology*, Vol. 6, Issue 1, 7 pages.
- www.ace-eco.org/vol6/iss1/art7/ACE-ECO-2011-458.pdf

Abstract: Despite declines in the grassland bird guild and increasing rates of natural gas extraction on the Canadian prairies, relatively few studies have examined the effects of well sites and related infrastructure on these species. We conducted point counts on Canadian Forces Base Suffield, Alberta to investigate the effects of two well densities (high: 16 wells/2.59km(2), low: 9 wells/2.59km(2)) on Savannah Sparrow (Passerculus sandwichensis), Chestnut-collared Longspur (Calcarius ornatus), and Sprague's Pipit (Anthus spragueii) occurrence and abundance. Additionally, model building was employed to determine if landscape features, i.e., soil type, elevation, and topography, along with well density and anthropogenic disturbance to natural vegetation, i.e., the combined areas affected by wells, pipelines, trails, and roads, could predict the occurrence of the three species. For Savannah Sparrows, occurrence and abundance were higher in areas with high well densities compared with low well densities, reflecting the species' general tolerance of human disturbances. Chestnut-collared Longspurs were ubiquitous in the study area and abundance was not related to well density. Models for this species performed poorly and failed to predict occurrence accurately. Models for Sprague's Pipit were the strongest and showed that this species' occurrence was negatively related to anthropogenic disturbance. For all three species, landscape features had low predictive power. Our results indicate that disturbance caused by well sites and related infrastructure affect occurrence of some species and should be incorporated into conservation strategies for grassland birds, especially as undisturbed grasslands become candidates for energy development.

June, 2011. [*Category:* Community]

A thematic analysis of local respondents' perceptions of Barnett Shale energy development.

- Wynveen, Brooklynn J.

- In: *Journal of Rural Sciences*, Vol. 26, Issue 1, pages 8-31 (Part of a special issue devoted to unconventional natural gas development).
- http://www.ag.auburn.edu/auxiliary/srsa/pages/Articles/JRSS%202011%2026%201%208-31.pdf

Abstract: Researchers have found that the economic, social, and environmental impacts of energy development vary with both the type and location of development. Previous studies have highlighted impacts associated with the conventional energy development that occurred in the western United States in the 1970s and 1980s, and with offshore oil drilling in the Gulf of Mexico. Recently, however, unconventional natural gas development has become a more common type of energy development, the impacts of which are not yet well understood. To assess these impacts, as part of a larger quantitative study conducted within two Texas counties, survey respondents were invited to share "additional comments" as desired. I analyzed these comments using open coding and constant comparison to identify prominent themes for each county. Themes ranged from positive to negative, and reflected economic, social, and environmental impacts accompanying unconventional natural gas development. Findings may inform theory and be of interest to community leaders and others interested in the impacts of unconventional gas development.

May 20, 2011. [*Category:* Waste / Fluids]

Influence of the Drilling Mud Formulation Process on the Bacterial Communities in Thermogenic Natural Gas Wells of the Barnett Shale.

- Struchtemeyer, Christopher G.; Davis, James P.; Elshahed, Mostafa S.

- In: *Applied and Environmental Microbiology*, Vol. 77, Issue 14, pages 4744-4753.
- http://www.ncbi.nlm.nih.gov/pubmed/21602366

Abstract: The Barnett Shale in north central Texas contains natural gas generated by high temperatures (120 to 150 degrees C) during the Mississippian Period (300 to 350 million years ago). In spite of the thermogenic origin of this gas, biogenic sulfide production and microbiologically induced corrosion have been observed at several natural gas wells in this formation. It was hypothesized that microorganisms in drilling muds were responsible for these deleterious effects. Here we collected drilling water and drilling mud samples from seven wells in the Barnett Shale during the drilling process. Using quantitative real-time PCR and microbial enumerations, we show that the addition of mud components to drilling water increased total bacterial numbers, as well as the numbers of culturable aerobic heterotrophs, acid producers, and sulfate reducers. The addition of sterile drilling muds to microcosms that contained drilling water stimulated sulfide production. Pyrosequencing-based phylogenetic surveys of the microbial communities in drilling waters and drilling muds showed a marked transition from typical freshwater communities to less diverse communities dominated by Firmicutes and Gammaproteobacteria. The community shifts observed reflected changes in temperature, pH, oxygen availability, and concentrations of sulfate, sulfonate, and carbon additives associated with the mud formulation process. Finally, several of the phylotypes observed in drilling muds belonged to lineages that were thought to be indigenous to marine and terrestrial fossil fuel formations. Our results suggest a possible alternative exogenous origin of such phylotypes via enrichment and introduction to oil and natural gas reservoirs during the drilling process.

May 8, 2011. [*Category:* Water Quality]

Effects of Unconventional Gas Development on Groundwater: A Call for Total Dissolved Gas Pressure Field Measurements.

- Roy, J.W.; Ryan, M.C.
- *In: Groundwater*, Vol. 51, Issue 4, pages 480-482.
- http://onlinelibrary.wiley.com/doi/10.1111/gwat.12065/abstract

Summary: One of the primary public concerns with new development of shale and other unconventional gas resources is potential contamination of shallow groundwater with natural gas (largely methane). Natural gas contamination of shallow groundwater can result from leaky gas production wellbores (e.g. Stein et al., 2003; Van Stempvoort et al., 2005). However, there is also concern that hydraulic fracturing may enhance natural gas migration from deep formations to shallow groundwater (see Jackson et al., this issue, for further details). Measurements of groundwater gases will be needed to appropriately address these concerns. Field measurement of total dissolved gas pressure (PTDG) can provide useful information during investigations of the effects of natural gas development on groundwater, but it is not being widely used. We make the case here that PTDG has a critical role as we endeavour to collect accurate and objective data for assessing the impacts of shale gas development.

April 26, 2011. [*Categories:* Ecology, Waste / Fluids]

Land application of hydrofracturing fluids damages a deciduous forest stand in West Virginia.

- Adams, Mary Beth.
- In: *Journal of Environmental Quality*, Vol. 40, Issue 4, pages 1340-1344.
- http://www.nrs.fs.fed.us/pubs/jrnl/2011/nrs_2011_adams_001.pdf

Abstract: In June 2008, 303,000 L of hydrofracturing fluid from a natural gas well were applied to a 0.20-ha area of mixed hardwood forest on the Fernow Experimental Forest, West Virginia. During application, severe damage and mortality of ground vegetation was observed, followed about 10 d later by premature leaf drop by the overstory trees. Two years after fluid application, 56% of the trees within the fluid application area were dead. Ehrh. was the tree species with the highest mortality, and L. was the least affected, although all tree species present on the site showed damage symptoms and mortality. Surface soils (0-10 cm) were sampled in July and October 2008, June and October 2009, and May 2010 on the fluid application area and an adjacent reference area to evaluate the effects of the hydrofracturing fluid on soil chemistry and to attempt to identify the main chemical constituents of the hydrofracturing fluid. Surface soil concentrations of sodium and chloride increased 50-fold as a result of the land application of hydrofracturing fluids and declined over time. Soil acidity in the fluid application area declined with time, perhaps from altered organic matter cycling. This case study identifies the need for further research to help understand the nature and the environmental impacts of hydrofracturing fluids to devise optimal, safe disposal strategies.

April 14, 2011. [*Category:* Water Quality]

Methane contamination of drinking water accompanying gas-well drilling and hydraulic fracturing.

- Osborn, Stephen G.; Vengosh, Avner; Warner, Nathaniel R.; Jackson, Robert B.
- In: *Proceedings of the National Academy of Sciences*, Vol. 108, Issue 20, pages 8172-8176.
- http://www.pnas.org/content/108/20/8172

Abstract: Directional drilling and hydraulic-fracturing technologies are dramatically increasing natural-gas extraction. In aquifers overlying the Marcellus and Utica shale formations of northeastern Pennsylvania and upstate New York, we document systematic evidence for methane contamination of drinking water associated with shale-gas extraction. In active gas-extraction areas (one or more gas wells within 1 km), average and maximum methane concentrations in drinking-water wells increased with proximity to the nearest gas well and were 19.2 and 64 mg CH4 L-1 ($n = 26$), a potential explosion hazard; in contrast, dissolved methane samples in neighboring nonextraction sites (no gas wells within 1 km) within similar geologic formations and hydrogeologic regimes averaged only 1.1 mg L-1 ($P < 0.05$; $n = 34$). Average δ13C-CH4 values of dissolved methane in shallow groundwater were significantly less negative for active than for nonactive sites (-37 ± 7‰ and -54 ± 11‰, respectively; $P < 0.0001$). These δ13C-CH4 data, coupled with the ratios of methane-to-higher-chain hydrocarbons, and δ2H-CH4 values, are consistent with deeper thermogenic methane sources such as the Marcellus and Utica shales at the active sites and matched gas geochemistry from gas wells nearby. In contrast, lower-concentration samples from shallow groundwater at nonactive sites had isotopic signatures reflecting a more biogenic or mixed biogenic/thermogenic methane source. We found no evidence for contamination of drinking-water samples with deep saline brines or fracturing fluids. We conclude that greater stewardship, data, and—possibly—regulation are needed to ensure the sustainable future of shale-gas extraction and to improve public confidence in its use.

April 12, 2011. [*Category:* Climate]

Methane and the greenhouse-gas footprint of natural gas from shale formations.

- Howarth, Robert W.; Santoro, Renee; Ingraffea, Anthony.
- In: *Climatic Change*, Vol. 106, Issue 4, pages 679-690.
- http://link.springer.com/article/10.1007/s10584-011-0061-5

Abstract: We evaluate the greenhouse gas footprint of natural gas obtained by high-volume hydraulic fracturing from shale formations, focusing on methane emissions. Natural gas is composed largely of methane, and 3.6% to 7.9% of the methane from shale-gas production escapes to the atmosphere in venting and leaks over the life-time of a well. These methane emissions are at least 30% more than and perhaps more than twice as great as those from conventional gas. The higher emissions from shale gas occur at the time wells are hydraulically fractured—as methane escapes from flow-back return fluids—and during drill out following the fracturing. Methane is a powerful greenhouse gas, with a global warming potential that is far greater than that of carbon dioxide, particularly over the time horizon of the first few decades following emission. Methane contributes substantially to the greenhouse gas footprint of shale gas on shorter time scales, dominating it on a 20-year time horizon. The footprint for shale gas is greater than that for conventional gas or oil when viewed on any time horizon, but particularly so over 20 years. Compared to coal, the footprint of shale gas is at least 20% greater and perhaps more than twice as great on the 20-year horizon and is comparable when compared over 100 years.

April 7, 2011. [*Category:* Economics]

The economic impact of shale gas extraction: A review of existing studies.

- Kinnaman, Thomas C.
- In: *Ecological Economics*, Vol. 70, Issue 7, pages 1243-1249.
- http://www.sciencedirect.com/science/article/pii/S0921800911000590

Abstract: Recent advances in drilling technology have allowed for the profitable extraction of natural gas from deep underground shale rock formations. Several reports sponsored by the gas industry have estimated the economic effects of the shale gas extraction on incomes, employment, and tax revenues. None of these reports has been published in an economics journal and therefore have not been subjected to the peer review process. Yet these reports may be influential to the formation of public policy. This commentary provides written reviews of several studies purporting to estimate the economic impact of gas extraction from shale beds. Due to questionable assumptions, the economic impacts estimated in these reports are very likely overstated.

April 7, 2011. [*Category:* General (Comment/Review)]

A critical evaluation of unconventional gas recovery from the marcellus shale, northeastern United States.

- Lee, Dae Sung; Herman, Jonathan D.; Elsworth, Derek; Kim, Hyun Tae; Lee, Hyun Suk.
- In: *KSCE Journal of Civil Engineering*, Vol. 15, Issue 4, pages 679-687.
- http://link.springer.com/article/10.1007/s12205-011-0008-4

Abstract: The Marcellus tight gas shale represents a significant resource within the northeastern United States. It is both a large reserve, with an estimated 30 to 300 TCF of recoverable gas, and is close to some of the largest prospective markets in the country. However, production is fraught with technological obstacles, the most significant of which include prospecting, access by drilling, stimulation, and recovery. Prospecting is difficult because viability of the reservoir relies both on the original gas in place and in the ability to access that gas through pre-existing fractures that may be developed through stimulation. Drilling is a challenge since drilling costs typically comprise 50% of the cost of the wells and access to the reservoir is improved with horizontal drilling which may access a longer productive zone within the reservoir than cheaper vertical wells. Finally, stimulation methods are necessary to improve gas yields and to reduce the environmental impacts of both consumptive water use and the subsequent problems of safe disposal of fracwater waste. We discuss the challenges involved in the economic recovery of gas from tight gas shales in general and the Marcellus in particular.

March 22, 2011. [*Category:* Regulation]

Regulating hydraulic fracturing in shale gas plays: The case of Texas.

- Rahm, Dianne.
- In: *Energy Policy*, Vol. 39, Issue 5, pages 2974-2981.
- http://www.sciencedirect.com/science/article/pii/S0301421511001893

Abstract: The ability to economically produce natural gas from unconventional shale gas reservoirs has been made possible recently through the application of horizontal drilling and hydraulic fracturing. This new technique has radically changed the energy future of the United States. The U.S. has shifted from a waning producer of natural gas to a growing producer. The Energy Information Administration forecasts that by 2035 nearly half of U.S. natural gas will come from shale gas. Texas is a major player in these developments. Of the eight states and coastal areas that account for the bulk of U.S. gas, Texas has the largest proved reserves. Texas' Barnett Shale already produces six percent of the continental U.S.' gas and exploration of Texas' other shale gas regions is just beginning. Shale gas production is highly controversial, in part because of environmental concerns. Some U.S. states have put hydraulic fracturing moratoriums in place because of fear of drinking water contamination. The federal government has gotten involved and some states, like Texas, have accused it of overreaching. The contention over shale gas drilling in the U.S. may be a bellwether for other parts of the world that are now moving forward with their own shale gas production.

March 18, 2011. [*Categories:* General (Comment / Review), Health]

The rush to drill for natural gas: a public health cautionary tale.

- Finkel, Madelon L.; Law, Adam.
- In: *American Journal of Public Health*, Vol. 101, Issue 5, May 2011, pages 784-785.
- http://www.ncbi.nlm.nih.gov/pubmed/21421959

Abstract: Efforts to identify alternative sources of energy have focused on extracting natural gas from vast shale deposits. The Marcellus Shale, located in western New York, Pennsylvania, and Ohio, is estimated to contain enough natural gas to supply the United States for the next 45 years. New drilling technology-horizontal drilling and high-volume hydraulic fracturing of shale (fracking) has made gas extraction much more economically feasible. However, this technique poses a threat to the environment and to the public's health. There is evidence that many of the chemicals used in fracking can damage the lungs, liver, kidneys, blood, and brain. We discuss the controversial technique of fracking and raise the issue of how to balance the need for energy with the protection of the public's health.

March 13, 2011. [*Category:* General (Comment / Review)]

Shale gas comes into its own: at a cost.

- Guidotti, Tee L.
- In: *Archives of Environmental & Occupational Health*, Vol. 66, Issue 1, pages 1-2.
- http://www.ncbi.nlm.nih.gov/pubmed/21337179

March, 2011. [*Category:* Health]

Drilling the Marcellus shale for natural gas: environmental health issues for nursing.

- Kaktins, Nina M.
- In: *The Pennsylvania Nurse*, Vol. 66, Issue, pages 4-8; quiz 8-9.
- http://www.ncbi.nlm.nih.gov/pubmed/21560965

February 2, 2011. [*Category:* Economics]

Geological characteristics and resource potential of shale gas in China.

- Zou, Caineng; Dong, Dazhong; Wang, Shejiao; Li, Jianzhong; Li, Xinjing; Wang, Yuman; Li, Denghua; Cheng, Keming.
- In: *Petroleum Exploration and Development*, Vol. 37, Issue 6, pages 641-653.
- http://www.sciencedirect.com/science/article/pii/S1876380411600013

Abstract: With Sichuan Basin as focus, this paper introduces the depositional environment, geochemical and reservoir characteristics, gas concentration and prospective resource potential of three different types of shale in China: marine shale, marine-terrigenous shale and terrigenous shale. Marine shale features high organic abundance (TOC: 1.0%–5.5%), high-over maturity (Ro: 2%–5%), rich accumulation of shale gas (gas concentration: 1.17–6.02 m^3/t) and mainly continental shelf deposition, mainly distributed in the Paleozoic in the Yangtze area, Southern China, the Paleozoic in Northern China Platform and the Cambrian-Ordovician in Tarim Basin; Marine-terrigenous coalbed carbonaceous shale has high organic abundance (TOC: 2.6%–5.4%) and medium maturity (Ro: 1.1%–2.5%); terrigenous shale in the Mesozoic and Cenozoic has high organic abundance (TOC: 0.5%–22.0%) and mid-low maturity (Ro: 0.6–1.5%). The study on shale reservoirs in the Lower Paleozoic in Sichuan Basin discoveried nanometer-sized pores for the first time, and Cambrian and Silurian marine shale developed lots of micro- and nanometer-sized pores (100–200 nm), which is quite similar to the conditions in North America. Through comprehensive evaluation, it is thought that several shale gas intervals in Sichuan Basin are the practical targets for shale gas exploration and development, and that the Weiyuan-Changning area in the Mid-South of Sichuan Basin, which is characterized by high thermal evolution degree (Ro: 2.0%–4.0%), high porosity (3.0%–4.8%), high gas concentration (2.82–3.28 m^3/t), high brittle mineral content (40%–80%) and proper burial depth (1500–4500 m), is the core area for shale gas exploration and development, the daily gas production for Well Wei 201 is 1×104–2×104 m^3.

January 13, 2010. [*Category:* Water Quality]

Chemical and isotopic tracers of the contribution of microbial gas in Devonian organic-rich shales and reservoir sandstones, northern Appalachian Basin.

- Osborn, Stephen G.; McIntosh, Jennifer C.
- In: *Applied Geochemistry,* Vol. 25, Issue 3, pages 456-471.
- http://www.sciencedirect.com/science/article/pii/S0883292710000065

Abstract: In this study, the geochemistry and origin of natural gas and formation waters in Devonian age organic-rich shales and reservoir sandstones across the northern Appalachian Basin margin (western New York, eastern Ohio, northwestern Pennsylvania, and eastern Kentucky) were investigated. Additional samples were collected from Mississippian Berea Sandstone, Silurian Medina Sandstone and Ordovician Trenton/Black River Group oil and gas wells for comparison. Dissolved gases in shallow groundwaters in Devonian organic-rich shales along Lake Erie contain detectable CH_4 (0.01–50.55 mol%) with low $\delta^{13}C–CH_4$ values (−74.68 to −57.86‰) and no higher chain hydrocarbons, characteristics typical of microbial gas. Nevertheless, these groundwaters have only moderate alkalinity (1.14–8.72 meq/kg) and relatively low $\delta^{13}C$ values of dissolved inorganic C (DIC) (−24.8 to −0.6‰), suggesting that microbial methanogenesis is limited. The majority of natural gases in Devonian organic-rich shales and sandstones at depth (>168 m) in the northern Appalachian Basin have a low CH_4 to ethane and propane ratios (3–35 mol%; $C_1/C_2 + C_3$) and high $\delta^{13}C$ and δD values of CH_4 (−53.35 to −40.24‰, and −315.0 to −174.6‰, respectively), which increase in depth, reservoir age and thermal maturity; the molecular and isotopic signature of these gases show that CH_4 was generated via thermogenic processes. Despite this, the geochemistry of co-produced brines shows evidence for microbial activity. High $\delta^{13}C$ values of DIC (>+10‰), slightly elevated alkalinity (up to 12.01 meq/kg) and low SO_4 values (<1 mmole/L) in select Devonian organic-rich shale and sandstone formation water samples suggest the presence of methanogenesis, while low $\delta^{13}C$–DIC values (<−22‰) and relatively high SO_4 concentrations (up to 12.31 mmole/L) in many brine samples point to SO_4 reduction, which likely limits microbial CH_4 generation in the Appalachian Basin. Together the formation water and gas results suggest that the vast majority of CH_4 in the Devonian organic-rich shales and sandstones across the northern Appalachian Basin margin is thermogenic in origin. Small accumulations of microbial CH_4 are present at shallow depths along Lake Erie and in western NY.

January 2011. [*Category:* Community]

Natural Gas Landowner Coalitions in New York State: Emerging Benefits of Collective Natural Resource Management.

- Jacquet, Jeffrey; Stedman, Richard C.
- In: *Journal of Rural Social Sciences*, Vol. 26, Issue 1, pages 62-91.
- http://www.ag.auburn.edu/auxiliary/srsa/pages/Articles/JRSS%202011%2026%201%2062-91.pdf

Abstract: Thousands of rural landowners in New York State have joined together to form grassroots organizations aimed at collectively bargaining with natural gas companies. The leverage afforded by acting collectively allows these landowner coalitions to potentially influence the economic, environmental, and community impacts of gas development across hundreds of thousands of acres. In-depth interviews with coalition leaders conducted for this article reveal the scope, motivations, and benefits of membership in these groups. Our work examines these elements using multiple frameworks for understanding collective natural resource management. The coalitions are primarily concerned with the advancement of private member benefits, while public benefits of the collective action are poised to accrue indirectly. Group leaders are also contemplating how to use their leverage to secure direct benefits for the wider community – actions that may give communities a modicum of local control over gas development.

January 2011. [*Category:* Community]

Residents' Perceptions of Community and Environmental Impacts from Development of Natural Gas in the Marcellus Shale: A Comparison of Pennsylvania and New York Cases.

- Braiser, Kathryn J.; Filteau, Matthew R.; McLaughlin, Diane K.; Jacquet, Jeffrey; Stedman, Richard C.; Kelsey, Timothy W.; Goetz, Stephan J.
- In: *Journal of Rural Social Sciences*, Vol. 26, Issue 1, pages 32-61.
- http://www.ag.auburn.edu/auxiliary/srsa/pages/Articles/JRSS%202011%2026%201%2032-61.pdf

Abstract: Communities experiencing rapid growth due to energy development ('boomtowns') have reported positive and negative impacts on community and individual well-being. The perceptions of impacts vary according to stage of energy development as well as experience with extractive industries. Development of the Marcellus Shale provides an opportunity to examine these impacts over time and across geographic and historical contexts. This paper describes case study research in Pennsylvania and New York to document preliminary impacts of development occurring there. Cases vary by level of development and previous extractive history. The study finds that, in areas with low population density, higher levels of development lead to a broader awareness of natural gas impacts, both positive and negative. Participants draw from the regional history of extraction to express environmental concern despite direct, local experience. Our findings suggest the need to track these perceptions during development, and as individuals and communities react and adapt to the impacts.

January, 2011. [*Category:* Community]

Explaining Residential Energy Consumption: A Focus on Location and Race Differences in Natural Gas Use.

- Adua, Lazardus; Sharp, Jeff S.

- In: *Journal of Rural Sciences*, Vol. 26, Issue 1, pages 107-141.
- http://www.ag.auburn.edu/auxiliary/srsa/pages/Articles/JRSS%202011%2026%201%20107-141.pdf

Abstract: Researchers have long considered factors related to residential energy consumption. We contribute to this genre of work by exploring how residential location (rural-urban) and race are related to residential natural gas consumption. We also consider whether these relationships, if they exist, are functions of differences in housing characteristics, investment in energy efficiency, and weather conditions. Analyzing four waves of the Residential Energy Consumption Surveys, we find that natural gas consumption differs by residential location only to the extent that investment in energy efficiency and weather conditions are not taken into consideration. We also find race differences in natural gas consumption, with African-Americans consuming more per year than whites. African-Americans' higher natural gas consumption persists even after the effects of housing characteristics, investment in energy efficiency, weather conditions, and other critical covariates of energy consumption are statistically held constant. More work, especially field research, is needed to understand why African-Americans consume more natural gas than other groups.

November 18, 2010. [*Category:* Air Quality]

Ozone Impacts of Natural Gas Development in the Haynesville Shale.

- Kemball-Cook, Susan; Bar-Ilan, Amnon; Grant, John; Parker, Lynsey; Jung, Jaegun; Santamaria, Wilson; Mathews, Jim; Yarwood, Greg.
- In: *Environmental Science & Technology*, Vol. 44, Issue 24, pages 9357-9363.
- http://dx.doi.org/10.1021/es1021137

Abstract: The Haynesville Shale is a subsurface rock formation located beneath the Northeast Texas/Northwest Louisiana border near Shreveport. This formation is estimated to contain very large recoverable reserves of natural gas, and during the two years since the drilling of the first highly productive wells in 2008, has been the focus of intensive leasing and exploration activity. The development of natural gas resources within the Haynesville Shale is likely to be economically important but may also generate significant emissions of ozone precursors. Using well production data from state regulatory agencies and a review of the available literature, projections of future year Haynesville Shale natural gas production were derived for 2009−2020 for three scenarios corresponding to limited, moderate, and aggressive development. These production estimates were then used to develop an emission inventory for each of the three scenarios. Photochemical modeling of the year 2012 showed increases in 2012 8-h ozone design values of up to 5 ppb within Northeast Texas and Northwest Louisiana resulting from development in the Haynesville Shale. Ozone increases due to Haynesville Shale emissions can affect regions outside Northeast Texas and Northwest Louisiana due to ozone transport. This study evaluates only near-term ozone impacts, but the emission inventory projections indicate that Haynesville emissions may be expected to increase through 2020.

October 8, 2010. [*Category:* Water Quality]

Carbon and hydrogen isotopic evidence for the origin of combustible gases in water-supply wells in north-central Pennsylvania.

- Révész, Kinga M.; Breen, Kevin J.; Baldassare, Alfred J.; Burruss, Robert C.
- In: *Applied Geochemistry*, Vol. 25, Issue 12, pages 1845-1859.
- http://www.sciencedirect.com/science/article/pii/S0883292710002131

Abstract: The origin of the combustible gases in groundwater from glacial-outwash and fractured-bedrock aquifers was investigated in northern Tioga County, Pennsylvania. Thermogenic methane (CH4) and ethane (C2H6) and microbial CH4 were found. Microbial CH4 is from natural in situ processes in the shale bedrock and occurs chiefly in the bedrock aquifer. The δ13C values of CH4 and C2H6 for the majority of thermogenic gases from water wells either matched or were between values for the samples of non-native storage-field gas from injection wells and the samples of gas from storage-field observation wells. Traces of C2H6 with microbial CH4 and a range of C and H isotopic compositions of CH4 indicate gases of different origins are mixing in sub-surface pathways; gas mixtures are present in groundwater. Pathways for gas migration and a specific source of the gases were not identified. Processes responsible for the presence of microbial gases in groundwater could be elucidated with further geochemical study.

July 10, 2010. [*Category:* General (Comment/Review)]

The potential of gas shale.

- James, Ann.
- In: *World Pumps*, Vol. 2010, Issue 7, pages 16-18.
- http://www.sciencedirect.com/science/article/pii/S0262176210701954

Abstract: Robert McIlvaine and Ann James of McIlvaine Company show how extracting gas from shale deposits has become ever more economical, and discuss how pumps can play a role in this increasingly important form of energy, looking at a selection of important wells across the U.S.

June 2, 2010. [*Category:* General (Comment / Review)]

Natural Gas Plays in the Marcellus Shale: Challenges and Potential Opportunities.

- Kargbo, David M.; Wilhelm, Ron G.; Campbell, David J.
- In: *Environmental Science & Technology*, Vol. 44, Issue 15, pages 5679-5684.
- http://dx.doi.org/10.1021/es903811p

Abstract: The Marcellus Shale in the NE U.S. is a significant deposit of natural gas. It is largely untapped because of the difficulty of accessing its hold, but advances in petroleum extraction are making its drilling more lucrative. However, the environmental impact of enhanced hydrofracture techniques may exceed the tolerance afforded to conventional drilling. Kargbo et al review the concerns and indicate what issues are in play when considering exploration of harder-to-reach fossil fuels.

October 14, 2009. [*Category:* Ecology]

Mapping Oil and Gas Development Potential in the US Intermountain West and Estimating Impacts to Species.

- Copeland, Holly E.; Doherty, Kevin E.; Naugle, David E.; Pocewicz, Amy; Kiesecker, Joseph M.
- In: *PLOS ONE*, Vol. 4, Issue 10, page e7400.
- http://dx.doi.org/10.1371/journal.pone.0007400

Background: Many studies have quantified the indirect effect of hydrocarbon-based economies on climate change and biodiversity, concluding that a significant proportion of species will be threatened with extinction. However, few studies have measured the direct effect of new energy production infrastructure on species persistence. Methodology/Principal Findings We propose a systematic way to forecast patterns of future energy development and calculate impacts to species using spatially-explicit predictive modeling techniques to estimate oil and gas potential and create development build-out scenarios by seeding the landscape with oil and gas wells based on underlying potential. We illustrate our approach for the greater sage-grouse (Centrocercus urophasianus) in the western US and translate the build-out scenarios into estimated impacts on sage-grouse. We project that future oil and gas development will cause a 7–19 percent decline from 2007 sage-grouse lek population counts and impact 3.7 million ha of sagebrush shrublands and 1.1 million ha of grasslands in the study area. Conclusions/Significance Maps of where oil and gas development is anticipated in the US Intermountain West can be used by decision-makers intent on minimizing impacts to sage-grouse. This analysis also provides a general framework for using predictive models and build-out scenarios to anticipate impacts to species. These predictive models and build-out scenarios allow tradeoffs to be considered between species conservation and energy development prior to implementation.

Fall, 2009. [*Category:* Economics]

The Influence of the Pace and Scale of Energy Development on Communities: Lessons from the Natural Gas Drilling Boom in the Rocky Mountains.

- Haefele, Michelle A.; Morton, Pete.
- In: *Western Economics Forum*, Vol. 8, Issue 2, Fall 2009.
- http://ageconsearch.umn.edu/handle/92810

Abstract: Both the number of oil and gas wells drilled annually2 (U.S. Department of Interior [U.S.D.I.], Bureau of Land Management 2009) and the number of producing natural gas wells3 (U.S. Department of Energy 2009) in the Rocky Mountain region4 more than doubled from 1998 to 2008. The proportion of U.S. natural gas production from the region increased from 16% in 1997 to 23% in 2007 (U. S. Department of Energy 2009) and the number of drilling rigs operating in the region grew from 131 in 2002 to 318 in 2009.5 This increase in natural gas drilling in the region has created boomtown conditions in several rural communities. While energy development can benefit rural communities, boomtowns in the Rockies experienced an influx of non-local workers, a rise in crime and emergency service calls, increased demand for public services, more wear and tear on local infrastructure, and upward pressure on local wages and housing costs. Natural gas prices had dropped dramatically by 2009, the drilling boom had subsided, and the bust phase may have begun (Figure 1). The recent energy boom-bust begs the question—how can communities learn from recent history to better take advantage of future energy development for both short-term and long-term benefits?

September 2009. [*Category:* Air Quality]

Regional impacts of oil and gas development on ozone formation in the western United States.

- Rodriguez, Marco A.; Barna, Michael G.; Moore, Tom.
- In: *Journal of the Air & Waste Management Association (1995)*, Vol. 59, Issue 9, pages 1111-1118.
- http://www.ncbi.nlm.nih.gov/pubmed/19785277

Abstract: The Intermountain West is currently experiencing increased growth in oil and gas production, which has the potential to affect the visibility and air quality of various Class I areas in the region. The following work presents an analysis of these impacts using the Comprehensive Air Quality Model with extensions (CAMx). CAMx is a state-of-the-science, "one-atmosphere" Eulerian photochemical dispersion model that has been widely used in the assessment of gaseous and particulate air pollution (ozone, fine [PM2.5], and coarse [PM10] particulate matter). Meteorology and emissions inventories developed by the Western Regional Air Partnership Regional Modeling Center for regional haze analysis and planning are used to establish an ozone baseline simulation for the year 2002. The predicted range of values for ozone in the national parks and other Class I areas in the western United States is then evaluated with available observations from the Clean Air Status and Trends Network (CASTNET). This evaluation demonstrates the model's suitability for subsequent planning, sensitivity, and emissions control strategy modeling. Once the ozone baseline simulation has been established, an analysis of the model results is performed to investigate the regional impacts of oil and gas development on the ozone concentrations that affect the air quality of Class I areas. Results indicate that the maximum 8-hr ozone enhancement from oil and gas (9.6 parts per billion [ppb]) could affect southwestern Colorado and northwestern New Mexico. Class I areas in this region that are likely to be impacted by increased ozone include Mesa Verde National Park and Weminuche Wilderness Area in Colorado and San Pedro Parks Wilderness Area, Bandelier Wilderness Area, Pecos Wilderness Area, and Wheeler Peak Wilderness Area in New Mexico.

July 1, 2009.

Public Perception of Desalinated Water from Oil and Gas Field Operations: Data from Texas.

- Theodori, Gene L.; Wynveen, Brooklynn J.; Fox, William E.; Burnett, David B.
- In: *Society & Natural Resources*, Vol. 22, Issue 7, pages 674-685.
- http://www.tandfonline.com/doi/abs/10.1080/08941920802039804

Abstract: This study is a replication of Theodori et al.'s (2009) research on public perception of desalinated produced water from oil and gas field operations. The data used in this paper were collected in twelve Texas counties. Overall, the findings of this investigation paralleled those uncovered in Theodori et al.'s original exploration. Our data reveal that small percentages of respondents are extremely familiar with the process of desalination and extremely confident that desalinated water could meet human drinking water quality and purity standards. Our data also indicate that respondents are more favorably disposed toward the use of desalinated water for purposes where the probability of human or animal ingestion is lessened. Lastly, our data show that individuals with higher levels of familiarity with the process of desalination were more likely than those with lower levels of familiarity to agree that desalinated water from oil and gas field operations could safely be used for each of nine proposed purposes. Possible implications of these findings are advanced.

May 19, 2009. [*Category:* Waste / Fluids]

Review of technologies for oil and gas produced water treatment.

- Fakhru'l-Razi, Ahmadun; Pendashteh, Alireza; Abdullah, Luqman Chuah; Biak, Dayang Radiah Awang; Madaeni, Sayed Siavash; Abidin, Zurina Zainal.
- In: *Journal of Hazardous Materials*, Vol. 170, Issue 2-3, pages 530-551.
- http://www.sciencedirect.com/science/article/pii/S030438940900778X

Abstract: Produced water is the largest waste stream generated in oil and gas industries. It is a mixture of different organic and inorganic compounds. Due to the increasing volume of waste all over the world in the current decade, the outcome and effect of discharging produced water on the environment has lately become a significant issue of environmental concern. Produced water is conventionally treated through different physical, chemical, and biological methods. In offshore platforms because of space constraints, compact physical and chemical systems are used. However, current technologies cannot remove small-suspended oil particles and dissolved elements. Besides, many chemical treatments, whose initial and/or running cost are high and produce hazardous sludge. In onshore facilities, biological pretreatment of oily wastewater can be a cost-effective and environmental friendly method. As high salt concentration and variations of influent characteristics have direct influence on the turbidity of the effluent, it is appropriate to incorporate a physical treatment, e.g., membrane to refine the final effluent. For these reasons, major research efforts in the future could focus on the optimization of current technologies and use of combined physico-chemical and/or biological treatment of produced water in order to comply with reuse and discharge limits.

January 18, 2009. [*Category:* Air Quality]

Rapid photochemical production of ozone at high concentrations in a rural site during winter.

- Schnell, Russell C.; Oltmans, Samuel J.; Neely, Ryan R.; Endres, Maggie S.; Molenar, John V.; White, Allen B.
- In: *Nature Geoscience*, Vol. 2. Issue 2, pages 120-122.
- http://www.nature.com/ngeo/journal/v2/n2/abs/ngeo415.html