Drilling Around the Law

ENVIRONMENTAL WORKING GROUP

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Executive Summary

Companies that drill for natural gas and oil are skirting federal law and injecting toxic petroleum distillates into thousands of wells, threatening drinking water supplies from Pennsylvania to Wyoming. Federal and state regulators, meanwhile, largely look the other way.

These distillates include kerosene, mineral spirits and a number of other petroleum products that often contain high levels of benzene, a known human carcinogen that is toxic in water at minuscule levels. Drillers inject these substances into rock under extremely high pressure in a process called hydraulic fracturing that energy companies use to extract natural gas and oil from underground formations. The process, known as "fracking," fractures the rock to allow additional gas and oil to flow to the surface. Fracking is currently used in 90 percent of the nation's oil and natural gas wells and has been instrumental in accessing huge new natural gas deposits trapped in shale formations (Carrillo 2005).

In a worst case scenario, the petroleum distillates used in a single well could contain enough benzene to contaminate more than 100 billion gallons of drinking water to unsafe levels, according to drilling company disclosures in New York State and published studies. (NYDEC DSGEIS 2009, Pagnotto 1961) That is more than 10 times as much water as the state of New York uses in a single day. (NYDEC DSGEIS 2009)

Fracking has already been linked to drinking water contamination and property damage in Colorado, Ohio, Pennsylvania, Wyoming and other states. (Lustgarten 2008a, 2008b)

Despite the risks, Congress in 2005 exempted hydraulic fracturing, except fracturing with diesel fuel, from regulation under the Safe Drinking Water Act (SDWA). Diesel is the only substance for which drillers must seek a permit before it is injected underground. (SDWA 2009)

Based on a six-month investigation of chemical disclosure records filed by several of the largest drilling corporations and interviews with regulators in five states, Environmental Working Group (EWG) found that:

1. Companies are injecting natural gas wells with millions of gallons of fracking fluids laced with petroleum distillates that can be similar to diesel and represent an equal or greater threat to water supplies. The distillates typically contain the same highly toxic chemicals as diesel: benzene, toluene, ethylbenzene and xylene. Distillates disclosed in records analyzed by EWG have been found to contain up to 93 times more benzene than diesel but require no authorization prior to use. Although the companies disclosed the distillates in the context of natural gas drilling, at least several of the companies, including Halliburton, Schlumberger Ltd. and B.J. Services Co., also help drill and fracture oil wells, suggesting that at least some of the same distillates may be used in oil drilling, too.

2. State and federal regulatory agencies surveyed in the report are generally not tracking fluids used in fracturing and in some cases appear to misinterpret the federal Safe Drinking Water Act. As a result, companies could easily be fracturing with diesel without a permit. Only one of five state or federal agencies contacted, in Wyoming, reported tracking the chemicals used in fracking operations. But even Wyoming requires companies to disclose trade names of fracking fluids only, not the specific chemical components of the fluids. (The other agencies were in Pennsylvania, New York, Montana, and Texas.)

3. A Wyoming state official reported that companies commonly use diesel in that state and that the state has not issued any permits for fracturing under the SDWA.

EWG's Recommendations

1. Congress should require companies to comply with the Safe Drinking Water Act when using any substance for hydraulic fracturing. Currently, the act allows companies to use substances that may be at least as toxic as diesel without any oversight.

2. Congress should require drilling companies to publicly disclose the chemicals they use in hydraulic fracturing in each well. At a minimum, companies must disclose Chemical Abstracts Services Registry Numbers in every chemical product to allow easy identification. Generic names such as "petroleum distillate" leave the public in the dark.

3. The U.S. Department of the Interior should exercise its authority under the oil and gas leasing program to require such disclosures for wells drilled on federal land.

4. Congress should investigate federal and state oversight of hydraulic fracturing and insist that federal and state personnel be properly informed about the law.

5. The U.S. Environmental Protection Agency should use its existing authority to determine whether companies are using diesel and enforce permit requirements.

Other Petrolum Distillates Used in Hydraulic Fracturing Can Contain 93 Times more Benzene than Diesel*

Distillate Used in Hydraulic Fracturing	Chemical Abstract Services (CAS) Number (not available for some substances)	Reported Maximum Benzene Concentration in Parts Per Million (not available for some substances)	Maximum Number of Times by which Benzene Concentration Exceeds EPA's Safe Level for Benzene in Drinking Water (five parts per billion)
Diesel[1]	N.A.	1,000[2]	200,000
Light Paraffin Oil[3]	1120-21-4	N.A.**	N.A.
Kerosene	8008-20-6	up to 5,000[4]	up to 1,000,000
Stoddard solvent	8052-41-3	up to 10,000[5]	up to 2,000,000
Petroleum naphtha	64741-68-0	93,000[6]	18,600,000
Multiple Distillates Listed Under Same CAS #			
Aliphatic hydrocarbon	64742-48-9	N.A.	N.A.
Distillates (petroleum) hydrotreated light		up to 5,000[7]	up to 1,000,000
Hydrotreated light distillate		up to 5,000[8]	up to 1,000,000
Isoparaffinic solvent		N.A.	N.A.
Low odor paraffin solvent		N.A.	N.A.
LVP aliphatic hydrocarbon		N.A.	N.A.
Paraffin solvent		N.A.	N.A.
Parafinnic napthenic solvent		N.A.	N.A.
Petroleum distillates		N.A.	N.A.
Petroleum light distillate		N.A.	N.A.
Naphtha (petroleum), hydrotreated heavy	64742-48-9	93,000[9]	18,600,000
Petroleum base oil	64742-65-0	N.A.	N.A.
Kerosine (petroleum, hydrodesulfurized)	64742-81-0	up to 5,000[10]	up tp 1,000,000
Kerosine (petroleum, hydrodesulfurized)	64742-88-7	up to 5,000[11]	up tp 1,000,000

Distillate Used in Hydraulic Fracturing	Chemical Abstract Services (CAS) Number (not available for some substances)	Reported Maximum Benzene Concentration in Parts Per Million (not available for some substances)	Maximum Number of Times by which Benzene Concentration Exceeds EPA's Safe Level for Benzene in Drinking Water (five parts per billion)
Multiple Distillates Listed Under Same CAS #			
Heavy aromatic petroleum naphtha	64742-94-5	93,000[12]	18,600,000
Light aromatic solvent naphtha		93,000[13]	18,600,000
Light aromatic solvent naphtha	64742-95-6	93,000[14]	18,600,000
Alkenes, C> 10 α-	64743-02-8	N.A.	N.A.
Mineral spirits	N.A.	10,000[15]	2,000,000
Petroleum distillate blend	N.A.	N.A.	N.A.
Aromatic Hydrocarbons			
Benzene	71-43-2	N.A.	N.A.
Toluene	108-88-3	N.A.	N.A.
Ethyl benzene	100-41-4	3,000[16]	600,000
Xylene	1330-20-7	N.A.	N.A.

[1] U.S. Environmental Protection Agency (EPA Fracturing Final). 2004. Evaluation of Impacts to Underground Sources of Drinking Water by Hydraulic Fracturing of Coalbed Methane Reservoirs, Final, June 2004, at 4-11. Accessed online Dec. 2, 2009 at http://www.epa.gov/safewater/uic/wells_coalbedmethanestudy.html.

[2] See id.

[3] New York Department of Environmental Conservation (NYDEC DSGEIS). 2009. Draft Supplemental Generic Environmental Impact Statement Relating to Drilling for Natural Gas in New York State Using Horizontal Drilling and Hydraulic Fracturing, September 30, 2009, at 5-53, 5-60. Accessed online November 6, 2009 at http://www.dec.ny.gov/energy/46288.html. All other petroleum distillates in the table were revealed only in the same New York DSGEIS except for petroleum distillate blend, hydrotreated light distillate and mineral spirits, which were also disclosed in the following source: Pennsylvania Department of Environmental Protection (PADEP). 2008. Summary of Hydraulic Fracture Solutions – Marcellus Shale. Accessed online August 19, 2009 at http://www.dep.state.pa.us/dep/deputate/minres/oilgas/new_forms/marcellus/marcellus.htm. In addition, Chesapeake disclosed petroleum distillate in the following source: Chesapeake (Chesapeake Fracturing). 2009. Hydraulic Fracturing Fact Sheet, May 2009. Submitted to U.S. House of Representatives Committee on Natural Resources. See also Chesapeake. 2009. Media Resources, Hydraulic Fracturing Fact Sheet, May 2009. Accessed online August 18, 2009 at http://www.chk.com/media/pages/mediaresources.aspx.

[4] U.S. Department of Health and Human Services (ATSDR TPH). 2009. Agency for Toxic Substances and Disease Registry, Toxicological Profile for Total Petroleum Hydrocarbons (TPH), September 1999, at 137. Accessed online Dec. 8, 2009, at www.atsdr.cdc.gov/toxprofiles/tp123.pdf.

[5] U.S. Department of Health and Human Services,(ATSDR Stoddard Solvent). 2000. Agency for Toxic Substances and Disease Registry, Stoddard Solvent Toxicity, October 2000, at 7. Accessed online Dec. 8, 2009, at www.atsdr.cdc.gov/HEC/CSEM/stoddard/docs/stoddard.pdf.

[6] Pagnotto, Leonard, et al., Industrial Benzene Exposure from Petroleum Naphtha: I. Rubber Coating Industry, Am Ind Hyg Assoc J 1961; 22: 417-21.

[7] ATSDR, supra note 4. The National Library of Medicine lists hydrotreated light distillate as a synonym for kerosene. See National Library of Medicine, ChemIDPlusLite. 2009. Distillates (petroleum), hydrotreated light; RN: 64742-47-8 (Names & Synonyms). Accessed online July 6, 2009 at http://chem.sis.nlm.nih.gov/chemidplus/ProxyServlet?objectHandle=DBMaint&actionHandle=def

ault&nextPage=jsp/chemidlite/ResultScreen.jsp&TXTSUPERLISTID=064742478.
[8] See id.
[9] Pagnatto, et al., supra note 6.
[10] ATSDR, supra note 4.
[11] ATSDR, supra note 4.
[12] Pagnatto, et al., supra note 6.
[13] See id
[14] See id
[15] Hunting, Katherine L., et al. (Hunting). 1995. Haematopoietic Cancer Mortality Among Vehicle Mechanics, 52 Occupational and Environmental Medicine 673-678 (1995). Hunting tested Varsol, a solvent that the National Library of Medicine says is synonymous with mineral spirits. See National Library of Medicine, ChemIDPlusLite. 2009. Distillates (petroleum), hydrotreated light; RN: 64742-47-8 (Names & Synonyms). Accessed online Dec. 8, 2009 at http://chem.sis.nlm.nih.gov/chemidplus/jsp/common/ChemInfo.jsp?calledFrom=lite&type=names.
[16] International Agency for Research on Cancer (IARC). 2000. IARC Monographs on the Evaluation of Carcinogenic Risks to Humans, Volume 77, Some Industrial Chemicals, 2000, at p. 228. Accessed online December 4, 2009 at http://monographs.iarc.fr/ENG/Monographs/vol77/index.php.

[*] Petroleum distillates used in hydraulic fracturing that companies have publicly disclosed. Where available, the table displays the Chemical Abstracts Service (CAS) registry numbers assigned by the American Chemical Society. CAS numbers identify unique chemical substances (ACS 2009), enabling scientists, governmental officials and citizens to know precisely what substances are being used. Disclosure of such numbers for hydraulic fracturing is not required. Where available, the table displays the highest published benzene concentration level that EWG could find for substances with the same common name as the petroleum distillate. The available published information does not list petroleum distillates by CAS number, so it is unclear whether the substances are exactly the same as those listed by drilling companies. It is possible that benzene levels for petroleum distillates used by the drilling companies are higher or lower than values shown here. EWG repeatedly asked several companies for the composition of their distillates, but they did not respond.

[**] Not Available

Hydraulic Fracturing and Petroleum Distillates

To release natural gas and oil from underground formations, drillers inject into their wells under extremely high pressure anywhere from tens of thousands to millions of gallons of fluid, typically a mixture of petroleum distillates, other chemicals, water and sand. (EPA Fracturing Final 2004, Schein 2008, Burnett and Vavra 2006, NYDEC DSGEIS 2009) The process creates fractures in the rock that extend out from the well and allow additional gas or oil to flow to the surface, dramatically increasing production.

Fracking presents a clear threat to water supplies. It has been implicated in recent incidents in which benzene and other hazardous substances contaminated drinking water and caused other damage in Colorado, Ohio, Pennsylvania, Wyoming and other states. (Lustgarten 2008a, 2008b) In addition to the risks created by injecting toxic fracking chemicals underground, these substances are sometimes spilled on the surface.

In 2005, following lobbying by energy companies, Congress largely exempted hydraulic fracturing from provisions of the Safe Drinking Water Act (SDWA) that protect underground sources of drinking water. (Hamburger and Miller 2004) The one exception was the requirement that companies obtain EPA or state authorization before fracturing with diesel fuel.

According to EPA, diesel makes fracturing more efficient because it dissolves thickeners used in fracking fluids more effectively than water. That reduces costs by allowing drilling companies to send a smaller number of tanker trucks supplying diesel-based thickener to well sites than when fracking with water-based thickeners. (EPA Fracturing Final 2004) Diesel also reduces friction in high-pressure injections and prevents clogging of the drilling pipe. (WOGCC 2009) Despite these advantages, Congress singled out diesel for regulation. Diesel is known to contain relatively high levels of benzene, toluene, ethylbenzene, and xylene – the so-called BTEX chemicals that can pollute water in very small amounts and are known to cause cancer and other serious health problems.

Despite the diesel requirement, regulators in four states queried by EWG (New York, Pennsylvania, Montana and Texas) said they do not check to determine whether companies are using diesel or other petroleum distillates in their fracking fluids. In Wyoming, an official with the Wyoming Oil and Gas Conservation Commission (WOGCC) said the Commission does track the types of fluids being used and has found that companies frequently use diesel. But in apparent contradiction of federal law, this official, along with regulators in Montana and Pennsylvania, said the Commission takes the position that the Safe Drinking Water Act does not apply to fracturing with diesel. (EPAII 2009, Hudak 2009, Johnson 2009, Nye 2009, WYOGCC 2009a, 2009b)

Companies contacted by EWG declined to say what petroleum distillates they use.

Fracking Unlocks Gas, Contamination Concerns

Hydraulic fracturing has recently helped companies access large new supplies of natural gas buried deep in shale formations in Texas, Pennsylvania and other states. These new supplies have sparked enthusiasm for several reasons. Natural gas produces half the greenhouse gas emissions of coal when it is burned to generate electricity (EPA Natural Gas 2009), and there is an abundant (though non-renewable) domestic supply in the United States. As a result, natural gas has

a legion of champions, including financier T. Boone Pickens and some conservationists. It is touted as a "bridge fuel" to a lower-carbon economy that could dramatically reduce U.S. dependence on coal and significantly cut greenhouse gas emissions, all with existing technologies.

However, drilling for natural gas (and oil) must be balanced with the need to protect precious water supplies. New York City officials have estimated that if its drinking water were contaminated by upstate drilling, the cost of cleaning up the pollution would be $20 billion or more. (Gennaro 2009) Because of these concerns, Chesapeake Energy, the nation's largest independent natural gas drilling company, announced late in 2009 that it would not drill in the watershed that provides New York City's drinking water. A 2004 incident in Garfield County, Colo., has shown that once a water supply is polluted by chemicals associated with gas drilling, it is extremely difficult to purify. (COGCC EnCana 2009, EPA Sparge 2009)

EWG believes that Congress should move quickly to repeal the exemption for hydraulic fracturing under the Safe Water Drinking Act to ensure that water supplies are not ruined in the rush to produce more natural gas.

Petroleum Distillates: Widely Used, but Details Are Scant

Several energy companies, including some of the largest, have recently disclosed what petroleum distillates they use for hydraulic fracturing. In September 2009, New York state officials released the most complete list to date of the fracking chemicals disclosed by industry, which include about 30 petroleum distillates (listed in Table 1 above). While it is unclear which fracturing companies are using which distillates and where, 18 energy and chemical companies contributed to the list, including three of the world's largest fracking specialists for natural gas and oil: Schlumberger Ltd., Halliburton and B.J. Services Co. (NYDEC DSGEIS 2009)

In 2009, Chesapeake Energy acknowledged on its website and in submissions to the U.S. House of Representatives and the New York City Council that it uses "petroleum distillate" in its fracturing operations. In an effort to allay concerns over environmental and health risks, the company noted that these substances are also "used in cosmetics, including hair, make-up, nail and skin products." (Chesapeake 2009a) The company did not mention, however, that since 1982 the European Union has banned a wide range of petroleum distillates from cosmetics products "except if the full refining history is known and it can be shown that the substance from which [the petroleum distillate] is produced is not a carcinogen." (EU 1982) In the United States, cosmetics are almost completely unregulated. (FDA 2009)

Chesapeake says on its website that it operates in 19 states: Alabama, Arkansas, Illinois, Indiana, Kentucky, Louisiana, Maryland, Michigan, Mississippi, New Mexico, Nebraska, New York, Ohio, Oklahoma, Pennsylvania, Tennessee, Texas, Virginia and West Virginia. (Chesapeake 2009a, Chesapeake 2009b)

In 2008, B.J. Services informed the Pennsylvania Department of Environmental Protection (PADEP) that it was using "hazardous components" including "petroleum distallate (sic) blend" and "hydrotreated light distillate" for hydraulic fracturing of natural gas wells in that state's portion of the Marcellus Shale, a natural gas-rich formation that lies beneath Pennsylvania and six other eastern states. A second company, Superior Well Services, Inc., told the state agency that it was using "hazardous components," including "hydrotreated light distillate" and "mineral spirits." (PADEP 2008, EPA Mineral Spirits 2009)

The Endocrine Disruption Exchange (TEDX), a Paonia, Colo.-based watchdog group, has collected information on chemicals used in hydraulic fracturing from several states. The organization found that companies are using petroleum distillates in Colorado, Montana, New Mexico, Pennsylvania, Texas, Washington and Wyoming and that companies are using diesel, in particular, in Colorado, Montana, New Mexico, Pennsylvania and Wyoming. The records obtained by the group do not indicate when drilling companies used these substances, but TEDX began collecting the information in 2004. (TEDX 2009)

Diesel vs. Other Distillates: Not Much Difference

What the disclosures by industry don't show is that other petroleum distillates can contain the same toxic components that are in diesel, even though only diesel is subject to EPA or state oversight under the federal Safe Drinking Water Act.

To distill crude oil into industrial and consumer products, refiners heat it to various boiling points. Different gaseous solutions are drawn off at each temperature, captured and cooled to liquefy them. All these liquids, including diesel, are petroleum distillates. (DOE Refining 2009, DOE Kids 2009)

According to the EPA, petroleum distillate "includes diesel fuel, kerosene and home heating oil." The federal Consumer Product Safety Commission similarly states that "petroleum distillates include gasoline, naphtha, mineral spirits, kerosene, paraffin wax and tar." (CPSC 1997) The National Institutes of Health's National Library of Medicine lists "hydrotreated light distillate" as a synonym for kerosene. (NLM Chemid 2009) The Merck Manual of Diagnosis and Therapy says that petroleum distillates include asphalt, benzine (benzin), fuel oil, gasoline, kerosene, lamp oil, lubricating oils, mineral oil, mineral spirits, model airplane glue, naphtha, paint thinners, petroleum ether and tar. (Merck 2006)

Such distillates may be finished products ready for use or undergo further processing. The EPA describes hydrotreating (as in "hydrotreated light distillate") as a chemical process that reduces diesel's sulfur content so that diesel engines emit less pollution. (EPA Diesel 2004)

Benzene and other toxic constituents are generally present in all petroleum distillates, including diesel fuel. In 1997, the National Park Service (NPS) examined diesel and other distillates known as fuel oils and concluded that "fuel oil no. 1, jet fuel 1, diesel no. 1, and kerosene are basically the same products." (NPS Kerosene 1997) The report said, "The most toxic components of fuel oils are the aromatics, such as benzene, toluene, xylene, naphthalene and others. These aromatics are relatively highly soluble in water." (NPS Diesel 1997) The Agency for Toxic Substances and Disease Registry (ATSDR) of the Centers for Disease Control and Prevention also says that "benzene is slightly soluble in water and can pass through the soil into underground water." (ATSDR Benzene 2007)

Melvyn Kopstein, a PhD chemical engineer who has testified on behalf of workers seeking compensation for benzene-related illnesses, reported in a 2006 paper published in the Journal of Occupational and Environmental Hygiene that a wide range of petroleum distillates, including "100% hydrotreated light distillate," "mineral spirits," "Stoddard-type aliphatic solvent" and "light aliphatic solvent naphtha," may contain benzene. (Kopstein 2006) All these substances have names that are the same as, or similar to, substances used in hydraulic fracturing.

Researchers have found that many petroleum distillates contain extremely high levels of

benzene, ranging up to 93,000 parts per million for naphtha solvents - 18.6 million times EPA's standard for benzene in drinking water. (Pagnotto 1961) Naphtha-based solvents are among the fracturing fluids that drillers reported using in New York state.

Several researchers studying mineral spirits (identified by Superior Well Services as a component of the company's hydraulic fracturing fluids in Pennsylvania) have found that these distillates contain benzene at a concentration of 10,000 parts per million -- two million times EPA's safe level in water. (Hunting 1995)

Drillers have also reported the use of kerosene in hydraulic fracturing. The CDC's ATSDR has reported that benzene can be present in kerosene at concentrations of up to 5,000 parts per million, one million times EPA's safe level in water. (ATSDR TPH 1999) In addition, kerosene is a synonym for hydrotreated light distillate, one of the fracturing chemicals reported to New York officials and used by both Superior Well Services and B.J. Services in Pennsylvania.

Diesel: "The Greatest Potential Threat" to Water

Like Congress, the EPA has singled out diesel fuel for special concern – and yet the chemicals in diesel are no different than those commonly found in other petroleum distillates. In a 2004 report on hydraulic fracturing of coalbed methane natural gas deposits, the agency concluded that "the use of diesel fuel in fracturing fluids poses the greatest potential threat to [underground sources of drinking water] because the BTEX constituents in diesel fuel exceed the [maximum contaminant level] at the point-of-injection."

Are Companies Fracturing with Diesel?

Some public officials believe that all natural gas and oil companies have agreed not to use diesel fuel for hydraulic fracturing anywhere they operate.

But that's not the case. What some major companies have said is that they will not use diesel fuel for hydraulic fracturing – in certain situations.

In 2003, B.J. Services Co., Halliburton and Schlumberger Ltd., the companies that conducted most of the hydraulic fracturing in the nation, signed a voluntary, non-binding agreement with EPA. The companies pledged "to eliminate diesel fuel in hydraulic fracturing fluids injected into coalbed methane (CBM) production wells in underground sources of drinking water (USDWs) and, if necessary, select replacements that will not cause hydraulic fracturing fluids to endanger USDWs." Coalbed methane is natural gas that companies extract from coalbeds (EPA MOA 2003).

This promise, however, applied to only coalbed methane wells -- a small portion of natural gas and oil wells drilled – and only to those drilled directly into underground sources of drinking water. For example, IHS, an energy data company, reported that of 26,065 natural gas and oil wells completed in the U.S. in 2005, less than 20 percent (4,625) were coalbed methane wells. As of December 2006, IHS reported that of 37,408 natural gas and oil wells completed in the U.S. that year, less than 15 percent (5,097) were coalbed methane wells. (IHS 2006) The percentage of coalbed methane wells drilled directly into underground sources of drinking water, where the three top fracking companies promised not to use diesel, was likely even smaller.

The EPA also said in its 2004 report on fracturing of coal beds that B.J. Services, Halliburton and Schlumberger "have indicated to EPA that they no longer use diesel fuel as a hydraulic fracturing fluid additive when injecting into USDWs." (EPA Fracturing Final 2004, ES-2) This leaves open the possibility that the companies have continued to use diesel when they are injecting fracturing fluid into wells that

BTEX refers to benzene, toluene, ethylbenzene and xylene, each of which is toxic at very low concentrations. According to EPA, long-term exposure to benzene can cause cancer, and short-term exposure can lead to temporary nervous system disorders. Long-term exposure to toluene, ethylbenzene and xylene can cause liver and kidney damage as well as nervous system disorders such as spasms, tremors and speech impairment. Short-term exposure can cause health problems ranging from fatigue to impaired cognitive abilities to nausea. (EPA Benzene 2009, EPA Toluene 2009, EPA Ethylbenzene 2009, EPA Xylene 2009)

EPA's maximum allowable concentration of benzene in drinking water is five parts per billion – higher amounts are considered harmful – and the agency's policy goal is to have no benzene in water. (EPA Benzene 2009) In a 2004 article published in the European Journal of Oncology, Myron A. Mehlman, a professor at the Robert Wood Johnson School of Medicine and Dentistry, wrote that "there is no safe level of benzene above zero that can protect workers and the public from the carcinogenic effects of benzene." (Mehlman 2004) EPA's maximum levels for the other BTEX chemicals in drinking water are one part per million (ppm) for toluene, 0.7 ppm for ethylbenzene and 10 ppm for xylene. (EPA Toluene 2009, EPA Ethylbenzene 2009, EPA Xylene 2009)

The EPA estimates that when diesel fuel is used for hydraulic fracturing, the concentration of benzene in fracturing fluid at the point of injection ranges between 9 times and 880 times the safe level for water. The agency also estimates that toluene, ethylbenzene and xylene also exceed safe levels in some situations. (EPA Fracturing Final 2004)

are not drilled directly into an underground water source, but through or near one.

In a 2008 email to EPA, Harold Brannon, B.J. Services Senior Advisor for Fracturing, wrote that the company "is not only continuing to abide by the voluntary Memorandum of Agreement with the US (sic) Environmental Protection Agency to eliminate the use of diesel fuel in hydraulic fracturing fluids for coalbed methane reservoirs, but has completed implementation of policies and procedures eliminating the use of diesel fuel in all water-based hydraulic fracturing applications performed in the United States of America." (Brannon 2008)

However, the EPA and another hydraulic fracturing firm, Superior Well Services, have noted that the language "water-based hydraulic fracturing applications" does not cover all types of hydraulic fracturing, suggesting that B.J. Services could continue using diesel in applications that are not water-based. In its 2004 report, EPA wrote that "water-based fracturing fluids have become the predominant type of coalbed methane fracturing fluid… however, fracturing fluids can also be based on oil, methanol, or a combination of water and methanol." (EPA Fracturing Final 2004, 4-2) Superior Well Services notes on its website that "water-based fracturing fluids are used in most stimulation applications," but it also lists two other types of systems: "oil-based fracturing systems" and "foam-based fracturing systems." (Superior 2009)

B.J. Services' Brannon referred questions about his company's use of diesel to a lawyer, Blaine Edwards. Edwards did not return a voice message requesting information. Halliburton and Schlumberger did not return phone calls from EWG requesting comment.

Neither Superior Well Services nor other fracturing companies signed the limited and voluntary agreement with EPA regarding the use of diesel in coalbed methane formations. As of late 2008, the EPA had not checked to see if B.J. Services Co., Schlumberger Ltd. and Halliburton were complying with the agreement. (Lustgarten 2008a)

Drilling Companies: No Comment

EWG tried repeatedly to find out from industry what petroleum distillates individual companies are using, what chemicals they contain and how they differ from diesel. To date, none of the companies contacted by EWG have supplied the information.
On Sept. 2, 2009, after a brief telephone conversation with Tom Price, who is Chesapeake Energy's Senior Vice President and spokesman, EWG Senior Counsel Dusty Horwitt emailed questions about the company's use of "petroleum distillate" to Price at his request. He did not respond. On Sept. 15, EWG followed up with a second email and left a voicemail for Price. On Sept. 17, Horwitt met with Chesapeake CEO Aubrey McClendon in Washington, DC and asked for a response. McClendon said the company would supply one, but EWG has yet to hear back.

On Aug. 31, 2009, EWG's Horwitt spoke by phone with Kenneth Komoroski, an attorney for the Pittsburgh office of the law firm K&L Gates LLP. In the fall of 2008, Komoroski's firm collected a list of hydraulic fracturing compounds used by companies operating in Pennsylvania and provided it to the Pennsylvania Department of Environmental Protection. On Sept. 1, 2009, at Komoroski's request, EWG emailed him questions about the petroleum distillates on the list. On Sept. 15, EWG followed up with a second email and left a phone message with Komoroski's assistant, but Komoroski has yet to respond.

On Sept. 2, 2009, EWG's Horwitt left a voice mail for and sent an email to Kenneth Brannon, Senior Advisor for Fracturing at B.J. Services, seeking information on the company's use of petroleum distillates and diesel. On Sept. 15, EWG sent a second email and called Brannon again. Brannon said he had forwarded the original email to Blaine Edwards, a lawyer for B.J. Services in Houston. Horwitt left a voicemail for Edwards that day but has not heard back.

On Aug. 26 and Sept. 15, 2009, Horwitt left voice messages seeking similar information from Lewis Cessna in the safety department at Superior Well Services. There has been no response.

EPA, States Largely Oblivious

EPA and at least some states appear to have paid minimal attention to the risks of hydraulic fracturing with petroleum distillates. Some officials also appear to be misinterpreting the law.

Ann Codrington, a spokeswoman for EPA's Office of Groundwater and Drinking Water, wrote in an email that EPA's position is that under the Safe Drinking Water Act, companies must gain approval before using diesel in hydraulic fracturing. (Codrington 2009) In fact, the language of the law provides that states "shall prohibit ... any underground injection in such State which is not authorized by a permit issued by the State." The law goes on to say that "the term 'underground injection' ... (A) means the subsurface emplacement of fluids by well injection; and (B) excludes ... the underground injection of fluids or propping agents [other than diesel fuels] pursuant to hydraulic fracturing operations related to oil, gas, or geothermal production activities."

Codrington said monitoring of hydraulic fracturing is the responsibility of state officials. (Codrington 2009a) However, several state offices that have been granted primary authority to enforce the Safe Drinking Water Act for oil and gas injection wells, as well as regional EPA offices that have retained enforcement authority, told EWG that they do not check on what fracturing fluids companies are using and have not issued permits. Some of these offices contend that the Act does not apply to hydraulic fracturing with diesel, a position that appears to contradict the law.

Following is a summary of responses from state regulators and EPA regional offices with responsibility over underground injections by the oil and gas industry under the Safe Drinking Water Act:

Montana

George Hudak, of the Montana Board of Oil and Gas Conservation, said his agency does not regulate or inspect hydraulic fracturing under the Safe Drinking Water Act. Hudak said it was his belief that all hydraulic fracturing is exempt from the Act – including the use of diesel. (Hudak 2009)

New York

EPA's Region II office, which has jurisdiction over oil and gas injection wells in New York, considers hydraulic fracturing with diesel to be covered by the Act, but an official, who did not wish to be quoted by name, said the office does not regulate fracturing and does not check on what fluids are used. (EPAII 2009)

Pennsylvania

Karen Johnson of EPA's Region III office echoed the views of Montana's Hudak, saying that her office does not monitor hydraulic fracturing and considers all fracturing – even with diesel – exempt from the Safe Drinking Water Act. EPA's Region III office has primary authority over oil and gas injection wells in Pennsylvania, Virginia and Washington, DC. (Johnson 2009)

Texas

Ramona Nye, of the Texas Railroad Commission (TRC), said in an email that the Commission does not monitor the use of hydraulic fracturing fluids. She indicated that her agency believes that the Safe Drinking Water Act does apply to diesel. (Nye 2009)

Wyoming

Of the agencies EWG contacted, only the Wyoming Oil and Gas Conservation Commission tracks the type of fracturing fluid used, and a Commission official said drillers in the state commonly use diesel for hydraulic fracturing. "Diesel's a big part of the injection fluid," said the official, who did not wish to be quoted by name. The official added that companies use diesel as a friction reducer to reduce the amount of energy required to inject the fracturing fluid into the well and as a way to prevent barriers from forming between the well bore and the oil or gas deposits. But the official said Wyoming takes the position that the Safe Drinking Water Act does not apply to fracturing – even with diesel – and that the commission monitors the types of fluid used under state, not federal, standards. The official said the state would take precautions, such as requiring drillers to use only chlorinated fresh water for fracturing, if it believed that underground aquifers might be in danger. (WYOGCC 2009a, WYOGCC 2009b)

Amounts Used Could Contaminate Vast Quantities of Water

Energy companies emphasize that hydraulic fracturing fluids contain mostly water and include very small amounts of additives such as petroleum distillates. But as the EPA has noted, minuscule amounts of BTEX chemicals can contaminate water, and the available data indicates that at least some companies are injecting petroleum distillates in quantities that could be dangerous.

The New York Department of Environmental Conservation (DEC) recently estimated that the amount of water used to hydraulically fracture a single well in the Marcellus Shale would range from about 1 million to 8 million gallons. (NYDEC DSGEIS 5-73, 6-137) The department also estimated that the amount of friction reducer mixed with the water would constitute about 0.08 percent of the total fracturing solution. (NYDEC DSGEIS 5-44) Chesapeake Energy uses a similar figure on its website. (Chesapeake Fracturing 2009) Petroleum distillates are widely used as friction reducers and for other purposes in fracturing solutions. (NYDEC DSGEIS 5-60, 5-61)

Based on these numbers, the amount of petroleum distillate used for fracturing a well in New York is likely to range from 800 gallons to 6,400 gallons (0.08 percent of 1 million to 8 million gallons). Published levels of benzene in petroleum distillates with names similar to those used or likely to be used in New York range from 1,000 ppm for diesel (200,000 times EPA's maximum for benzene in drinking water) to 93,000 ppm in naphtha solvents (18.6 million times the EPA maximum for in drinking water).

By these estimates, 800 gallons of petroleum distillate could contain enough benzene to contaminate between 160 million gallons and 14.9 billion gallons of water, and 6,400 gallons of distillate could have enough benzene to pollute between 12.8 million and 119 billion gallons of water.

That means that the amount of petroleum distillates used in a single well under many scenarios could contaminate more than the 650 million gallons of water that New York City uses daily, according to the New York Department of Environmental Conservation. (NYDEC SDGEIS 6-10) In some cases, the amount of petroleum distillates used at a single well could pollute more than the 9 billion to 10 billion gallons of water used each day by the entire state of New York. (NYDEC SDGEIS 6-9)

Distillates Have Multiple Routes of Contamination

Not all the petroleum distillates used to fracture a well would pose a threat to water supplies. Some or all could be trapped underground or might not dissolve in water. Some companies might safely dispose of their petroleum distillates. However, companies drill thousands of wells in the United States each year, and the combined effects of many smaller contamination incidents involving petroleum distillates could pollute large quantities of water through a variety of pathways.

Petroleum distillates used for fracturing must be transported to drilling sites and can be spilled by trucks or workers. In the spring of 2009, Pennsylvania officials fined Cabot Oil and Gas Corp. for an 800-gallon diesel spill from an overturned truck. It is unclear for what purpose the diesel was being used or whether there was any benzene contamination as a result, but diesel typically contains benzene. (Lustgarten 2009a) (More recently, Pennsylvania officials ordered Cabot to stop hydraulic fracturing operations in Susquehanna County after a series of three hydraulic fracturing chemical spills in nine days that contaminated a creek and resulted in a fish kill.) (Lustgarten 2009b)

Diesel is also used to power drilling equipment at well sites, increasing the volume of petroleum distillate that could be spilled. The NY Department of Environmental Conservation calculated that it takes an average of 29,000 gallons of diesel just to fuel the equipment used on each fracturing job in the Marcellus Shale in West Virginia and Pennsylvania. (NYDEC 6-120)

Distillates could spread underground through natural or man-made fractures. The EPA found in its 2004 study of hydraulic fracturing in coalbeds that "fluids can be 'lost'(i.e. remain in the subsurface unrecovered) due to "leakoff" into connected fractures and the pores of porous rocks ... the high injection pressures of hydraulic fracturing can force the fracturing fluids to be transported deep into secondary fractures." The EPA added that "if fracturing fluids have been injected to a point outside of the well's capture zone [the portion of an aquifer that contributes water to an oil or natural gas well], they will not be recovered through production pumping and, if mobile, may be available to migrate through an aquifer." (EPA Fracturing Final 2004)

In 2008, Garfield County, Colorado officials released a study that linked methane contamination in local water wells to methane in the same rock layer a mile and a half underground, where gas companies are drilling. The scientists who conducted the study did not determine how the gas reached the wells, but their results provide evidence that gas or other contaminants from drilling can work their way to the surface from deep underground.

"It challenges the view that natural gas, and the suite of hydrocarbons that exist around it, is isolated from water supplies by its extreme depth," Judith Jordan, the oil and gas liaison for Garfield County, told ProPublica, an independent non-profit investigative journalism organization. (Lustgarten 2008b)

After the fracturing process is complete, companies typically pump some of the fluids to the surface, where more contamination can occur. (EPA Fracturing Final 2004) These fluids are often mixed with naturally occurring "produced water" that must also be pumped out of the well and that may contain benzene and other toxics. To prevent water contamination, this wastewater should be properly stored in tanks, but it is often dumped in lined or unlined pits. Even lined pits can leak. (Epstein and Selber 2002, NMOCD Pit Testing 2007) New Mexico's Oil Conservation Division has identified more than 400 cases of groundwater contamination from oil and gas waste pits statewide. (Prukop 2008, Farmington 2008) In Pennsylvania, officials expressed concerns in 2008 that a water pollution control plant in McKeesport was polluting the Monongahela River because the plant was accepting drilling wastewater, including hydraulic fracturing fluids. The state ordered the plant to reduce the amount of wastewater it accepted and to test it for contaminants. (PADEP McKeesport 2008)

The result is an increased likelihood that somewhere in the process, some quantity of petroleum distillate will spill or leak, threatening water supplies with contamination by benzene and other dangerous chemicals. And as the data show, a little benzene goes a long way.

Benzene Contamination Cases Have Been Linked to Drilling

Contamination of water supplies by benzene or related chemicals associated with drilling is not just a theoretical risk.

In the summer of 2008, in one of the few government tests ever conducted on water contamination near natural gas fields, the federal Bureau of Land Management found

benzene in drinking water wells in Sublette County, Wyo. The researchers did not identify where the contamination came from, but the only likely source in the otherwise rural area is intensive natural gas drilling involving hydraulic fracturing. (Lustgarten 2008a)

In 2007, Windsor Energy notified the state of Wyoming's Department of Environmental Quality that a private water well in Clark, Wyo. had been contaminated by benzene after one of Windsor's nearby natural gas wells blew out in 2006, polluting soil and groundwater. The state and Windsor provided the well owner with drinking water, and Windsor installed a filtration system for the well. A consultant estimated that the cost of testing water in the area for contaminants over a 10-year period would range from $667,000 to $833,000. A Windsor spokesman said he did not know how much it would cost to clean up the pollution (WYDEQ 2007, Prevost 2009)

In another disturbing case, health officials found in May 2008 that the tap water in Colorado outfitter Ned Prather's rural cabin was contaminated with all of the BTEX chemicals, including 100 parts per billion of benzene. The source of the chemicals is unknown, but natural gas companies have drilled 18 wells within 3,000 feet of the spring that supplies Prather's water. There is also a waste pit full of production water on a hill overlooking his cabin, a second pit that has been reclaimed, and in the winter of 2007, drillers spilled nearly 8,000 gallons of diesel on a nearby hill when a spigot was accidentally left open. The Denver Post reported that "bad water has decimated his outfitting business. Hunters don't want to stay in a cabin with suspect water or to harvest deer and elk they fear could be drinking contaminated water." Thus far, medical tests have found no damage to Prather's health, but he has unexplained problems that predate his toxic drink. His hands and head shake, and the tremors have grown worse recently. "Not that many people have turned up a glass and drank that much benzene at one time," Prather told the Post. (Lofholm 2009)

Four years earlier in Colorado, drillers working for EnCana Corp., a natural gas company, fractured an improperly cemented well in Garfield County. Gas escaped from about 7,000 feet underground, entered a natural fracture about 3,000 feet below the surface and traveled laterally about 3,500 feet to contaminate Divide Creek, forcing local residents to drink bottled water. Inspectors found high levels of benzene in the water (99 parts per billion) the day after residents noticed unusual bubbles in the creek. One resident, Lisa Bracken, described the creek as having so many bubbles it looked like a "popped can of soda." Another resident, Steve Thompson, said, "I came down with a funnel and scooped some of the biggest bubbles with it… I lit the bubbles with a match, and they burned like gas. It even melted my funnel." (Chakrabarty 2004a, Chakrabarty 2004b, Chakrabarty 2004c, Thyne 2004, Thyne 2009, COGCC Thyne 2009)

A report prepared for Garfield County found that the contaminants in Divide Creek included methane gas and the BTEX chemicals. (Thyne 2004). In August 2004, the Colorado Oil and Gas Conservation Commission (COGCC) concluded that Encana's drilling had caused the contamination, levied the highest fine in its history on the company ($371,200) and imposed a moratorium on drilling within a two-mile radius. (Chakrabarty 2004a, Chakrabarty 2004b, Thyne 2004, Thyne 2009, COGCC Thyne 2009). For the last four years, EnCana has operated an air sparge decontamination system that injects air into the creek to dissipate the benzene into the atmosphere. (Thyne 2009, COGCC EnCana 2009, EPA Sparge 2009)

Conclusion and Recommendations

EWG's research shows conclusively that the petroleum distillates used in hydraulic fracturing pose a serious threat to the nation's water supplies, and that the risks have been largely ignored by federal and state regulators despite repeated incidents that reveal the potential for catastrophic harm.

EWG therefore is making these recommendations for Congress and federal agencies:

1. Congress should require companies to comply with the Safe Drinking Water Act when using any substance for hydraulic fracturing. Currently, the act allows companies to use substances that may be at least as toxic as diesel without any oversight.

2. Congress should require drilling companies to publicly disclose the chemicals they use in hydraulic fracturing in each well. At a minimum, companies must disclose Chemical Abstracts Services Registry Numbers for each substance to allow easy identification. Generic names such as "petroleum distillate" leave the public in the dark.

3. The U.S. Department of the Interior, which oversees drilling on public land, should exercise its authority to require such disclosures.

4. Congress should investigate federal and state oversight of hydraulic fracturing and insist that federal and state personnel be properly informed about the law.

5. The U.S. Environmental Protection Agency should use its existing authority to determine whether companies are using diesel and enforce permit requirements.

References:

Agency for Toxic Substances and Disease Registry (ATSDR Benzene). 2007. U.S. Department of Health and Human Services, Public Health Service, Agency for Toxic Substances and Disease Registry, Division of Toxicology and Environmental Medicine, Public Health Statement: Benzene, August 2007. Accessed online Sept. 28, 2009 at http://www.atsdr.cdc.gov/toxprofiles/tp3-c1-b.pdf.

Agency for Toxic Substances and Disease Registry (ATSDR TPH). 1999. U.S. Department of Health and Human Services, Toxicological Profile for Total Petroleum Hydrocarbons (TPH), September 1999, at 137. Accessed online Dec. 8, 2009, at www.atsdr.cdc.gov/toxprofiles/tp123.pdf.

American Chemical Society (ACS). 2009. CAS (Chemical Abstracts Service) Registration Criteria-Overview. Accessed online Dec. 8, 2009 at http://www.cas.org/ASSETS/362851E849D642E8AF2D94ADCF85B28A/regcriteria.pdf.

American Petroleum Institute (API). 2003. High Production Volume Chemical Challenge Program, Test Plan, Kerosene/Jet Fuel Category, Robust Summary of Information on Kerosene/Jet Fuel. American Petroleum Institute submission to U.S. Environmental Protection Agency, Dec. 31, 2003. Accessed online Aug. 23, 2009 at http://www.epa.gov/oppt/chemrtk/pubs/summaries/kerjetfc/c15020.pdf.

Bell Fuels (Bell Fuels). 1999. Super K-1 Kerosene Material Data Safety Sheet (MSDS) at http://www2.itap.purdue.edu/msds/docs/6430.pdf.

Brannon, Harold D. (Brannon). 2008. Electronic mail from Harold D. Brannon; Senior Advisor, Fracturing; BJ Services Company to Jeff Jollie, Geologist, U.S. Environmental Protection Agency, Office of Ground Water and Drinking Water, Drinking Water Protection Division (Oct. 23, 2008) (on file with Environmental Working Group).

Burnett, D.B. and Vavra, C.J. 2006. Desalination of Oil Field Brine, Presentation for "The Future of Desalination in Texas," Global Petroleum Research Institute, Texas A&M University, College Station, Texas, Aug. 6-8, 2006. Accessed online March 15, 2009 at http://www.pe.tamu.edu/gpri-new/home/BrineDesal/MembraneWkshpAug06/Burnett8-06.pdf (commenting that wells in the Barnett Shale use five to six million gallons of fracturing fluid; an industry source told Environmental Working Group that the figure can range as high as six million gallons).

Carrillo, Victor (IOGCC Carrillo). 2005. Testimony submitted to the House Committee on Energy and Commerce by Victor Carrillo, Chairman, Texas Railroad Commission Representing the Interstate Oil and Gas Compact Commission, Feb. 10, 2005. Accessed online June 4, 2005 at http://www.rrc.state.tx.us/commissioners/carrillo/press/ energytestimony.html.

Chakrabarty, Gargi (2004a). Toxic Bubbles Trouble Silt; Divide Creek Tainted by Natural Gas Leak, Toxic Benzene, Rocky Mountain News, April 13, 2004, at 1B.

Chakrabarty, Gargi (2004b). Regulators Seek Record Fine for Gas Seep, Rocky Mountain News, August 17, 2004, at 1B.

Chakrabarty, Gargi (2004c). Commission OKs Record Fine for EnCana Gas Seep, Rocky Mountain News, Aug. 18, 2004, at 3B.

Chesapeake (Chesapeake). 2009a. Hydraulic Fracturing Fact Sheet, May 2009. Submitted to U.S. House of Representative Committee on Natural Resources. See also Chesapeake. 2009. Media Resources, Hydraulic Fracturing Fact Sheet, May 2009. Accessed online Aug. 18, 2009 at http://www.chk.com/media/pages/mediaresources.aspx.

Chesapeake (Chesapeake). 2009b. Area of Operations. Accessed online Aug. 18, 2009 at http://www.chk.com/Operations/Pages/Default.aspx.

Codrington, Ann (Codrington). 2009. Electronic mail from Ann Codrington, U.S. Environmental Protection Agency, Office of Ground Water and Drinking Water (Sept. 30, 2009).

Codrington, Ann (Codrington). 2009a. Personal communication with Ann Codrington, U.S. Environmental Protection Agency, Office of Ground Water and Drinking Water (Sept. 15, 2009).

Colorado Oil and Gas Conservation Commission (COGCC Thyne). 2009. Library, Public Presentations, Materials Related to the July 14-15, 2009 Commission Hearing in Glenwood Springs, West Divide Creek 2009 by Geoffrey Thyne. Accessed online Oct. 22, 2009 at http://cogcc.state.co.us/.

Colorado Oil and Gas Conservation Commission, Library, Public Presentations, Materials Related to the July 14-15, 2009 Commission Hearing in Glenwood Springs, West Divide Creek Gas Seep Overview by EnCana. Accessed online Oct. 22, 2009 at http://cogcc.state.co.us/.

Consumer Product Safety Commission (CSPC). 1997. Household Products Containing Petroleum Distillates and Other Hydrocarbons, Advance Notice of Proposed Rulemaking; Request for Comments and Information, 62 Fed. Reg. 8,659 (Feb. 26, 1997).

Environmental Working Group (EWG). 2009. Free Pass for Oil and Gas: Environmental Protections Rolled Back as Western Drilling Surges. Accessed online Oct. 2, 2009 at http://www.ewg.org/reports/Free-Pass-for-Oil-and-Gas.

Epstein, Paul R. and Jesse Selber (Epstein and Selber). 2002. Oil – A Life Cycle Analysis of Its Health and Environmental Impacts, The Center for Health and the Global Environment, Harvard Medical School. Accessed online March 16, 2009 at http://chge.med.harvard.edu/publications/documents/oilfullreport.pdf.

European Union (EU). 1982. Council Directive 778/76 of 27 July 1976 On the Approximation of the Laws of the Member States Relating to Cosmetic Products, 1976 O.J. (L 262) 169; amended by Council Directive 368/82 of 17 May 1982 List of Substances which Must Not Form Part of the Composition of Cosmetic Products, 1982 O.J. (L167) 1.

Farmington Daily Times (Farmington). 2008. New Regulations, Fees Slow Down Drilling Production, Farmington Daily Times, Oct. 5, 2008.

Gennaro, James F. (Gennaro). 2009. Letter from James F. Gennaro, Chairman, New York City Council Committee on Environmental Protection to Pete Grannis, Secretary, New York State Department of Environmental Conservation (Feb. 19, 2009). Accessed online Aug. 27, 2009 at http://www.ewg.org/files/letter-grannis-gennaro-final.pdf.

Hamburger, Tom and Alan Miller. 2004. A Changing Landscape: Halliburton's Interests Assisted by White House, Los Angeles Times, Oct. 14, 2004, at A1.

Hanel, Joe (Hanel). 2008a. Chemical Exposure Leads to Liver, Heart, Lung Failure, Durango Herald, July 17, 2008.

Hanel, Joe (Hanel). 2008b. S. Ute Land Was Site of Frac Fluid Spill, Durango Herald, Aug. 1, 2008.

Hudak, George (Hudak). 2009. Personal communication with George Hudak, Montana Board of Oil and Gas Conservation (Sept. 9, 2009).

Hunting, Katherine L., et al. (Hunting). 1995. Haematopoietic Cancer Mortality Among Vehicle Mechanics, 52 Occupational and Environmental Medicine 673-678 (1995). Hunting tested Varsol, a solvent that the National Library of Medicine says is synonymous with mineral spirits. See National Library of Medicine, ChemIDPlusLite. 2009. Distillates (petroleum), hydrotreated light; RN: 64742-47-8 (Names & Synonyms). Accessed online Dec. 8, 2009 at http://chem.sis.nlm.nih.gov/chemidplus/jsp/common/ChemInfo.jsp?calledFrom=lite&type=names.

Hurdle, Jon (Hurdle). 2009. U.S. Finds Water Polluted Near Gas-drilling Sites, Reuters, Aug. 27, 2009.

IHS (IHS). 2006. 2006 U.S. Well Completions, December 2006 (map on file with Environmental Working Group).

Johnson, Karen (Johnson). 2009. Personal communication with Karen Johnson (Sept. 11, 2009).

Kopstein, Melvyn (Kopstein). 2006. Potential Uses of Petrochemical Products Can Result in Significant Benzene Exposures: MSDSs Must List Benzene as an Ingredient, Journal of Occupational and Environmental Hygiene, 3: 1-8 (January 2006).

Lofholm, Nancy (2009). Fears of Tainted Water Well up in Western Colorado, The Denver Post, Oct. 12, 2009.

Lustgarten, Abrahm (2008a). Buried Secrets: Is Natural Gas Drilling Endangering U.S. Water Supplies? ProPublica, Published on the front page of the Denver Post, Nov. 17, 2008.

Lustgarten, Abrahm (2008b). Officials in Three States Pin Water Woes on Gas Drilling, ProPublica, April 26, 2009. Accessed online Oct. 2, 2009 at http://www.propublica.org/feature/officials-in-three-states-pin-water-woes-on-gas-drilling-426.

Lustgarten, Abrahm (Lustgarten). 2009a. Frack Fluid Spill in Dimock Contaminates Stream, Killing Fish, ProPublica, September 21, 2009. Accessed online Oct. 22, 2009 at http://www.propublica.org/feature/frack-fluid-spill-in-dimock-contaminates-stream-killing-fish-921.

Lustgarten, Abrahm (Lustgarten). 2009b. Pennsylvania Orders Cabot Oil and Gas to Stop Fracturing in Troubled County, ProPublica, Sept. 25, 2009. Accessed online Oct. 22, 2009 at http://www.propublica.org/feature/pennsylvania-orders-cabot-to-stop-fracturing-in-troubled-county-925.

Mehlman, Myron A. (Mehlman). 2004. Benzene: A Haematopoietic and Multi-organ Carcinogen at Any Level Above Zero. 9 (no. 1) European Journal of Oncology 15 (2004).

Merck (Merck). 2006. The Merck Manual of Diagnosis and Therapy, Mark H. Beers, MD, Editor, 2667, 2690 (2006).

National Library of Medicine, ChemIDPlusLite. 2009. Distillates (petroleum), hydrotreated light; RN: 64742-47-8 (Names & Synonyms). Accessed online July 6, 2009 at http://chem.sis.nlm.nih.gov/chemidplus/ProxyServlet?objectHandle=DBMaint&actionHandle=default&nextPage=jsp/chemidlite/ResultScreen.jsp&TXTSUPERLISTID=064742478.

National Park Service (NPS). 1997. Environmental Contaminants Encyclopedia, Kerosene Entry, July 1, 1997. Accessed online Aug. 28, 2009 at http://www.nature.nps.gov/hazardssafety/toxic/fueloil.pdf.

National Park Service (NPS). 1997. Environmental Contaminants Encyclopedia, Fuel Oil, General Entry. Accessed online Aug. 28, 2009 at http://www.nature.nps.gov/hazardssafety/toxic/fueloil.pdf.

New Mexico Oil Conservation Division (NMOCD Pit Testing). 2007. OCD's 2007 Pit Sampling Program: What's in that Pit? Accessed online March 16, 2009 at www.earthworksaction.org/pubs/15vonpitsamplingpgm.pdf.

New York Department of Environmental Conservation (NYDEC DSGEIS). 2009. Draft Supplemental Generic Environmental Impact Statement Relating to Drilling for Natural Gas in New York State Using Horizontal Drilling and Hydraulic Fracturing, Sept. 30, 2009. Accessed online November 6, 2009 at http://www.dec.ny.gov/energy/46288.html.

New York Department of Environmental Conservation (NYDEC). 2009. Oil and Gas Searchable Database, Wells Data Search. Accessed online Oct. 1, 2009 at http://www.dec.ny.gov/cfmx/extapps/GasOil/search/wells/index.cfm.

Nye, Ramona (Nye). 2009. Electronic mail from Ramona Nye, Media Affairs, Texas Railroad Commission (Sept. 17, 2009).

Pagnotto, Leonard, et al. (Pagnotto). 1961. Industrial Benzene Exposure from Petroleum Naphtha: I. Rubber Coating Industry, Am Ind Hyg Assoc J 1961; 22: 417-21.

Pennsylvania Department of Environmental Protection (PADEP). 2008. Summary of Hydraulic Fracture Solutions – Marcellus Shale. Accessed online Aug. 19, 2009 at http://www.dep.state.pa.us/dep/deputate/minres/oilgas/new_forms/marcellus/marcellus.htm. Includes information submitted by BJ Services, Fractech, Universal, Halliburton and Superior. Two companies said that they used petroleum distillates. BJ Services said that it used "petroleum distallate (sic) blend" and "hydrotreated light distillate." Superior said that it used "hydrotreated light distillate" and "mineral spirits." An official with the Pennsylvania Bureau of Oil and Gas said that the state received the list in 2008. Personal communication, Aug. 19, 2009.

Pennsylvania Department of Environmental Protection (PADEP McKeesport). 2008. Order of the Department of Environmental Protection in the Matter of The Municipal Authority of the City of McKeesport, Oct. 23, 2008.

Prevost, Ruffin. Clark Residents to Discuss Response to Gas Well Blowout, Billings Gazette, September 9, 2009.

Prukop, Joanna (Prukop). 2008. Drilling Rules Tough but Fair, Albuquerque Journal, Dec. 3, 2008.

Safe Drinking Water Act (SDWA). 2009. 42 USC 300h (2009).

Schein, Gary (Schein). 2008. Hydraulic Fracturing in Gas Shale Plays – Are They all the Same? Presentation at Barnett Shale Breakfast Symposium, Feb. 29, 2008. Accessed online March 15, 2009 at http://www.barnettshalenews.com/studies.htm (commenting that shale formations in the Barnett Shale may require four million gallons of fracturing fluid).

Slothower, Chuck (Slothower). 2008. Gas Worker: Chemical not to Blame, Durango Herald, July 23, 2008.

Superior Well Services (Superior). 2009. Superior Well Services, Products, Fracturing Systems. Accessed online Aug. 29, 2009 at http://www.superiorwells.com/pfracsys.php.

The Endocrine Disruption Exchange (TEDX). 2009. Chemicals in Natural Gas Operations, Spreadsheets and Summaries by State. Accessed online Aug. 20, 2009 at http://www.endocrinedisruption.com/chemicals.spreadsheets.php.

Thyne, Geoffrey (Thyne). 2009. Personal communication with Geoffrey Thyne, Oct. 22, 2009.

U.S. Department of Energy (DOE). 2009. Energy Information Administration, Oil Market Basics, Refining. Accessed online Aug. 21, 2009 at http://www.eia.doe.gov/pub/oil_gas/petroleum/analysis_publications/oil_market_basics/refining_text.htm. U.S. Department of Energy (DOE Kids). 2009 Energy Information Administration, Petroleum (Oil) – Refining. Accessed online Aug. 23, 2009 at http://www.eia.doe.gov/kids/energyfacts/sources/non-renewable/refinery.html.

U.S. Department of Energy (DOE Wells). 2000. United States Total 2000, Distribution of Wells by Production Rate Bracket. Accessed online Oct. 2, 2009 at: http://www.eia.doe.gov/pub/oil_gas/petrosystem/us_table.html.

U.S. Environmental Protection Agency (EPA Fracturing Final). 2004. Evaluation of Impacts to Underground Sources of Drinking Water by Hydraulic Fracturing of Coalbed Methane Reservoirs, Final, June 2004. Accessed online March 13, 2009 at http://www.epa.gov/safewater/uic/wells_coalbedmethanestudy.html (see p. ES11 commenting that coal bed methane wells may require 50,000 to 350,000 gallons of fracturing fluids).

U.S. Environmental Protection Agency (EPA MOA). 2003. A Memorandum of Agreement Between The United States Environmental Protection Agency and BJ Services Company, Halliburton Energy Services, Inc., and Schlumberger Technology Corporation: Elimination of Diesel Fuel in Hydraulic Fracturing Fluids Injected into Underground Sources of Drinking Water During Hydraulic Fracturing of Coalbed Methane Wells, Dec. 12, 2003. Accessed online Aug. 20, 2009 at http://www.epa.gov/safewater/uic/pdfs/moa_uic_hyd-fract.pdf.

U.S. Environmental Protection Agency (EPA Natural Gas). 2009. Natural Gas. Accessed online Nov. 6, 2009 at http://www.epa.gov/RDEE/energy-and-you/affect/natural-gas.html.

U.S. Environmental Protection Agency (EPA Mineral Spirits). 2009. Emergency Management, Substances Covered Under Reporting Requirements. Accessed online Aug. 20, 2009 at http://www.epa.gov/OEM/content/reporting/faq_subs.htm#faq19.

U.S. Environmental Protection Agency (EPA Diesel). 2004. Draft Regulatory Impact Analysis: Control of Emissions from Nonroad Diesel Engines, Assessment and Standards Division, Office of Transportation and Air Quality, Chapter 5: Fuel Standard Feasibility, April 2003. Accessed online Aug. 23, 2009 at http://www.epa.gov/otaq/cleaner-nonroad/.

U.S. Environmental Protection Agency (EPA Benzene). 2009. Consumer Factsheet on: BENZENE. Accessed online Aug. 18, 2009 at http://www.epa.gov/safewater/contaminants/dw_contamfs/benzene.html.

U.S. Environmental Protection Agency (EPA Toluene). 2009. Consumer Factsheet on: TOLUENE. Accessed online Aug. 18, 2009 at http://www.epa.gov/safewater/contaminants/dw_contamfs/toluene.html.

U.S. Environmental Protection Agency (EPA Ethylbenzene). 2009. Consumer Factsheet on: ETHYLBENZENE. Accessed online Aug. 18, 2009 at http://www.epa.gov/safewater/contaminants/dw_contamfs/ethylben.html.

U.S. Environmental Protection Agency (EPA Xylene). 2009. Consumer Factsheet on: XYLENES. Accessed online Aug. 21, 2009 at http://www.epa.gov/safewater/contaminants/dw_contamfs/xylenes.html.

U.S. Environmental Protection Agency (EPA Sparge), 2009. Underground Storage Tanks, Air Sparging. Accessed online Oct. 22, 2009 at http://www.epa.gov/swerust1/cat/airsparg.htm.

U.S. Environmental Protection Agency (EPA Pavillion). 2009. Site Investigation, Analytical Results Report, Pavillion Area Groundwater Investigation, Pavillion, Fremont County, Wyoming, Aug. 19, 2009.

U.S. Environmental Protection Agency, Region II (EPAII). 2009. Personal communication with spokesperson for Region II Underground Injection Control Program, Oct. 1, 2009.

U.S. Food and Drug Administration (FDA). 2006. Cosmetics Q&A: FDA's Authority. Accessed online Sept. 16, 2009 at http://www.fda.gov/Cosmetics/ResourcesForYou/Consumers/CosmeticsQA/ucm135709.htm. See also U.S. Food and Drug Administration (FDA). 2009. Cosmetics Q&A: Animal Testing. Accessed online Sept. 16, 2009 at http://www.fda.gov/Cosmetics/ResourcesForYou/Consumers/CosmeticsQA/ucm167216.htm and Cosmetics Q&A: Prohibited Ingredients Accessed online at http://www.fda.gov/Cosmetics/ResourcesForYou/Consumers/CosmeticsQA/ucm167234.htm.

Wyoming Department of Environmental Quality (WYDEQ). 2007. Benzene detected in one private water well in Clark, WY, News Release, September 26, 2007. Accessed online January 11, 2010 at deq.state.wy.us/out/downloads/Benzene detected.pdf.

Wyoming Oil and Gas Conservation Commission (WYOGCC). 2009a. Important Notices, Memos & Etc., Hydraulic Fracturing Rules and Regulations July 2009. Accessed online Oct. 2, 2009 at http://wogcc.state.wy.us/notices_memos_menu.cfm.

Wyoming Oil and Gas Conservation Commission (WYOGCC). 2009b. Personal communication with official from the WYOGCC (Oct. 1, 2009).