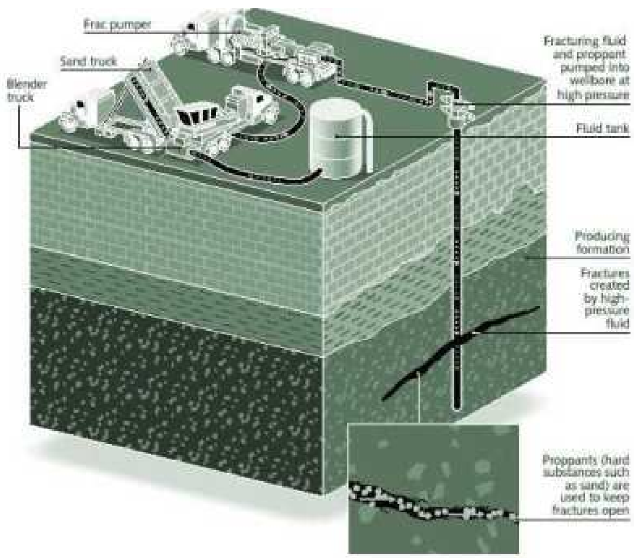
EARTHWORKS

HYDRAULIC FRACTURING 101

Often an oil- or gas-bearing formation may contain large quantities of oil or gas, but have a poor flow rate due to low permeability, or from damage or clogging of the formation during drilling. [1] This is particularly true for tight sands, oil shales and coalbed methane. Hydraulic fracturing (also known as fracking, which rhymes with cracking) is a technique used to create fractures that extend from the well bore into rock or coal formations. These fractures allow the oil or gas to travel more easily from the rock pores, where the oil or gas is trapped, to the production well. [2] Typically, in order to create fractures a mixture of water, proppants (sand or ceramic beads) and chemicals is pumped into the rock or coal formation.



Hydraulic Fracturing Operation

Eventually, the formation will not be able to absorb the fluid as quickly as it is being injected. At this point, the pressure created causes the formation to crack or fracture. The fractures are held open by the proppants, and the oil or gas is then able to flow through the fractures to the well. [3] Some of the fracturing fluids are pumped out of the well and into surface pits or tanks during the process of extracting oil, gas and any produced water, but studies have shown that anywhere from 20-40% of fracing fluids may remain underground. [4]

Acidizing involves pumping acid (usually hydrochloric acid), into the formation. The acid dissolves some of the rock material so that the rock pores open and fluid flows more quickly into the well. Fracking and acidizing are sometimes performed simultaneously, in an acid fracture treatment. [5]

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[1] U.S. Environmental Protection Agency (U.S. EPA). October, 2000. Profile of the Oil and Gas Extraction Industry. EPA Office of Compliance Sector Notebook Project. EPA/310-R-99-006. p.27

[2] U.S. Environmental Protection Agency. August, 2002. DRAFT Evaluation of Impacts to Underground Sources of Drinking Water by Hydraulic Fracturing of Coalbed Methane Reservoirs. EPA 816-D-02-006.

[3] See footnote [2]. Chapter 1.

[4] See footnote [2]. p. 7-3.

[5] See footnote [1], p.27.

Hydraulic Fracturing - Issues and Impacts

Hydraulic Fracturing Chemicals - Coalbed fracture treatments use anywhere from 50,000 to 350,000 gallons of various stimulation and fracturing fluids, and from 75,000 to 320,000 pounds of proppant during the hydraulic fracturing of a single well. [6] Many fracturing fluids contain chemicals that can be toxic to humans and wildlife, and chemicals that are known to cause cancer. These include potentially toxic substances such as diesel fuel, which contains benzene, ethylbenzene, toluene, xylene, naphthalene and other chemicals; polycyclic aromatic hydrocarbons; methanol; formaldehyde; ethylene glycol; glycol ethers; hydrochloric acid; and sodium hydroxide. [7] Very small quantities of chemicals such as benzene, which causes cancer, are capable of contaminating millions of gallons of water.

Product	Chemical Composition of Existing Products	Concentration of Interest (µg/L)	
	Chemical Compound	Point-of-Injection	MCL, RBC or *MCP*
Linear gel delivery system	guar gum derivative		
	diesel, which contains the following:		
	benzene	313.20	5.00
	toluene	522.00	1,000.00
	ethylbenzene	522.00	700.00
	xylene	522.00	10,000.00
	naphthalene	14,094.00	20.00
	1-methylnapthalene	71,340.00	*20 / 6,000*
	2-methylnapthalene	34,974.00	121.67
	dimethylnapthalenes	270,570.00	na
	trimethylnapthalenes	160,080.00	na
	fluorenes	31,320.00	2190.00
	phenanthrenes	7,830.00	*300 / 50*
	aromatics	574,200.00	*200 / 30,000*
Water Gelling Agent	guar gum		
	water	495,049.50	na
	fumaric acid	132,337.87	na
Linear Gel Polymer	fumaric acid	529,351.49	na
	adipic acid	366,257.43	na
Gelling Agents (BLM Lists)	benzene		5.00
	ethylbenzene		700.00
	methyl tert-butyl ether		2.64
	naphthalene		20.00
	polynuclear aromatic hydrocarbons (pahs)		na
	polycyclic organic matter (pom)		na
	sodium hydroxide		na
	toluene		1,000.00
	xylene		10,000.00
Crosslinker	boric acid	170,998.00	na
	ethylene glycol	285,788.42	73,000.00
	monoethanolamine	na	na
Crosslinker	sodium tetraborate decahydrate		na
Crosslinker (BLM Lists)	ammonium chloride		na
	potassium hydroxide		na
	zirconium nitrate		na
	zirconium sulfate		na
Foaming Agent	isopropanol	234,945.16	na
	salt of alkyl amines	na	na
	diethanolamine	na	na
Foaming Agent	ethanol	236,081.75	na
	2-butoxyethanol	269,641.08	na
	ester salt	na	na
	polyglycol ether	na	na
	water		na
Foamers (BLM)	glycol ethers	na	na
Acid Treatment	hydrochloric acid	na	na
Acid Treatment	formic acid	na	73,000.00
Breaker Fluid	diammonium peroxidisulfate	na	na
Breaker Fluids (BLM Lists)	ammonium persulfate		na
	ammonium sulfate		na
	copper compounds		1,460.00
	ethylene glycol		na
	glycol ethers		na
Microbiocide	2-bromo-2nitrol,3-propanediol		na
Biocide	2,2-dibromo-3-nitrilopropionamide		na
	2-bromo-3-nirtrilopropionamide		na
Bactericides	polycyclic organic matter (pom)		na
	polynuclear aromatic hydrocarbons (pahs)		na
Acid Corrosion Inhibitor	methanol	236,070,000.00	18,250.00
	propargyl alcohol	47,425,000.00	na
Acid Corrosion Inhibitor	pyridinium, 1-(phenylmethyl)-,ethyl methyl deriv.	na	na
	thiourea	210,750,000.00	na
	propan-2-ol	39,275,000.00	na
	poly(oxy-1,2-ethanediyl)-nonylphenyl-hydroxy	na	na

[shaded box] = Exceeds regulatory standard
MCL = Maximum Contaminant Level - The highest level of a contaminant that is allowed in drinking water.
RBC = EPA's Risk Based Concentration Tables. (http://www.epa.gov/reg3hwmd/risk/index.html, developed by Region 3, serving: Delaware, District of Columbia, Maryland, Pennsylvania, Virginia, West Virginia)
MCP = Massachusetts Contingency Plan - Risk-based ground water standards for drinking water protection chosen because Massachusetts has developed standards for many constituents in diesel fuel. Two numbers are given (the first is drinking water standard, the second is standard for groundwater discharging to surface water).

Chemicals in Fracking Fluids. Source: Environmental Protection Agency. August, 2002. Draft version of EPA's study Evaluation of Impacts of Underground Sources of Drinking Water by Hydraulic Fracturing of Coalbed Methane Reservoirs. Table 4-2.

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[6] U.S. Environmental Protection Agency (EPA). June, 2004. Evaluation of Impacts to Underground Sources of Drinking Water by Hydraulic Fracturing of Coalbed Methane Reservoirs. EPA 816-R-04-003. p. 3-11.
[7] See footnote 2. Chapter 4.

Potential Groundwater Contamination - As mentioned previously, hydraulic fracturing is used in many coalbed methane (CBM) production areas. Some coal beds contain groundwater of high enough quality to be considered underground sources of drinking water (USDWs). According to the U.S. Environmental Protection Agency (EPA) ten out of eleven CBM basins in the U.S. are located, at least in part, within USDWs. Furthermore, EPA has determined that in some cases, hydraulic fracturing chemicals are injected directly into USDWs during the course of normal fracturing operations. [8] (Read stories by Peggy Hocutt and Laura Amos to learn how hydraulic fracturing of coalbeds and other geological formations has affected their lives.)

Frac Pit

Calculations performed by EPA show that at least nine hydraulic fracturing chemicals may be injected into or close to USDWs at concentrations that pose a threat to human health. These chemicals may be injected at concentrations that are anywhere from 4 to almost 13,000 times the acceptable concentration in drinking water. [9]

Not only does the injection of these chemicals pose a short-term threat to drinking water quality, it is quite possible that there could be long-term negative consequences for USDWs from these fracturing fluids. According to the EPA study, and studies conducted by the oil and gas industry, [10] between 20 and 40% of the fracturing fluids may remain in the formation, which means the fluids could continue to be a source of groundwater contamination for years to come.

The potential long-term consequences of dewatering and hydraulic fracturing on water resources have been summed up by professional hydrogeologist who spent 32 years with the U.S. Geological Survey:

> At greatest risk of contamination are the coalbed aquifers currently used as sources of drinking water. For example, in the Powder River Basin (PRB) the coalbeds are the best aquifers. CBM production in the PRB will destroy most of these water wells; BLM predicts drawdowns...that will render the water wells in the coal unusable because the water levels will drop 600 to 800 feet. The CBM production in the PRB is predicted to be largely over by the year 2020. By the year 2060 water levels in the coalbeds are predicted to have recovered to within 95% of their current levels; the coalbeds will again become useful aquifers. However, contamination associated with hydrofracturing in the basin could threaten the usefulness of the aquifers for future use. [11]

[8] See footnote 6. p.ES-1.
[9] See footnote 2. Table 4-2.
[10] Puri, R., G.E. King, and I.D. Palmer. 1991. "Damage to Coal Permeability During Hydraulic Fracturing," *Society of Petroleum Engineers Proceedings from Rocky Mountain Regional Meeting and Low-Permeability Reservoirs Symposium*, Denver, CO, p. 109-115; and I.D. Palmer et al. "Comparison between Gel-Fracture and Water-Fracture Stimulations in the Black Warrior Basin," Proceedings of the 1991 Coalbed Methane Symposium, pp. 233, 237. Cited in Natural Resources Defense Council. January, 2002. "Hydraulic Fracturing: A threat to drinking water."
[11] Letter from John Bredehoeft, PhD to Joan Harrigan-Farrelly, Chief, Underground Injection Control, Prevention Program, Environmental Protection Agency. May 22, 2003.

One potentially frustrating issue for surface owners is that it may not be easy to find out what chemicals are being used during the hydraulic fracturing operations in your neighborhood. According to the Natural Resources Defense Council, attempts by various environmental and ranching advocacy organizations to obtain chemical compositions of hydraulic fracturing fluids have not been successful because oil and gas companies refuse to reveal this "proprietary information." [12]

As mentioned above, anywhere from 20-40% of fracing fluids remain in the ground. Some fracturing gels remain stranded in the formation, even when companies have tried to flush out the gels using water and strong acids. [13] Also, studies show that gelling agents in hydraulic fracturing fluids decrease the permeability of coals, which is the opposite of what hydraulic fracturing is supposed to do (i.e., increase the permeability of the coal formations). Other similar, unwanted side effects from water- and chemical-based fracturing include: solids plugging up the cracks; water retention in the formation; and chemical reactions between the formation minerals and stimulation fluids. All of these cause a reduction in the permeability in the geological formations. [14]

Hydraulic Fracturing Chemical Disposal - When companies have an excess of hydraulic fracturing fluids, they either use them at another job or dispose of them. Some company Material Safety Data Sheets include information on disposal options for fracturing fluids and additives. The table below summarizes the disposal considerations that the company Schlumberger Technology Corp. ("Schlumberger") includes in its MSDSs. [15]

As seen in the table, Schlumberger recommends that many fracturing fluid chemicals be disposed of at hazardous waste facilities. Yet these same fluids (in diluted form) are allowed to be injected directly into or adjacent to USDWs. Under the Safe Drinking Water Act, hazardous wastes may not be injected into USDWs. [16]

Hydraulic fracturing fluids or additive	Recommended Disposal
Foaming Agent F104 Corrosion Inhibitor A186 Organic Acid L36 Chelating Agent Liquid Breaker Aid J318 Breaker J218 Biocide B69 PSG Polymer Slurry J877	Hazardous waste disposal facility.
Water Gelling Agent J424	Hazardous waste landfill, incineration, or sanitary landfills in some jurisdictions.
Potassium Chloride M117	Hazardous waste landfill. Material may be acceptable in some sanitary landfills.
Coalbed Methane Additive J473	Incineration, disposal well injection or other acceptable methods according to local regulations.
Borate Crosslinker J532	Inject in disposal well. Small amounts may be acceptable in sanitary sewer.
Gelling Agent U28	Neutralized material is generally acceptable in sanitary sewers.

[12] See footnote 10.
[13] See footnote 10.
[14] McCallister, Ted. (updated 2002). Impact of Unconventional Gas Technology in the Annual Energy Outlook 2000. Energy Information Administration, U.S. Department of Energy.
[15] In October of 2004, OGAP filed a *Freedom of Information Act* request with EPA to obtain the Material Safety Data Sheets (MSDS) supplied to the agency by hydraulic fracturing companies. (Freedom of Information Act, 5 U.S.C. 552, Request Number HQ-RIN-00044-05). The information in this table were contained in MSDS sheets from Schlumberger.
[16] According to EPA's Underground Injection Control Regulations: Class I wells, "shall be sited in such a fashion that they inject into a formation which is beneath the lowermost formation containing, within one quarter mile of the well bore, an underground source of drinking water," (40 CFR Ch. 1 §146.12) and, "in no case shall injection pressure initiate fractures in the confining zone or cause the movement of injection or formation fluids into an underground source of drinking water." (40 CFR Ch. 1 §146.13)For both Class II and III wells, "In no case, shall injection pressure initiate fractures in the confining zone or cause the migration of injection or formation fluids into an underground source of drinking water." (40 CFR Ch. 1 §146.23 and #167;146.33). Class V wells, "inject non-hazardous fluids into or above formations that contain underground sources of drinking water." (40 CFR Ch. 1 §146.51) Class IV wells allow

Moreover, even if hazardous wastes are diluted with water so that the hazardous characteristics of the fluids are removed, the wastes still cannot be injected into USDWs. If unused hydraulic fracturing fluids are indeed "hazardous wastes", it is unconscionable that EPA is allowing these substances to be injected directly into underground sources of drinking water.

Hydraulic Fracturing Best Practices

- From a public health perspective, if hydraulic fracturing stimulation takes place, the best option is to fracture formations using sand and water without any additives, or sand and water with non-toxic additives. Non-toxic additives are being used by the offshore oil and gas industry, which has had to develop fracturing fluids that are non-toxic to marine organisms. [17]

- It is common to use diesel in hydraulic fracturing fluids. This should be avoided, since diesel contains the carcinogen benzene, as well as other harmful chemicals such as naphthalene, toluene, ethylbenzene and xylene. According to the company Halliburton, "Diesel does not enhance the efficiency of the fracturing fluid; it is merely a component of the delivery system." [18] It is technologically feasible to replace diesel with non-toxic "delivery systems," such as plain water. According to the EPA, "Water-based alternatives exist and from an environmental perspective, these water-based products are preferable." [19]

- Oil and gas wastes are often flowed back to and stored in pits on the surface. Often these pits are unlined. But even if they are lined, the liners can tear and contaminate soil and possibly groundwater with toxic chemicals. (Read more about pits.) As mentioned above, toxic chemicals are used during hydraulic fract uring operations. The same chemicals that are injected come back to the surface in the flowed-back wastes. As well, hydrocarbons from the fractured formation may flow back into the waste pits. A preferable way of storing wastes would be to flow them back into steel tanks.

Torn pit liners can lead to groundwater contamination

Tips for Landowners

- **Obtaining fracking chemical information:** The law requires that all employees have access to a Material Safety Data Sheet (MSDS), which contains information on health hazards, chemical ingredients, physical characteristics, control measures, and special handling procedures for all hazardous substances in the work area. The MSDSs are produced and distributed by the chemical manufacturers and distributors. It should be noted that MSDSs may not list all of the chemicals or chemical constituents being used (if they are

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for the injection of hazardous waste directly into USDWs, but these wells have been banned. (EPA. 2002. *Protecting Drinking Water through underground Injection Control*. Drinking Water Pocket Guide #2. EPA 816-K-02-001. p.7

[17] Sumi, Lisa. 2005. *Our Drinking Water at Risk: What EPA and the Oil and Gas Industry Don't Want Us to Know About Hydraulic Fracturing*. p. 53.

[18] See footnote 6. p. 4-4.

[19] See footnote 2. p.ES-1.

trade secrets). [20] Landowners may be able to obtain copies of MSDSs from company employees, the chemical manufacturers, or possibly from state agency representatives.

FOR MORE INFORMATION

Hydraulic fracturing of oil and gas wells

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[20] American Federation of State, County And Municipal Employees, AFL-CIO. "How To Read A Material Safety Data Sheet."