Concerned Health Professionals of NY

COMPENDIUM OF SCIENTIFIC, MEDICAL, AND MEDIA FINDINGS DEMONSTRATING RISKS AND HARMS OF FRACKING (UNCONVENTIONAL GAS AND OIL EXTRACTION)

2nd edition

December 11, 2014

Photo credit: Les Stone

Foreword to the Second Edition

The *Compendium of Scientific, Medical, and Media Findings Demonstrating Risks and Harms of Fracking* (the Compendium) is a fully-referenced compilation of the evidence for the risks and harms of fracking that brings together findings from the scientific and medical literature, government and industry reports, and journalistic investigation. It is a public, open-access document that is housed on the website of Concerned Health Professionals of New York (www.concernedhealthny.org). Since its release in July 2014, it has been used and referenced all over the world.

The Compendium, a subject of public health forums on both sides of the Atlantic—and on both coasts here in the United States—has been translated into Spanish and adopted for use in the European Union, South Africa, and Australia. Here in New York State, it serves as the foundation and comprehensive rationale for a minimum three-to-five-year moratorium on fracking: from its first publication, the evidence contained in the Compendium leads us to this unwavering conclusion.

But this document has not traveled as fast as the science itself. In the five months since the Compendium's original release, dozens of additional investigative reports and research papers have been published that clarify, corroborate, and further explicate the intractable problems that natural gas extraction via hydraulic fracturing brings with it. As documented by the study citation database maintained by Physicians, Scientists and Engineers for Healthy Energy, three-fourths of the available studies on the impacts of shale gas development have been published within the past 24 months. The number of peer-reviewed publications doubled between 2011 and 2012 and then doubled again between 2012 and 2013. In the last year alone, 154 peer-reviewed studies on the impacts of fracking were released. Almost all of them reveal problems. (See footnote 1.)

Thus, this second edition, which contains more than 80 new entries, continues to be top-heavy with recent publications.

Here are some emerging trends in the new data. First, growing evidence shows that **regulations are simply not capable of preventing harm.** That is both because the number of wells and their attendant infrastructure keeps increasing and, more importantly, because some of fracking's many component parts, which include the subterranean geological landscape itself, are simply not controllable.

As noted last month in a new study on fracking-related air pollution in northeastern Colorado: even though the volume of toxic emissions per well might be decreasing, overall air quality in the shale field continues to deteriorate as the rapid, continuing increase in the number of wells cancels out improvements to air quality brought about by more stringent regulations. (See footnote 4.) Similarly, the results of a new study from Texas raises the possibility that methane can migrate into aquifers through unseen cracks and fissures in the rock surrounding the wellbore in ways that no cementing and casing protocols, however strictly applied, can prevent. (See footnotes 55 and 56.) New findings from West Virginia show how unmapped, long-abandoned wells—including those drilled generations ago—can become re-pressurized during nearby fracking operations and serve as conduits for the contamination of drinking water. (See footnote 57.) A new study by Princeton researchers working in Pennsylvania found that, many decades

after their abandonment, plugged and unplugged wells alike leaked significant amounts of methane into the atmosphere. There are an estimated three million abandoned oil and gas wells in the United States; the locations of many are unmapped and unknown. (See footnotes 265 and 266.) No set of regulations can obviate these problems.

Second, **drinking water is at risk from drilling and fracking activities and associated waste disposal practices.** As documented by the Pennsylvania Department of Environmental Protection in a review of its records, 234 private drinking water wells in Pennsylvania have been contaminated by drilling and fracking operations during the past seven years. These do not include drinking water wells contaminated by spills of fracking wastewater or wells that went dry as a result of nearby drilling and fracking activities. (See footnotes 68 and 69.) In California, the injection of liquid fracking waste directly into groundwater aquifers threatens contamination of large numbers of public drinking water supplies. (See footnote 78.)

Third, **drilling and fracking emissions often contain strikingly high levels of benzene.** A potent human carcinogen, benzene has been detected in the urine of wellpad workers (at levels known to raise risks for leukemia), in private drinking water wells contaminated by fracking operations, and in ambient air at nearby residences. In some cases, concentrations have far exceeded federal safety standards. Such exposures represent significant public health risks. (See footnotes 3–8, 12, 57, 174.)

Fourth, **public health problems associated with drilling and fracking are becoming increasingly apparent.** Documented indicators variously include increased rates of hospitalization, ambulance calls, emergency room visits, self-reported respiratory and skin problems, motor vehicle fatalities, trauma, drug abuse, infant mortality, congenital heart defects, and low birth weight. (See footnotes 192–205.)

Fifth, **natural gas is a bigger threat to the climate than previously supposed.** Methane is not only a more potent greenhouse gas than formerly appreciated, real-world leakage rates are higher than predicted. Within the last five months, multiple teams of independent scientists have published data on fugitive emissions that, all together, call into question earlier presumed climate benefits from replacing coal with natural gas. Further, evidence increasingly suggests that the natural gas abundance brought by fracking is slowing the transition to renewable energy and is thus exacerbating, rather than mitigating, the climate change crisis. (See footnotes 313–318.)

Introduction

Directional drilling combined with high-volume hydraulic fracturing and clustered multi-well pads are recently combined technologies for extracting oil and natural gas from shale bedrock. As this unconventional extraction method (collectively known as “fracking”) has pushed into more densely populated areas of the United States, and as fracking operations have increased in frequency and intensity, a significant body of evidence has emerged to demonstrate that these activities are inherently dangerous to people and their communities. Risks include adverse impacts on water, air, agriculture, public health and safety, property values, climate stability and economic vitality.

Researching these complex, large-scale industrialized activities—and the ancillary infrastructure that supports them—takes time and has been hindered by institutional secrecy. Nonetheless, research is gradually catching up to the last decade's surge in unconventional oil and gas extraction from shale. A growing body of peer-reviewed studies, accident reports, and investigative articles is now detailing specific, quantifiable evidence of harm and has revealed fundamental problems with the entire life cycle of operations associated with unconventional drilling and fracking. Industry studies as well as independent analyses indicate inherent engineering problems including uncontrolled and unpredictable fracturing, induced seismicity, and well casing and cement impairments that cannot be prevented.

Earlier scientific predictions and anecdotal evidence are now bolstered by empirical data, confirming that the public health risks from unconventional gas and oil extraction are real, the range of adverse impacts significant, and the negative economic consequences considerable. Our examination of the peer-reviewed medical and public health literature uncovered no evidence that fracking can be practiced in a manner that does not threaten human health.

Despite this emerging body of knowledge, industry secrecy and government inaction continue to thwart scientific inquiry, leaving many potential problems—especially cumulative, long-term risks—unidentified, unmonitored and largely unexplored. This problem is compounded by non-disclosure agreements, sealed court records, and legal settlements that prevent families (and their doctors) from discussing injuries. As a result, no comprehensive inventory of human hazards yet exists.

At the same time, inflated estimates of shale reserves and potential profitability continue to fuel the rush to drill new wells, cut regulatory corners, and press into densely populated communities, as corporations attempt to compensate for the unexpectedly rapid depletion of their existing wells and coincident drop off in revenue. Thus do the fundamental economic uncertainties of shale gas and oil production further exacerbate the risks of fracking to public health and society.

Each day in the United States, more than two billion gallons of fluid are injected under high pressure into the earth with the purpose of enabling oil and gas extraction via fracking or, after the fracking is finished, to flush what's left down any of the 177,000 disposal wells across the country that accept oil and gas waste. All of those two billion daily gallons of fluid is toxic, and it all traverses our nation's groundwater aquifers on its way to the deep geological strata below. With more than 15 million Americans already living within a mile of a fracking well that has been drilled since 2000, the stakes could not be higher.

About This Report

The Compendium is a fully referenced compilation of the significant body of scientific, medical, and journalistic findings demonstrating risks and harms of fracking. Organized to be accessible to public officials, researchers, journalists and the public at large, the Compendium succinctly summarizes key studies and other findings relevant to the ongoing public debate about unconventional methods of oil and gas extraction. The Compendium should be used by readers to grasp the scope of the information about both public health and safety concerns and the economic realities of fracking that frame these concerns. The reader who wants to delve deeper

can easily consult the reviews, studies, and articles referenced. In addition, the Compendium is complemented by a fully searchable, near-exhaustive citation database of peer-reviewed journal articles pertaining to shale gas and oil extraction, housed at the PSE Healthy Energy scientific literature database.[1]

The pace at which new studies and information are emerging has rapidly accelerated in the past year and a half: the first few months of 2014 saw more studies published on the health effects of fracking than all studies published in 2011 and 2012 combined.[2] In accordance, the Compendium is organized in reverse chronological order, with the most recent information first.

In our review of the data, sixteen compelling themes emerged: these serve as the organizational structure of the Compendium. The document opens with sections on two of the most acute threats—air pollution and water contamination—and ends with medical and scientific calls for more study and transparency. Readers will quickly notice the ongoing upsurge in reported problems and health impacts, making each section top-heavy with recent data.

The Compendium focuses on topics most closely related to the public health and safety impacts of unconventional gas and oil drilling and fracking. Many additional risks and harms arise from associated infrastructure and industrial activities that necessarily accompany drilling and fracking operations. These include pipelines, compressor stations, oil trains, sand mining operations, cryogenic and liquefaction facilities, processing and fractionation complexes, import/export terminals, and so forth. While impacts from infrastructure are critically important to public health and safety and while the Compendium refers to these impacts in certain instances when studies covered have also addressed them, a detailed accounting of these ancillary impacts are not included in this document.

Given the rapidly expanding body of evidence related to the harms and risks of unconventional oil and gas extraction, we plan to revise and update the Compendium approximately every six months. It is a living document, housed on the Concerned Health Professionals of New York website, and serves as an educational tool in the public and policy dialogue. The studies cited in this second edition are current through early December 2014.

The Compendium is not a funded project; it was written utilizing the benefit of the experience and expertise of numerous health professionals and scientists who have been involved in this issue for years.

We welcome your feedback and comments.

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[1] PSE Healthy Energy. http://www.psehealthyenergy.org/site/view/1180.

[2] Mobbs, P. (2014). Shale gas and public health - the whitewash exposed. *The Ecologist*. Retrieved July 3, 2014, from http://www.theecologist.org/News/news_analysis/2385900/shale_gas_and_public_health_the_whitewash_exposed.html

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Please cite this report as: Concerned Health Professionals of New York. (2014, December 11). Compendium of scientific, medical, and media findings demonstrating risks and harms of fracking (unconventional gas and oil extraction) (2nd ed.). http://concernedhealthny.org/compendium/.

Cover photo: Marcellus Shale wellpad in Doddridge County, West Virginia where private water wells were contaminated after a gas drilling accident. See footnote 57.

About Concerned Health Professionals of New York

Concerned Health Professionals of New York (CHPNY) is an initiative by health professionals, scientists and medical organizations for raising science-based concerns about the impacts of fracking on public health and safety. CHPNY provides educational resources and works to ensure that careful consideration of the science and health impacts are at the forefront of the fracking debate. http://concernedhealthny.org

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*Note that for the purposes of this compendium, the terms "fracking" and "drilling and fracking" refer to the entire unconventional oil and gas extraction and distribution process, from well site preparation to waste disposal and all associated infrastructure including pipelines and compressor stations. Not every aspect of this process is fully addressed in the Compendium.

Executive Summary

Evidence of risks, harms, and associated trends demonstrated by this Compendium:

- **Air pollution** – Studies increasingly show that air pollution associated with drilling and fracking operations is a grave concern with a range of impacts. Researchers have documented dozens of air pollutants from drilling and fracking operations that pose serious health hazards. Areas with substantial drilling and fracking build-out show high levels of ozone, striking declines in air quality, and, in several cases, increased rates of health problems with known links to air pollution. Air sampling surveys find exceedingly high concentrations of volatile organic compounds, especially carcinogenic benzene and formaldehyde, both at the wellhead and at distances that exceed legal setback distances from wellhead to residence. In some cases, concentrations exceeded federal safety standards by several orders of magnitude.

- **Water contamination** – Emerging science confirms that drilling and fracking inherently threaten groundwater. In Pennsylvania alone, more than 240 private drinking water wells have been contaminated or have dried up as the result of drilling and fracking operations over a seven-year period. A range of studies from across the United States presents strong evidence that groundwater contamination occurs and is more likely to occur close to drilling sites. The nation's 172,000 injection wells for disposal of fracking waste also pose demonstrable threats to the drinking water aquifers. Disposal of fracking waste in sewage treatment plants can encourage the formation of carcinogenic byproducts during chlorination. Overall, the number of well blowouts, spills and cases of surface water contamination has steadily grown. Meanwhile, the gas industry's use of "gag orders," non-disclosure agreements and settlements impede scientific study and stifle public awareness of the extent of these problems.

- **Inherent engineering problems that worsen with time** – Studies and emerging data consistently show that oil and gas wells routinely leak, allowing for the migration of natural gas and potentially other substances into groundwater and the atmosphere. Recent research suggests that the act of fracking itself may induce pathways for leaks. Leakage from faulty wells is an issue that the industry has identified and for which it has no solution. For instance, Schlumberger, one of the world's largest companies specializing

in fracking, published an article in its magazine in 2003 showing that about five percent of wells leak immediately, 50 percent leak after 15 years and 60 percent leak after 30 years. Data from Pennsylvania's Department of Environmental Protection (DEP) for 2000-2012 show over nine percent of shale gas wells drilled in the state's northeastern counties leaking within the first five years. Leaks pose serious risks including potential loss of life or property from explosions and the migration of gas or other chemicals into drinking water supplies. Leaks also allow methane to escape into the atmosphere, where it acts as a powerful greenhouse gas. There is no evidence to suggest that the problem of cement and well casing impairment is abating. Indeed, a 2014 analysis of more than 75,000 compliance reports for more than 41,000 wells in Pennsylvania found that newer wells have higher leakage rates and that unconventional shale gas wells leak more than conventional wells drilled within the same time period. Industry has no solution for rectifying the chronic problem of well casing/cement leakage.

- **Radioactive releases –** High levels of radiation documented in fracking wastewater from shale raise special concerns in terms of impacts to groundwater and surface water. Studies have indicated that the Marcellus Shale is more radioactive than other shale formations. Measurements of radium in fracking wastewater in New York and Pennsylvania have been as high as 3,600 times the United States Environmental Protection Agency's (EPA) limit for drinking water. One recent study found toxic levels of radiation in a Pennsylvania waterway even after fracking wastewater was disposed of through an industrial wastewater treatment plant. In addition, the disposal of radioactive drill cuttings is a concern. Unsafe levels of radon and its decay products in natural gas produced from the Marcellus Shale, known to have particularly high radon content, may also contaminate pipelines and compressor stations, as well as pose risks to end-users when allowed to travel into homes.

- **Occupational health and safety hazards** – Fracking jobs are dangerous jobs. Occupational hazards include head injuries, traffic accidents, blunt trauma, burns, toxic chemical exposures, heat exhaustion, dehydration, and sleep deprivation. As a group, oil and gas industry workers have an on-the-job fatality rate that is 2.5 times higher than the construction industry and seven times that of general industry. A new investigation of occupational exposures found high levels of benzene in the urine of workers on the wellpad, especially those in close proximity to flowback fluid. Exposure to silica dust, which is definitively linked to silicosis and lung cancer, was singled out by National Institutes for Occupational Safety and Health as a particular threat to workers in fracking operations where silica sand is used. At the same time, research shows that many gas field workers, despite these serious occupational hazards, are uninsured or underinsured and lack access to basic medical care.

- **Public health effects, measured directly** – In Pennsylvania, as the number of gas wells increases in a community so to do rates of hospitalization. Drilling and fracking operations are correlated with elevated motor vehicle fatalities (Texas), self-reported skin and respiratory problems (southwestern Pennsylvania), ambulance runs and emergency room visits (North Dakota), infant deaths (Utah), birth defects (Colorado), and low birthweight (multiple states). Benzene levels in ambient air surrounding drilling and

fracking operations are sufficient to elevate risks for future cancers in both workers and nearby residents, according to new studies.

- **Noise pollution, light pollution and stress –** Drilling and fracking operations and ancillary infrastructure expose workers and nearby residents to continuous noise and light pollution that is sustained for periods lasting many months. Chronic exposure to light at night is linked to adverse health effects, including breast cancer. Sources of fracking-related noise pollution include blasting, drilling, flaring, generators, compressor stations and truck traffic. Exposure to environmental noise pollution is linked to cardiovascular disease, cognitive impairment, and sleep disturbance. Workers and residents whose homes, schools and workplaces are in close proximity to well sites are at risk from these exposures as well as from related stressors. A UK Health Impact Assessment identified stress and anxiety resulting from drilling-related noise—as well as from a sense of uncertainty about the future and eroded public trust—as key public health risks related to fracking operations.

- **Earthquake and seismic activity** – A growing body of evidence, from Ohio, Arkansas, Texas, Oklahoma and Colorado, links fracking wastewater injection (disposal) wells to earthquakes of magnitudes as high as 5.7, in addition to "swarms" of minor earthquakes and fault slipping. Many recent studies focus on the mechanical ability of pressurized fluids to trigger seismic activity. In some cases, the fracking process itself has been linked to earthquakes and seismic activity, including instances in which gas corporations have acknowledged the connection. In New York, this issue is of particular concern to New York City's aqueduct-dependent drinking water supply and watershed infrastructure, as the New York City Department of Environmental Protection (NYC DEP) has warned repeatedly, but similar concerns apply to all drinking water resources. The question of what to do with wastewater remains a problem with no viable, safe solution.

- **Abandoned and active oil and natural gas wells (as pathways for gas and fluid migration)** – Millions of abandoned and undocumented oil and gas wells exist across the United States, according to the U.S. Department of Energy. All serve as potential pathways for pollution, heightening the risks of groundwater contamination and other problems when horizontal drilling and fracking operations intersect with pre-existing vertical channels leading through drinking water aquifers and to the atmosphere. New research from Pennsylvania shows that, cumulatively, abandoned wells are a significant source of methane into the atmosphere and may exceed cumulative total leakage from oil and gas wells currently in production. No state or federal agency routinely monitors methane leakage from orphaned and abandoned wells. Industry experts, consultants and government agencies including the U.S. Environmental Protection Agency, the U.S. General Accounting Office (now the Government Accountability Office), Texas Department of Agriculture, New York State Department of Environmental Conservation, Pennsylvania Department of Environmental Protection, Illinois Environmental Protection Agency and the British Columbia Oil and Gas Commission have all warned about problems with abandoned wells due to the potential for pressurized fluids and gases to

migrate through inactive and in some cases, active wells.

- **Flood risks –** Massive land clearing and forest fragmentation that necessarily accompany well site preparation increase erosion and risks for catastrophic flooding, as do access roads, pipeline easements and other related infrastructure. In addition, in some cases, operators choose to site well pads on flood-prone areas in order to have easy access to water for fracking, to abide by setback requirements intended to keep well pads away from inhabited buildings, or to avoid productive agricultural areas. In turn, flooding increases the dangers of unconventional gas extraction, resulting in the contamination of soils and water supplies, the overflow or breaching of containment ponds, and the escape of chemicals and hazardous materials. In at least six of the past ten years, New York State has experienced serious flooding in parts of the state targeted for drilling and fracking. Some of these areas have been hit with "100-year floods" in five or more of the past ten years. Gas companies acknowledge threats posed by flooding, and the New York State Department of Environmental Conservation (DEC) has recommended drilling be prohibited from 100-year flood areas; however, accelerating rates of extreme weather events make existing flood maps obsolete, making this approach insufficiently protective.

- **Threats to agriculture and soil quality –** Drilling and fracking pose risks to the agricultural industry. In California, fracking wastewater illegally dumped into aquifers has threatened crucial irrigation supplies to farmers in a time of severe drought. Studies and case reports from across the country have highlighted instances of deaths, neurological disorders, aborted pregnancies, and stillbirths in cattle and goats associated with livestock coming into contact with wastewater. Potential water and air contamination puts soil quality as well as livestock health at risk. Additionally, farmers have expressed concern that nearby fracking operations can hurt the perception of agricultural quality and nullify value-added organic certification.

- **Threats to the climate system –** A range of studies has shown high levels of methane leaks from gas drilling and fracking operations, undermining the notion that natural gas is a climate solution or a transition fuel. Major studies have concluded that early work by the EPA greatly underestimated the impacts of methane and natural gas drilling on the climate. Drilling, fracking and expanded use of natural gas threaten not only to exacerbate climate change but also to stifle investments in, and expansion of, renewable energy.

- **Inaccurate jobs claims, increased crime rates, threats to property value and mortgages and local government burden** – Experiences in various states and accompanying studies have shown that the oil and gas industry's promises for job creation from drilling for natural gas have been greatly exaggerated and that many of the jobs are short-lived and/or have gone to out-of-area workers. With the arrival of drilling and fracking operations, communities have experienced steep increases in rates of crime – including sex trafficking, sexual assault, drunk driving, drug abuse, and violent victimization, all of which carry public health consequences, especially for women. Social costs include strain on law enforcement, municipal services and road damage. Economic analyses have found that drilling and fracking operations threaten property

values and can diminish tax revenues for local governments. Additionally, gas drilling and fracking pose an inherent conflict with mortgages and property insurance due to the hazardous materials used and the associated risks.

- **Inflated estimates of oil and gas reserves and profitability** – Industry estimates of oil and gas reserves and profitability of drilling have proven unreliable, casting serious doubts on the bright economic prospects the industry has painted for the public, media and investors. Increasingly, well production has been short-lived, which has led companies drilling shale to reduce the value of their assets by billions of dollars, creating shortfalls that are largely filled through asset sales and increasing debt load, according to a recent analysis by the US Energy Information Administration.

- **Disclosure of serious risks to investors** – Oil and gas companies are required to disclose risks to their investors in an annual Form 10-K. Those disclosures acknowledge the inherent dangers posed by gas drilling and fracking operations, including leaks, spills, explosions, blowouts, environmental damage, property damage, injury and death. Adequate protections have not kept pace with these documented dangers and inherent risks.

- **Medical and scientific calls for more study and more transparency** – With increasing urgency, groups of medical professionals and scientists are issuing calls for comprehensive, long-term study of the full range of the potential health and ecosystem effects of drilling and fracking. These appeals underscore the accumulating evidence of harm, point to the major knowledge gaps that remain, and denounce the atmosphere of secrecy and intimidation that continues to impede the progress of scientific inquiry. Health professionals and scientists in the United States and around the world have urged tighter regulation of and in some cases, suspension of unconventional gas and oil extraction activities in order to limit, mitigate or eliminate its serious, adverse public health hazards.

Compilation of Studies & Findings

Air pollution

- November 20, 2014 – The Texas Commission on Environmental Quality (TECQ) confirmed high levels of benzene emissions and other volatile organic compounds around an oil and gas facility in the Eagle Ford Shale. Symptoms reported by local residents were consistent with those known to be associated with exposure to such chemicals.[3]

[3] Davis, Barry. (2014, November 20). TCEQ memo proves toxic chemicals are being released in the Eagle Ford Shale. KENS 5 Eyewitness News. Retrieved Nov. 25, 2014 from http://www.kens5.com/story/news/investigations/i-team/2014/11/20/benzene-oil-toxic-fumes/70020596/.

- November 14, 2014 – A University of Colorado at Boulder research team found that residential areas in intensely drilled northeastern Colorado have high levels of fracking-related air pollutants, including benzene. In some cases, concentrations exceed those found in large urban centers and are within the range of exposures known to be linked to chronic health effects. According to the study, "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." The study also noted that tighter regulations have not resulted in lower air pollution levels, "Even though the volume of emissions per well may be decreasing, the rapid and continuing increase in the number of wells may potentially negate any real improvements to the air quality situation."[4]

- October 30, 2014 – A research team assembled by University at Albany Institute for Health and the Environment identified eight highly toxic chemicals in air samples collected near fracking and associated infrastructure sites across five states: Arkansas, Colorado, Pennsylvania, Ohio, and Wyoming. The most common airborne chemicals detected included two proven human carcinogens (benzene and formaldehyde) and two potent neurotoxicants (hexane and hydrogen sulfide). In 29 out of 76 samples, concentrations far exceeded federal health and safety standards, sometimes by several orders of magnitude. Further, high levels of pollutants were detected at distances exceeding legal setback distances from wellheads to homes. Highly elevated levels of formaldehyde, for example, were found up to a half-mile from a wellhead. In Arkansas, seven air samples contained formaldehyde at levels up to 60 times the level known to raise the risk for cancer.[5] "This is a significant public health risk," said lead author David O. Carpenter, MD, in an accompanying interview, "Cancer has a long latency, so you're not seeing an elevation in cancer in these communities. But five, 10, 15 years from now, elevation in cancer is almost certain to happen."[6]

- October 21, 2014 – Responding to health concerns by local residents, a research team from University of Cincinnati and Oregon State University found high levels of air pollution in heavily drilled areas of rural Carroll County, Ohio. Air monitors showed 32 different hydrocarbon-based air pollutants, including the carcinogens naphthalene and benzo[a]pyrene.[7] The researchers plan additional monitoring and analysis.

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[4] Thompson C.R., Hueber J., Helmig D. (2014). Influence of oil and gas emissions on ambient atmospheric non-methane hydrocarbons in residential areas of Northeastern Colorado. *Elementa: Science of the Anthropocene*, *2*. doi: 10.12952/journal.elementa.000035

[5] Macey, G.P., Breech, R., Chernaik, M., Cox, C., Larson, D., Thomas, D., Carpenter, D.O. (2014). Air concentrations of volatile compounds near oil and gas production: a community-based exploratory study. *Environmental Health*, *13*(82). doi: 10.1186/1476-069X-13-82

[6] Neuhauser, A. (2014, October 30). Toxic chemicals, carcinogens skyrocket near fracking sites. *U.S. News and World Report*. Retrieved from http://www.usnews.com/news/articles/2014/10/30/toxic-chemicals-and-carcinogens-skyrocket-near-fracking-sites-study-says

[7] Environmental Health Sciences Center, Oregon State University. (2014). List of 62 PAH analyzed in Carroll County, OH. Retrieved November 15, 2014 from http://ehsc.oregonstate.edu/air/62PAH

- October 21, 2014 – Using a mobile laboratory designed by the National Oceanic and Atmospheric Administration, a research team from the University of Colorado at Boulder, the NOAA Earth System Research Laboratory, and the Karlsruhe Institute of Technology looked at air pollution from drilling and fracking operations in Utah's Uintah Basin. The researchers found that drilling and fracking emit prodigious amounts of volatile organic air pollutants, including benzene, toluene, and methane, all of which are precursors for ground-level ozone (smog). Multiple pieces of equipment on and off the well pad, including condensate tanks, compressors, dehydrators, and pumps, served as the sources of these emissions. This research shows that drilling and fracking activities are the cause of the extraordinarily high levels of winter smog in the remote Uintah basin—which regularly exceed air quality standards and rival that of downtown Los Angeles.[8]

- October 2, 2014. – A joint investigation by InsideClimate News and the Center for Public Integrity found that toxic air emissions wafting from fracking waste pits in Texas are unmonitored and unregulated due to federal exemptions that classify oil and gas field waste as non-hazardous.[9]

- October 1, 2014 – In a major paper published in *Nature*, an international team led by the National Oceanic and Atmospheric Administration demonstrated that exceptionally high emissions of volatile organic compounds (VOCs) explain how drilling and fracking operations in Utah's Uintah Basin create extreme wintertime ozone events even in the absence of abundant ultraviolet light and water vapor, which are typically required to produce ground-level ozone (smog). Current air pollution trends in the United States are toward lower nitrogen oxides from urban sources and power generation, but increasing methane and VOCs from oil and gas extraction activities threaten to reverse decades of progress in attaining cleaner air. According to the study, the consequences for public health are "as yet unrecognized."[10]

- September 6, 2014 – As part of a comparative lifecycle analysis, a British team from the University of Manchester found that of shale gas extracted via fracking in the United Kingdom would generate more smog than any other energy source evaluated (coal, conventional and liquefied gas, nuclear, wind, and solar). Leakage of vaporous organic compounds during the necessary removal of hydrogen sulfide gas, along with the venting

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[8] Warneke, C., Geiger, F., Edwards, P. M., Dube, W., Pétron, G., Kofler, J., Zahn, A., Brown, S. S., Graus, M., Gilman, J. B., Lerner, B. M., Peischl, J., Ryerson, T. B., de Gouw, J. A., and Roberts, J. M. (2014). Volatile organic compound emissions from the oil and natural gas industry in the Uintah Basin, Utah: oil and gas well pad emissions compared to ambient air composition. *Atmospheric Chemistry and Physics, 14*, 10977-10988. doi:10.5194/acp-14-10977-2014

[9] Hasemyer, D. and Hirji, Z. (2014, October 2). Open piles offer cheap disposal for fracking sludge, but health worries mount. InsideClimate News and the Center for Public Integrity. Retrieved on November 15, 2014 from http://www.publicintegrity.org/2014/10/02/15826/open-pits-offer-cheap-disposal-fracking-sludge-health-worries-mount

[10] Edwards, P. M., Brown, S. S., Roberts, J. M., Ahmadov, R., Banta, R. M., deGouw, J. A., . . Zamora, R. (2014). High winter ozone pollution from carbonyl photolysis in an oil and gas basin. *Nature, 514*(7522), 351-354. doi: 10.1038/nature13767

of gas both during drilling and during the process of making the well ready for production, were major contributors. "In comparison to other technologies, shale gas has high [photochemical smog]. In the central case, it is worse than solar PV, offshore wind and nuclear power by factors of 3, 26 and 45, respectively. Even in the best case, wind and nuclear power are still preferable (by factors of 3.3 and 5.6 respectively)."[11]

- September 2014 – ShaleTest Environmental Testing conducted ambient air quality tests and gas-finder infra-red video for several children's play areas in North Texas that are located in close proximity to shale gas development. The results showed a large number of compounds detected above the Method Reporting Limit (the minimum quantity of the compound that can be confidently determined by the laboratory). Air sampling found three known/suspected carcinogens, and a number of other compounds associated with significant health effects. Benzene results from Denton, Dish, and Fort Worth are particularly alarming since they exceeded the long-term ambient air limits set by the Texas Commission on Environmental Quality, and benzene is a known carcinogen. "Benzene was found at all but one sampling location …. This is particularly noteworthy as benzene is a known carcinogen (based on evidence from studies in both people and lab animals), AND because it exceeds both the TCEQ ESL and AMCV."[12]

- August 24, 2014 – A *Salt Lake City Tribune* investigation found that evaporation from 14 fracking waste pits in western Colorado has added tons of toxic chemicals to Utah's air in the last six years. Further, the company responsible operated with no permit, underreported its emissions and provided faulty data to regulators.[13]

- August, 2014 – A four-part investigation by the *San Antonio Express-News* found that natural gas flaring in the Eagle Ford Shale in 2012 contributed more than 15,000 tons of volatile organic compounds and other contaminants to the air of southern Texas—which is roughly equivalent to the pollution that would be released annually by six oil refineries. No state or federal agency is tracking the emissions from individual flares.[14]

- June 26, 2014 – Public health professionals at the Southwest Pennsylvania Environmental Health Project reported significant recurrent spikes in the amount of particulate matter in the air inside of residential homes located near drilling and fracking operations. Captured by indoor air monitors, the spikes tend to occur at night when stable atmospheric conditions hold particulate matter low to the ground. Director Raina Ripple emphasized that spikes in airborne particulate matter are likely to cause acute health impacts in

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[11] Stamford, L. and Azapagic, A. (2014). Life cycle environmental impacts of UK shale gas. *Applied Energy* 134, 506-518. doi:10.1016/j.apenergy.2014.08.063

[12] ShaleTest Environmental Testing. (2014, September). Project playground: Cleaner air for active kids. Retrieved from http://www.shaletest.org/wp-content/uploads/2014/09/ProjectPlaygoundPatagoniaReport-5-1.pdf

[13] Maffly, B. (2014, August 24). Utah grapples with toxic water from oil and gas industry. *Salt Lake City Tribune*. Retrieved on November 15, 2014 from http://www.sltrib.com/sltrib/news/58298470-78/danish-flats-ponds-company.html

[14] Hiller, J. and Tedesco, J. (2014, August). Up in flames: Flare in Eagle Ford Shale wasting natural gas. *San Antonio Express News.* Retrieved from: http://www.expressnews.com/business/eagleford/item/Up-in-Flames-Day-1-Flares-in-Eagle-Ford-Shale-32626.php

community members. She added, "What the long-term effects are going to be, we're not certain." At this writing, researchers from Yale University and the University of Washington are working to collect and analyze more samples.[15]

- May 8, 2014 – Researchers at the National Oceanic and Atmospheric Administration (NOAA) found high levels of methane leaks as well as benzene and smog-forming volatile organic compounds in the air over oil and gas drilling areas in Colorado. Researchers found methane emissions three times higher than previously estimated and benzene and volatile organic compound levels seven times higher than estimated by government agencies. *The Denver Post* noted that Colorado's Front Range has failed to meet federal ozone air quality standards for years.[16]

- April 26, 2014 – A Texas jury awarded a family $2.8 million because, according to the lawsuit, a fracking company operating on property nearby had "created a 'private nuisance' by producing harmful air pollution and exposing [members of the affected family] to harmful emissions of volatile organic compounds, toxic air pollutants and diesel exhaust." The family's 11-year-old daughter became ill, and family members suffered a range of symptoms, including "nosebleeds, vision problems, nausea, rashes, blood pressure issues."[17] Because drilling did not occur on their property, the family had initially been unaware that their symptoms were caused by activities around them.

- April 16, 2014 – Reviewing the peer-review literature to date of "direct pertinence to the environmental public health and environmental exposure pathways," a U.S. team of researchers concluded: "[a] number of studies suggest that shale gas development contributes to levels of ambient air concentrations known to be associated with increased risk of morbidity and mortality."[18]

  April 11, 2014 – A modeling study commissioned by the state of Texas made striking projections about worsening air quality in the Eagle Ford Shale. Findings included the possibility of a 281 percent increase in emissions of volatile organic compounds (VOCs). Some VOCs cause respiratory and neurological problems; others, like benzene, are also carcinogens. Another finding was that nitrogen oxides—which react with VOCs in sunlight to create ground-level ozone, the main component of smog—increased 69 percent during the peak ozone season."[19]

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[15] McMahon, J. (2014, June 26). Air pollution spikes in homes near fracking wells. *Forbes*. Retrieved July 4, 2014, from http://www.forbes.com/sites/jeffmcmahon/2014/06/26/air-pollution-spikes-in-homes-near-fracking-wells/

[16] Finley, B. (2014, May 8). Scientists flying over Colorado oil boom find worse air pollution. *The Denver Post*. Retrieved June 10, 2014, from http://www.denverpost.com/environment/ci_25719742/scientists-flying-over-colorado-oil-boom-find-worse

[17] Morris, J. (2014, April 26). Texas family plagued with ailments gets $3M in 1st-of-its-kind fracking judgment. *CNN*. Retrieved June 10, 2014, from http://www.cnn.com/2014/04/25/justice/texas-family-wins-fracking-lawsuit/

[18] Shonkoff, S. B., Hays, J., & Finkel, M. L. (2014). Environmental public health dimensions of shale and tight gas development. *Environmental Health Perspectives*, *122*, 787–795. doi: 10.1289/ehp.1307866

[19] Morris, J., Song, L., & Hasemayer, D. (2014, April 11). Report: Air quality to worsen in Eagle Ford shale. *The Texas Tribune*. Retrieved June 10, 2014, from http://www.texastribune.org/2014/04/11/report-air-quality-worsen-eagle-ford-shale/

- March 29, 2014 – Scientists warn that current methods of collecting and analyzing emissions data do not accurately assess health risks. Researchers with the Southwest Pennsylvania Environmental Health Project showed that methods do not adequately measure the intensity, frequency or durations of community exposure to the toxic chemicals routinely released from drilling and fracking activities. They found that exposures may be underestimated by an order of magnitude, mixtures of chemicals are not taken into account, and local weather conditions and vulnerable populations are ignored.[20]

- March 27, 2014 – University of Texas research pointed to "potentially false assurances" in response to community health concerns in shale gas development areas. Dramatic shortcomings in air pollution monitoring to date include no accounting for cumulative toxic emissions or children's exposures during critical developmental stages, and the potential interactive effects of mixtures of chemicals. Chemical mixtures of concern include benzene, toluene, ethylbenzene, and xylenes.[21] [22]

- March 13, 2014 – Volatile organic compounds (VOCs) emitted in Utah's heavily drilled Uintah Basin led to 39 winter days exceeding the EPA's eight-hour National Ambient Air Quality Standards level for ozone pollutants the previous winter. "Levels above this threshold are considered to be harmful to human health, and high levels of ozone are known to cause respiratory distress and be responsible for an estimated 5,000 premature deaths in the U.S. per year," according to researchers at the University of Colorado. Their 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."[23] Researchers estimated that total annual VOC emissions at the fracking sites are equivalent to those of about 100 million cars.[24]

- March 3, 2014 – In a report summarizing "the current understanding of local and regional air quality impacts of natural gas extraction, production, and use," a group of researchers from the NOAA, Stanford, Duke, and other institutions described what is known and unknown with regard to air emissions including greenhouse gases, ozone precursors (volatile organic compounds and nitrogen oxides), air toxics, and particulates. Crystalline

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[20] Brown, D., Weinberger, B., Lewis, C., & Bonaparte, H. (2014). Understanding exposure from natural gas drilling puts current air standards to the test. *Reviews on Environmental Health, 0*(0). doi: 10.1515/reveh-2014-0002

[21] Rawlins, R. (2013). Planning for fracking on the Barnett shale: Urban air pollution, improving health based regulation, and the role of local governments. *Virginia Environmental Law Journal, 31*, 226-306. Retrieved June 10, 2014, from http://www.velj.org/uploads/1/2/7/0/12706894/2._rawlins_-_barnett_shale.pdf

[22] University of Texas at Austin. (2014, March 27). Air pollution and hydraulic fracturing: Better monitoring, planning and tracking of health effects needed in Texas. Retrieved June 10, 2014, from http://www.utexas.edu/news/2014/03/27/hydraulic-fracturing-texas/

[23] Helmig, D., Thompson, C. R., Evans, J., Boylan, P., Hueber, J., & Park, J. (2014). Highly elevated atmospheric levels of volatile organic compounds in the Uintah Basin, Utah [Abstract]. *Environmental Science & Technology, 48*(9), 4707-4715. doi: 10.1021/es405046r

[24] Lockwood, D. (2014, March 25). Harmful air pollutants build up near oil and gas fields. *Chemical & Engineering News.* Retrieved June 10, 2014, from http://cen.acs.org/articles/92/web/2014/03/Harmful-Air-Pollutants-Build-Near.html

silica was also discussed, including as a concern for people living near well pads and production staging areas.[25]

- February 18, 2014 – An eight-month investigation by the *Weather Channel*, *Center for Public Integrity* and *InsideClimate News* into fracking in the Eagle Ford Shale in Texas revealed that fracking is "releasing a toxic soup of chemicals into the air." They noted very poor monitoring by the state of Texas and reported on hundreds of air complaints filed relating to air pollution associated with fracking.[26]

- December 18, 2013 – An interdisciplinary group of researchers in Texas collected air samples in residential areas near shale gas extraction and production, going beyond previous Barnett Shale studies by including emissions from the whole range of production equipment. They found that most areas had "atmospheric methane concentrations considerably higher than reported urban background concentrations," and many toxic chemicals were "strongly associated" with compressor stations.[27]

- December 10, 2013 – Health department testing at fracking sites in West Virginia revealed dangerous levels of benzene in the air. Wheeling-Ohio County Health Department Administrator Howard Gamble stated, "The levels of benzene really pop out. The amounts they were seeing were at levels of concern. The concerns of the public are validated."[28]

- October 11, 2013 – Air sampling before, during, and after drilling and fracking of a new natural gas well pad in rural western Colorado documented the presence of the toxic solvent methylene chloride, along with several polycyclic aromatic hydrocarbons (PAHs) at "concentrations greater than those at which prenatally exposed children in urban studies had lower developmental and IQ scores."[29]

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[25] Moore, C. W., Zielinska, B., Petron, G., & Jackson, R. B. (2014). Air impacts of increased natural gas acquisition, processing, and use: A critical review. *Environmental Science & Technology*. doi: 10.1021/es4053472

[26] Morris, J., Song, L., & Hasemayer, D. (2014, February 18). Fracking the Eagle Ford Shale. *The Weather Channel*. Retrieved June 10, 2014, from http://stories.weather.com/fracking

[27] Rich, A., Grover, J. P., & Sattler, M. L. (2014). An exploratory study of air emissions associated with shale gas development and production in the Barnett Shale. *Journal of the Air & Waste Management Association, 64*(1), 61-72. doi: 10.1080/10962247.2013.832713

[28] Junkins, C. (2013, December 10). Health dept. concerned about benzene emissions near local gas drilling sites. *The Intelligencer, Wheeling News-Register*. Retrieved June 10, 2014, from http://www.theintelligencer.net/page/content.detail/id/593209/Health-Dept--Concerned-About-Benzene-Emissions-Near-Local-Gas-Drilling-Sites.html?nav=510

[29] Colborn, T., Schultz, K., Herrick, L., & Kwiatkowski, C. (2014). An exploratory study of air quality near natural gas operations. *Human and Ecological Risk Assessment: An International Journal, 20*(1), 86-105. doi: 10.1080/10807039.2012.749447

- September 19, 2013 – In Texas, air monitoring data in the Eagle Ford Shale area revealed potentially dangerous exposures of nearby residents to hazardous air pollutants, including cancer-causing benzene and the neurological toxicant, hydrogen sulfide.[30]

- September 13, 2013 – A study by researchers at the University of California at Irvine found dangerous levels of volatile organic compounds in Canada's "Industrial Heartland" where there are more than 40 oil, gas and chemical facilities. The researchers noted high levels of hematopoietic cancers (leukemia and non-Hodgkin's lymphoma) in men who live closer to the facilities.[31]

- April 29, 2013 – Using American Lung Association data, researchers with the Environmental Defense Fund determined that air quality in rural areas with fracking was worse than air quality in urban areas.[32]

- March, 2013 – A review of regional air quality damages in parts of Pennsylvania in 2012 from Marcellus Shale development found that air pollution was a significant concern, with regional damages ranging from $7.2 to $32 million dollars in 2011.[33]

- February 27, 2013 – In a letter from Concerned Health Professionals of New York to Governor Andrew Cuomo, a coalition of hundreds of health organizations, scientists, medical experts, elected officials and environmental organizations noted serious health concerns about the prospects of fracking in New York State, making specific note of air pollution.[34] Signatory organizations included the American Academy of Pediatrics of New York, the American Lung Association of New York and Physicians for Social Responsibility. The New York State Medical Society, representing 30,000 medical professionals, has issued similar statements.[35]

- January 2, 2013 – A NOAA study identified emissions from oil and gas fields in Utah as a significant source of pollutants that contribute to ozone problems.[36] Exposure to

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[30] Wilson, S., Sumi, L., & Subra, W. (2013, September 19). Reckless endangerment while fracking the Eagle Ford shale. *Earthworks*. Retrieved June 10, 2014, from http://www.earthworksaction.org/library/detail/reckless_endangerment_in_the_eagle_ford_shale#.UkGi-4Y3uSo.

[31] Blake, D. R. Air quality in the Industrial Heartland of Alberta, Canada and potential impacts on human health. *Atmospheric Environment*, 702-709. Retrieved June 16, 2014, from http://concernedhealthny.org/wp-content/uploads/2013/07/Simpson2013-AE-in-press.pdf

[32] Grossman, D. (2013, April 29). Clean air report card: CO, WY Counties get F's due to oil and gas pollution. *Environmental Defense Fund*. Retrieved June 10, 2014, from http://blogs.edf.org/energyexchange/2013/04/29/clean-air-report-card-co-wy-counties-get-fs-due-to-oil-and-gas-pollution/#sthash.FXRV6Nxi.dpuf

[33] Litovitz, A., Curtright, A., Abramzon, S., Burger, N., & Samaras, C. (2013). Estimation of regional air-quality damages from Marcellus Shale natural gas extraction in Pennsylvania. *Environmental Research Letters, 8*(1). doi: 10.1088/1748-9326/8/1/014017

[34] Concerned Health Professionals of NY. (2013, February 27). Letter to Governor Cuomo. Retrieved June 10, 2014, from http://concernedhealthny.org/letters-to-governor-cuomo/

[35] Campbell, J. (2013, April 17). Fracking roundup: Gas prices up; Medical society wants moratorium. *Politics on the Hudson*. Retrieved June 10, 2014, from http://polhudson.lohudblogs.com/2013/04/17/fracking-roundup-gas-prices-up-medical-society-wants-moratorium/

[36] Tollefson, J. (2013). Methane leaks erode green credentials of natural gas. *Nature, 493*(7430), 12-12. doi: 10.1038/493012a

elevated levels of ground-level ozone is known to worsen asthma and has been linked to respiratory illnesses and increased risk of stroke and heart attack.[37]

- December 3, 2012 – A study linked a single well pad in Colorado to more than 50 airborne chemicals, 44 of which have known health effects.[38]

- July 18, 2012 – A study by the Houston Advanced Research Center modeled ozone formation from a natural gas processing facility using accepted emissions estimates and showed that regular operations could significantly raise levels of ground-level ozone (smog) in the Barnett Shale in Texas and that gas flaring further contributed to ozone levels.[39]

- March 19, 2012 – A Colorado School of Public Health study found air pollutants near fracking sites linked to neurological and respiratory problems and cancer.[40] [41] The study, based on three years of monitoring at Colorado sites, found a number of "potentially toxic petroleum hydrocarbons in the air near gas wells including benzene, ethylbenzene, toluene and xylene." Lisa McKenzie, PhD, MPH, lead author of the study and research associate at the Colorado School of Public Health, said, "Our data show that it is important to include air pollution in the national dialogue on natural gas development that has focused largely on water exposures to hydraulic fracturing."[42]

- December 12, 2011 – Cancer specialists, cancer advocacy organizations, and health organizations summarized the cancer risks posed by all stages of the shale gas extraction process in a letter to New York Governor Andrew Cuomo.[43]

- October 5, 2011 – More than 250 medical experts and health organizations reviewed the multiple health risks from fracking in a letter sent to New York Governor Andrew Cuomo.[44]

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[37] American Lung Association. (2013). American Lung Association state of the air 2013 - Ozone pollution. Retrieved June 10, 2014, from http://www.stateoftheair.org/2013/health-risks/health-risks-ozone.html

[38] Song, L. (2012, December 3). Hazardous air pollutants detected near fracking sites. *Bloomberg*. Retrieved June 10, 2014, from http://www.bloomberg.com/news/2012-12-03/hazardous-air-pollutants-detected-near-fracking-sites.html

[39] Olaguer, E. P. (2012). The potential near-source ozone impacts of upstream oil and gas industry emissions. *Journal of the Air & Waste Management Association, 62*(8), 966-977. doi: 10.1080/10962247.2012.688923

[40] Kelly, D. (2012, March 19). Study shows air emissions near fracking sites may pose health risk. *University of Colorado Denver*. Retrieved June 10, 2014, from http://www.ucdenver.edu/about/newsroom/newsreleases/Pages/health-impacts-of-fracking-emissions.aspx

[41] McKenzie, L. M., Witter, R. Z., Newman, L. S., & Adgate, J. L. (2012). Human health risk assessment of air emissions from development of unconventional natural gas resources. *Science of the Total Environment, 424*, 79-87. doi: 10.1016/j.scitotenv.2012.02.018

[42] Banerjee, N. (2012, March 20). Study: 'Fracking' may increase air pollution health risks. *Los Angeles Times*. Retrieved June 11, 2014, from http://articles.latimes.com/2012/mar/20/local/la-me-gs-fracking-increases-air-pollution-health-risks-to-residents-20120320

[43] Physicians, Scientists & Engineers for Healthy Energy. (2011, December 12). Appeal to Gov. Cuomo to consider cancer risks re: High volume hydraulic fracturing for natural gas [Letter to A. Cuomo].

[44] Physicians, Scientists & Engineers for Healthy Energy. (2011, October 5). Letter to Governor Cuomo [Letter to A. Cuomo].

- April 21, 2011 – *Environment & Energy (E&E)* reported that ozone levels exceeding federal health standards in Utah's Uintah Basin, as well as wintertime ozone problems in other parts of the Intermountain West, stem from oil and gas extraction. Levels reached nearly twice the federal standard, potentially dangerous even for healthy adults to breathe. Keith Guille, spokesman for the Wyoming Department of Environmental Quality, said, "We recognize that definitely the main contributor to the emissions that are out there is the oil and gas industry…."[45]

- March 8, 2011 – The Associated Press reported that gas drilling in some remote areas of Wyoming caused a decline of air quality from pristine mountain air to levels of smog and pollution worse than Los Angeles on its worst days, resulting in residents complaining of watery eyes, shortness of breath and bloody noses.[46]

- November 18, 2010 – A study of air quality in the Haynesville Shale region of east Texas, northern Louisiana, and southwestern Arkansas found that shale oil and gas extraction activities contributed significantly to ground-level ozone (smog) via high emissions of ozone precursors, including volatile organic compounds and nitrogen oxides.[47] Ozone is a key risk factor for asthma and other respiratory and cardiovascular illnesses.[48] [49] [50] [51]

- September, 2010 – A health assessment by the Colorado School of Public Health for gas development in Garfield County, Colorado determined that air pollution will likely "be high enough to cause short-term and long-term disease, especially for residents living

[45] Streater, S. (2011, April 21). Air pollution: Winter ozone problem continues to mystify regulators, industry. *E&E Publishing, LLC*. Retrieved June 11, 2014, from http://www.eenews.net/stories/1059948108

[46] Gruver, M. (2011, March 8). Wyoming is beset by a big-city problem: Smog. *USA Today*. Retrieved June 11, 2014, from http://usatoday30.usatoday.com/money/industries/energy/2011-03-08-natural-gas-ozone-wyoming_N.htm

[47] Kemball-Cook, S., Bar-Ilan, A., Grant, J., Parker, L., Jung, J., Santamaria, W., ... Yarwood, G. (2010). Ozone impacts of natural gas development in the Haynesville Shale. *Environmental Science & Technology, 44*(24), 9357-9363. doi: 10.1021/es1021137

[48] U.S. Environmental Protection Agency. (2013). Integrated science assessment for ozone and related photochemical oxidants. Retrieved June 11, 2014, from http://www.epa.gov/ncea/isa/ozone.htm

[49] Kemball-Cook, S., Bar-Ilan, A., Grant, J., Parker, L., Jung, J., Santamaria, W., ... Yarwood, G. (2010). Ozone impacts of natural gas development in the Haynesville Shale. *Environmental Science & Technology, 44*(24), 9357-9363. doi: 10.1021/es1021137

[50] McKenzie, L. M., Witter, R. Z., Newman, L. S., & Adgate, J. L. (2012). Human health risk assessment of air emissions from development of unconventional natural gas resources. *Science of the Total Environment, 424*, 79-87. doi: 10.1016/j.scitotenv.2012.02.018

[51] Myers, O., Flowers, H., Kang, H., Bedrick, E., Whorton, B., Cui, X., & Stidley, C. A. (2007). The association between ambient air quality ozone levels and medical visits for asthma in San Juan County. New Mexico Department of Health, Environmental Health Epidemiology Bureau Epidemiology and Response Division. Retrieved from http://www.nmenv.state.nm.us/aqb/4C/Documents/SanJuanAsthmaDocBW.pdf

near gas wells. Health effects may include respiratory disease, neurological problems, birth defects and cancer."[52] [53]

- January 27, 2010 – Of 94 drilling sites tested for benzene in air over the Barnett Shale, the Texas Commission on Environmental Quality (TECQ) discovered two well sites emitting what they determined to be "extremely high levels" and another 19 emitting elevated levels.[54]

Water contamination

- November 27, 2014 – An interdisciplinary team of researchers found methane contamination in drinking water wells located in eight areas above the Marcellus Shale in Pennsylvania and the Barnett Shale in Texas, with evidence of declining water quality in the Barnett Shale area. By analyzing noble gases and their isotopes (helium, neon, argon), the investigators were able to isolate the origin of the fugitive methane in drinking water. The results implicate leaks through cement well casings as well as via naturally occurring cracks and fissures in the surrounding rock.[55] In a related editorial, one of the study's authors, Robert Jackson, called on the EPA to re-open its aborted investigation into drinking water contamination in heavily fracked areas of Texas. Jackson also emphasized that methane migration through unseen cracks in the rock surrounding the wellbore "raises the interesting possibility that a drilling company could follow procedures — cementing and casing below the local aquifer — and still create a potential pathway for gas to migrate into drinking water."[56]

- November 3, 2014 – The West Virginia Department of Environmental Protection confirmed that three private drinking water wells were contaminated when Antero Resources mistakenly drilled into one of its own gas wells. Benzene, a human carcinogen, and toluene, a reproductive toxicant, were detected in the drinking water at concentrations four times the legal maximum limit. Additionally, a nearby abandoned gas

[52] Witter, R., McKenzie, L., Towle, M., Stinson, K., Scott, K., Newman, L., & Adgate, J. (2010). Health impact assessment for Battlement Mesa, Garfield County Colorado. *Colorado School of Public Health*. Retrieved June 10, 2014, from http://www.garfield-county.com/public-health/documents/1%20%20%20Complete%20HIA%20without%20Appendix%20D.pdf

[53] Battlement Mesa HIA/EHMS. (2013, November 30). Retrieved June 10, 2014, from http://www.garfield-county.com/environmental-health/battlement-mesa-health-impact-assessment-draft2.aspx

[54] The Associated Press. (2010, January 27). Texas agency finds high benzene levels on Barnett Shale. Retrieved June 10, 2014, from http://www.nola.com/business/index.ssf/2010/01/texas_agency_finds_high_benzen.html

[55] Darrah, T.H., Vengosh, A., Jackson, R.B., Warner, N.R., and Poreda, R.J. (2014). Noble gases identify the mechanisms of fugitive gas contamination in drinking-water wells overlying the Marcellus and Barnett Shales. *Proceedings of the National Academy of Sciences, 111* (39), 14076-14081. doi: 10.1073/pnas.1322107111

[56] Jackson, R. (2014, December 1). Reopen Barnett Shale water probe. *The Texas Tribune*. Retrieved from http://tribtalk.org/2014/12/01/reopen-barnett-shale-water-probe/

well, a drinking water well, and an actively producing gas well were all pressurized as a result of the mishap and began exhibiting "artesian flow."[57]

- October 22, 2014 – A follow-up to the August 2014 Environmental Integrity Project report describes an even greater potential public health threat from a loophole in the Safe Drinking Water Act, wherein companies are allowed to inject other petroleum products (beyond diesel) without a permit, and many of these non-diesel drilling fluids contain even higher concentrations of the same toxins found in diesel. The authors recommend that "EPA should revisit its guidance and broaden the categories of diesel products that require Safe Drinking Water Act permits before they can be injected into oil and gas wells."[58]

- October 20, 2014 – While developing a technique to fingerprint and trace accidental releases of hydraulic fracturing fluids, researchers showed that liquid waste from shale gas fracking operations is chemically different than waste flowing out of conventional wells. The researchers hypothesized that the hydraulic fracturing process itself liberates elements from clay minerals in the shale formations, including boron and lithium, which then enter the liquid waste.[59]

- October 15, 2014 – Four thousand gallons of liquid fracking waste dumped into Waynesburg sewer system was discovered by sewage treatment plant workers in Greene County, Pennsylvania. The Department of Environmental Protection surmised that "someone removed a manhole cover in a remote location and dumped the fluid." The treatment plant discharges into a creek that feeds the Monongahela River, which provides drinking water to more than 800,000 people.[60]

- October 6, 2014 – A state investigation that found no fracking-related water contamination in a drinking water well in Pennsylvania's Washington County was invalidated by testimony presented to the state Environmental Hearing Board. Not all contaminants that were present in the water were reported, and the investigation relied on obsolete testing methods. More sophisticated testing revealed the presence of several chemical contaminants in the well water. The well is located 2,800 feet down gradient

[57] Board, G. (2014, November 3). September drilling accident contaminated water in Doddridge County. *West Virginia Public Broadcasting*. Retrieved from http://wvpublic.org/post/dep-september-drilling-accident-contaminated-water-doddridge-county

[58] Schaeffer, E. and Bernhardt, C. (2014, October 22). Fracking's toxic loophole. The Environmental Integrity Project. Retrieved from http://environmentalintegrity.org/wp-content/uploads/FRACKINGS-TOXIC-LOOPHOLE.pdf

[59] Warner, N.R., Darrah, T.H., Jackson, R.B., Millot, R., Kloppmann, W., and Vengosh, A. (2014). New tracers identify hydraulic fracturing fluids and accidental releases from oil and gas operations. *Environ. Sci. Technol*., *48*(21), 12552–12560. doi: 10.1021/es5032135

[60] Hopey, D. (2014, October 15). Waynesburg officials investigate dumping of fracking wastewater. *Pittsburgh Post-Gazette*. Retrieved from http://powersource.post-gazette.com/news/environment/2014/10/15/Waynesburg-investigates-dumping-of-fracking-wastewater/stories/201410150056

from a drilling site and fracking waste pit where multiple spills and leaks more than four years earlier had contaminated two springs.[61]

- September 23, 2014 – In a two-part audit of records, the U.S. Government Accountability Office (GAO) found that the EPA is failing to protect U.S. drinking water sources from fracking-related activities such as waste disposal via injection wells. Nationwide, 172,000 injection wells accept fracking waste; some are known to have contaminated drinking water. And yet, both short-term and long-term monitoring is lax, and record-keeping varies widely from state to state. The EPA neither mandates nor recommends a fixed list of chemicals for monitoring on the grounds that "injection fluids can vary widely in composition and contain different naturally occurring chemicals and fluids used in oil and gas production depending on the source of the injection fluid."[62] Disposal of oil and gas waste via injection wells is, in fact, subject to regulation under the Safe Drinking Water Act, but, in practice, no one knows exactly what the waste contains, and regulations are deficient. In the United States, at least two billion gallons of fluids are injected into the ground *each day* to enable oil and gas extraction via fracking or to dispose of liquid waste from fracking operations.[63] [64]

- September 18, 2014 – Range Resources was fined a record $4.5 million by the Pennsylvania Department of Environmental Protection for contaminating groundwater. The culprits were six leaking pits in Washington County that each held millions of gallons of fracking wastewater.[65]

- September 12, 2014 – A Pennsylvania State ecosystems scientist, together with U.S. Geological Survey scientists, reviewed the current knowledge of the effects of fracking and its associated operations on terrestrial and aquatic ecosystems in 20 shale plays in the U.S. Findings of species and habitats at highest risk include (in addition to land-based examples) vernal pond inhabitants and stream biota. The research builds on previous reviews identifying "three main potential stressors to surface waters: changes in water quantity (hydrology), sedimentation, and water quality." Researchers determined that there are no published data specifically on the effects of fracking on forest-dwelling amphibians, but "many species breed in vernal ponds which are negatively affected by changes in water quantity and quality and direct disturbance. Many amphibians are also

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[61] Hopey, D. (2014, October 6). Testimony: obsolete tests tainted shale analysis. *Pittsburgh Post-Gazette.* Retrieved from http://powersource.post-gazette.com/powersource/companies-powersource/2014/10/06/Testimony-Obsolete-tests-tainted-shale-analysis/stories/201410060075

[62] U.S. Government Accountability Office. (2014, September 23). Drinking water: characterization of injected fluids associated with oil and gas production. GAO-14-657R. Retrieved from http://www.gao.gov/products/GAO-14-857R.

[63] Sadasivam N. (2014, July 29). Report criticizes EPA oversight of injection wells, *ProPublica* Retrieved from http://www.propublica.org/article/report-criticizes-epa-oversight-of-injection-wells

[64] U.S. Government Accountability Office. (June 27, 2014). EPA program to protect underground sources from injection of fluids associated with oil and gas production needs improvement. GAO-14-555. Retrieved from http://www.gao.gov/products/GAO-14-555

[65] Hopey, D. (2014, September 18). Range resources to pay $4.15M penalty. *Pittsburgh Post-Gazette*. Retrieved from http://www.post-gazette.com/local/2014/09/18/DEP-orders-Range-Resources-to-pay-4-million-fine/stories/201409180293

highly sensitive to road salts." Given that the U.S. EPA recently found 55% of all rivers and streams to be in poor condition, these researchers warned, "Large-scale development of shale resources might increase these percentages." They expressed concern for the native range of brook trout by the cumulative effects of shale development, especially in Pennsylvania.[66]

- September 9, 2014 – A research team from Stanford and Duke Universities discovered that fracking wastewater processed by sewage treatment plants contributes to the formation of carcinogenic chemical byproducts. These raise public health risks when downstream surface water is used for drinking. Even when fracking wastewater was diluted by a factor of 10,000, the bromides and iodides in the waste reacted with organic matter to create highly toxic halogenated compounds—at troublingly high concentrations. These toxic compounds are not filterable by municipal wastewater treatment plants. Halogenated disinfection byproducts in drinking water are linked to both colon and bladder cancers.[67]

- August 29, 2014 – A review of Pennsylvania Department of Environmental Protection files on fracking-related damage to drinking water—which are kept on paper and stored in regional offices—revealed that 243 private water supplies in 22 counties had been contaminated or had lost flow and dried up as a result of nearby drilling and fracking operations in the past seven years. Pollutants included methane, metals, and salts as well as carbon-based compounds (ethylene glycol and 2-butoxyethanol) that are known to be constituents of fracking fluid. As reported by the *Pittsburgh Post-Gazette*, this tally—which came as a response to multiple lawsuits and open-records requests by media sources—was the first time the agency "explicitly linked a drilling operation to the presence of industrial chemicals in drinking water."[68] [69]

- August 13, 2014 – Over the last decade, drilling companies have repeatedly claimed they are no longer using diesel fuel in fracking, although a 2011 investigation by U.S. House Democrats concluded otherwise. The Environmental Integrity Project examined disclosure data submitted to FracFocus and identified at least 351 wells in 12 states that have been fracked over the last four years with one or more of the five prohibited products identified as diesel. EIP researchers also discovered numerous fracking fluids

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[66] Brittingham, M.C., Maloney, K.O., Farag, A.M., Harper, D.D., Bowen, Z.H. (2014). Ecological risks of shale oil and gas development to wildlife, aquatic resources and their habitats. *Environmental Science & Technology*, *48*(19), 11034–11047. doi: dx.doi.org/10.1021/es5020482

[67] Parker, K.M., Zeng, T., Harkness, J., Vengosh, A., and Mitch, W.A. 2014. Enhanced formation of disinfection byproducts in shale gas wastewater-impacted drinking water supplies. *Environ. Sci. Technol.*, *48*(19), 11161–11169. doi: 10.1021/es5028184

[68] Pennsylvania Department of Environmental Protection. (2014 August 29). Water supply determination letters. Retrieved from http://files.dep.state.pa.us/OilGas/BOGM/BOGMPortalFiles/OilGasReports/Determination_Letters/Regional_Determination_Letters.pdf

[69] Legere, L. (2014, September 9). DEP releases updated details on water contamination near drilling sites: some 240 private supplies damaged by drilling in the past 7 years. *Pittsburgh Post-Gazette.* Retrieved from http://powersource.post-gazette.com/powersource/policy-powersource/2014/09/09/DEP-releases-details-on-water-contamination/stories/201409090010

with high diesel content for sale online, including over a dozen products sold by Halliburton and advertised as additives, friction reducers, emulsifiers, etc.[70]

- August 13, 2014 – An international team of researchers found high levels of carbon-based compounds in liquid fracking waste. These impurities can react with chlorine and bromine to create toxic byproducts. This study suggests that chemical treatment of liquid fracking waste will magnify its toxic potency, as will reusing and recycling it.[71]

- August 13, 2014 – A team from Lawrence Berkeley National Laboratory reported that scientific efforts to understand the hazards of fracking continue to be hampered by industry secrecy. A comprehensive examination of the chemical formulations of fracking fluid—whose precise ingredients are protected as proprietary business information—revealed that no publicly available toxicity or physical chemical information was available for one-third of all the fracking chemicals surveyed. Another ten percent of chemicals, including biocides and corrosion inhibitors, were known to be toxic to mammals.[72] [73]

- August 12, 2014 – A Stanford University research team working in the Pavillion gas basin in Wyoming documented that fracking in shallow layers of bedrock, including those that serve as drinking water aquifers, is not uncommon. This finding overturns the industry claim that oil and gas deposits targeted by fracking operations are located at much greater depths than underground drinking water sources and are isolated from them by hundreds of feet of impermeable rock. Because it is exempt from provisions of the Safe Drinking Water Act, fracking in drinking water aquifers is not prohibited by law.[74]

- August 3, 2014 – An investigation by the *Pittsburgh Post-Gazette* found that half of all fracking-related spills that resulted in violations and fines were not discovered by the gas companies themselves, even though Pennsylvania state law requires them to pro-actively seek and report such incidents. The newspaper's analysis of hundreds of thousands of state and company documents showed that self-regulation in the gas fields is a failure.

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[70] Greene, M. (2014, August 13). Fracking beyond the law: Despite industry denials, investigation reveals continued use of diesel in hydraulic fracturing. The Environmental Integrity Project. Retrieved from http://environmentalintegrity.org/wp-content/uploads/Fracking-Beyond-the-Law.pdf

[71] Maguire-Boyle, S.J., and Barron, A.R. (2014). Organic compounds in produced waters from shale gas wells. *Environ. Sci.: Processes Impacts*, *16*, 2237-2248. doi: 10.1039/C4EM00376D

[72] Stringfellow, W.T., Domen, J.K., Carmarillo, M.K., Sandelin, W.L., Tinnacher, R., Jordan, P., Houseworth, J., and Birkholzer, J. (August 13, 2014). Characterizing compounds used in hydraulic fracturing: a necessary step for understanding environmental impacts. Presentation before the American Chemical Society conference, San Francisco. Abstract retrieved from http://abstracts.acs.org/chem/248nm/program/view.php?obj_id=262051&terms=

[73] Robinson, P. (2014, August 19). Fracking fluid survey shows missing information. *Scientific American.* Retrieved from http://www.scientificamerican.com/article/fracking-fluid-survey-shows-missing-information/

[74] Banerjee, N. (2014, August 12). Oil companies fracking into drinking water sources, new research finds. *Los Angeles Times.* Retrieved from http://www.latimes.com/nation/la-na-fracking-groundwater-pavillion-20140811-story.html#page=1

One third of all spills were discovered by state inspectors, while one-sixth were found by residents. Likely, much contamination is entirely undetected and unreported.[75]

- July 21, 2014 – An investigation by the *Columbus Dispatch* showed that Halliburton delayed disclosure to federal and state EPA agencies of the full list of chemicals that spilled into a creek following a fire on a its well pad in Monroe County, Ohio. Although the creek is an important supply of drinking water for downstream communities and the spill precipitated a mass die-off of fish and other aquatic wildlife, five full days passed before EPA officials were provided a full inventory of chemicals used at Halliburton's operation. As a result, the public was denied knowledge of potential chemical exposures.[76]

- July 17, 2014 – A team of environmental scientists, biologists, and engineers, from institutions including the University of Michigan and McGill University, assessed the current state of understanding of the impact fracking and its associated activities have on the ecological health of surface waters. Though various approaches such as geographic information systems and site monitoring provide insights into potential risks to aquatic ecosystems, the authors concluded that inadequate data currently exist. They identified possible outcomes such as, "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."[77]

- July 7, 2014 – California Department of Gas, Oil, and Geothermal Resources ordered seven energy companies to stop injecting liquid fracking waste into aquifers. The ongoing drought that has compelled farmers to supplement irrigation with water drawn from groundwater sources prompted state officials to look at the status of aquifers previously considered too deep for use or too poor in quality. They discovered that at least seven injection wells were very likely pumping liquid fracking waste into protected groundwater supplies rather than aquifers that had been sacrificed for the purpose of waste disposal. Across the United States, more than 1000 aquifers are exempt from any form of pollution protection at all, and many of these are in California, according to a related *ProPublica* investigation.[78]

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[75] Hamill, S.D. (2014, August 3). Drillers did not report half of spills that led to fines. *Pittsburgh Post-Gazette*. Retrieved from http://www.post-gazette.com/news/state/2014/08/03/Drillers-did-not-report-half-of-spills-that-led-to-fines/stories/201408020142

[76] Arenschield, L. (2014, July 21). Halliburton delayed releasing details on fracking chemicals after Monroe County spill. *The Columbus Dispatch*. Retrieved from http://www.dispatch.com/content/stories/local/2014/07/21/details-on-chemicals-trickle-in-after-spill.html

[77] Burton Jr., G.A., Basu, N., Ellis, B.R., Kapo, K.E., Entrekin, S. and Nadelhoffer, K. (2014). Hydraulic "fracking": are surface water impacts an ecological concern? *Environmental Toxicology and Chemistry*, *33*(8), 1679-1689.

[78] Lustgarten, A. (2014, July 18). California halts injects of fracking waste, warning it may be contaminating aquifers. *ProPublica.* Retrieved from http://www.propublica.org/article/ca-halts-injection-fracking-waste-warning-may-be-contaminating-aquifers

- June 25, 2014 – A study by Cornell University researchers found that fracking fluid and fracking wastewater mobilized previously deposited chemical contaminants in soil particles in ways that could potentially exacerbate the impacts of fracking fluid spills or leaks. That research team concluded that, by interfering with the ability of soil to bond to and sequester pollutants such as heavy metals, fracking fluids may release from soils an additional repository of contaminants that could migrate into groundwater.[79]

- June 23, 2014 – Building on earlier findings that water samples collected from sites with confirmed fracking spills in Garfield County, Colorado exhibited moderate to high levels of estrogen and androgen-disrupting activity, a University of Missouri team extended their investigation to other types of hormonal effects. As reported at a joint meeting of the International Society of Endocrinology and the Endocrine Society, their research documented that commonly used fracking chemicals can also block the receptors for thyroid hormone, progesterone, and glucocorticoids (a family of hormones involved in both fertility and immune functioning). Of 24 fracking chemicals tested, all 24 interfered with the activity of one or more important hormone receptors. There is no known safe level of exposure to hormone-disrupting chemicals.[80]

- May 11, 2014 – According to the U.S. Government Accountability Office, the federal government is failing to inspect thousands of oil and gas wells located on public land, including those that pose special risks of water contamination or other environmental damage. An investigation by the Associated Press found that the Bureau of Land Management (BLM) "had failed to conduct inspections on more than 2,100 of the 3,702 wells that it had specified as 'high priority' and drilled from 2009 through 2012. The agency considers a well 'high priority' based on a greater need to protect against possible water contamination and other environmental safety issues."[81]

- May 4, 2012 – A report for the Canadian Government, released under the Access to Information Act, reviewed the process, the regulatory framework globally, the health hazards related to water and air contamination, and evaluated sub-processes for potential impacts, risks, regulations, and summarized the data knowledge and data gaps. Regarding water contamination, the report determined, "Although quantitative data are lacking, the qualitative data available indicate that potential contamination of water related to the shale gas industry may present hazard to the public health, especially for local population." And, "it can be concluded that air emissions related to the shale gas industry present health hazards since the air pollutants originating from the vehicles and engines

[79] Sang, W., Stoof, C., Zhang, W., Morales, V., Gao, B., Kay, R., et al. (2014). Effect of hydrofracking fluid on colloid transport in the unsaturated zone. *Environmental Science & Technology*, *48*(14), 8266–8274. Retrieved from http://pubs.acs.org/doi/abs/10.1021/es501441e

[80] The Endocrine Society (2014). Hormone-disrupting activity of fracking chemicals worse than initially found. *Science Daily*, June 23, 2014 Retrieved from: http://www.sciencedaily.com/releases/2014/06/140623103939.htm?utm_source=feedburner&utm_medium=email&utm_campaign=Feed%3A+sciencedaily%2Ftop_news%2Ftop_health+%28ScienceDaily%3A+Top+Health+News%29

[81] Yen, H. (2014, May 11). Fed govt failed to inspect higher risk oil wells. *Associated Press*. Retrieved June 9, 2014, from http://bigstory.ap.org/article/fed-govt-failed-inspect-higher-risk-oil-wells

fuelled by diesel are toxic to the respiratory and cardiovascular systems and can cause premature mortality, volatile organic compounds have been associated to neurotoxicity and some of these compounds (e.g. benzene) as well as NORMs are known or possible human carcinogens." The report concluded, "Any step of shale gas exploration/exploitation may represent a potential source of drinking water and air contamination; Hydraulic fracturing and wastewater disposal were identified as the main potential sources of risk."[82]

- March 25, 2014 – An industry-funded study of oil and gas well integrity found that more than six percent of wells in a major shale exploration region in Pennsylvania showed evidence of leaking and conceded that this number is likely an underestimate. Researchers concluded that the percentage of wells with some form of well barrier or integrity failure is highly variable and could be as high as 75 percent. A separate analysis in the same study found 85 examples of cement or casing failures in Pennsylvania wells monitored between 2008 and 2011.[83]

- March 7, 2014 – In a comprehensive evaluation, Duke University scientists and colleagues reviewed the state of knowledge on possible effects of shale gas and hydraulic fracturing on water resources in the United States and concluded, "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."[84]

- February 19, 2014 – A Pennsylvania court found a gas corporation guilty of contaminating a woman's drinking water well in Bradford County. Methane levels after fracking were 1,300 to 2,000 times higher than baseline, according to the court brief. Iron levels and turbidity had also increased. The brief stated, "In short, Jacqueline Place lived for ten months deprived totally of the use of her well, and even after its 'restoration,' has been burdened with a water supply with chronic contamination, requiring constant vigilance and ongoing monitoring."[85]

- January 16, 2014 – Data from the Colorado Oil and Gas Commission showed that fracking-related chemical spills in Colorado exceed an average rate of one spill per day.

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[82] Louis, S. (2012, May 4). Potential health hazards from shale gas exploration and exploitation–Drinking water and ambient air. Presented to Health Canada by SANEXEN Environmental Services; 0/Ref.: RA11-410. Document released under the (Canadian) Access to Information Act.

[83] Davies, R. J., Almond, S., Ward, R. S., Jackson, R. B., Adams, C., Worrall, F., ... Whitehead, M. A. (2014). Oil and gas wells and their integrity: Implications for shale and unconventional resource exploitation. *Marine and Petroleum Geology, 56*, 239-254. doi: 10.1016/j.marpetgeo.2014.03.001

[84] Vengosh, A., Jackson, R. B., Warner, N., Darrah, T. H., & Kondash, A. (2014). A critical review of the risks to water resources from unconventional shale gas development and hydraulic fracturing in the United States [Abstract]. *Environmental Science & Technology*. doi: 10.1021/es405118y

[85] Gibbons, B. (2014, February 19). Woman wins case against Chesapeake Jaqueline Place of Terry Township to receive compensation for well contamination. *Thedailyreview.com*. Retrieved June 9, 2014, from http://thedailyreview.com/news/woman-wins-case-against-chesapeake-jaqueline-place-of-terry-township-to-receive-compensation-for-well-contamination-1.1636832

Of the 495 chemical spills that occurred in that state over a one-year period of time, nearly a quarter impacted ground or surface water. Sixty-three of the spills spread within 1,500 feet of pigs, sheep and cows, and 225 spread within 1,500 feet of buildings.[86]

- January 10, 2014 – Duke University water tests revealed ongoing water contamination in Parker County, Texas, providing evidence that EPA had prematurely ended its prior investigation into the water contamination.[87] A letter sent to the EPA from more than 200 environmental organizations called on the EPA to re-open its investigation.[88]

- January 5, 2014 – An Associated Press investigation into drinking water contamination from fracking in four states—Pennsylvania, Ohio, West Virginia and Texas—found many cases of confirmed water contamination and hundreds more complaints. The Associated Press noted that their analysis "casts doubt on industry view that it rarely happens."[89]

- December 24, 2013 – A report from the EPA Inspector General concluded that evidence of fracking-related water contamination in Parker County, Texas was sound and faulted the EPA for prematurely ending its investigation there, relying on faulty water testing data from the gas industry in doing so, and failure to intervene when affected residents' drinking water remained unsafe.[90] As reported by *Business Insider*, "The EPA Screwed Up When It Dropped This Fracking Investigation."[91]

- December 16, 2013 – Lead by Susan Nagel of the University of Missouri School of Medicine, researchers documented endocrine-disrupting properties in chemicals commonly used as ingredients of fracking fluid and found similar endocrine-disrupting activity in groundwater and surface water samples collected near drilling and fracking sites in Garfield County, Colorado. Endocrine disruptors are chemicals that interfere with the activity of hormones in the body and, at very low concentrations, can raise the risk of

[86] Tomasic, J. (2014, January 16). Colorado drilling data: More than a spill a day. *The Colorado Independent*. Retrieved June 9, 2014, from http://www.coloradoindependent.com/145629/colorado-drilling-data-more-than-a-spill-a-day

[87] Drajem, M. (2014, January 9). Duke fracking tests reveal dangers driller's data missed. *Bloomberg*. Retrieved June 9, 2014, from http://www.bloomberg.com/news/2014-01-10/epa-s-reliance-on-driller-data-for-water-irks-homeowners.html

[88] Drajem, M. (2014, January 27). EPA needs fracking review: 'Gasland' maker, environmentalists. *Bloomberg*. Retrieved June 9, 2014, from http://go.bloomberg.com/political-capital/2014-01-27/epa-needs-fracking-review-gasland-producer-environmentalists-say/.

[89] Begos, K. (2014, January 05). 4 states confirm water pollution from drilling. *USA Today*. Retrieved June 9, 2014, from http://www.usatoday.com/story/money/business/2014/01/05/some-states-confirm-water-pollution-from-drilling/4328859/

[90] Banjeree, N. (2013, December 24). EPA report on fracking in Texas raises new concerns. *Los Angeles Times*. Retrieved June 9, 2014, from http://www.latimes.com/nation/la-na-epa-fracking-20131225,0,6042944.story#ixzz2oVB9FXVY

[91] Miedema, D. (2013, December 25). The EPA screwed up when it dropped this fracking investigation. *Business Insider*. Retrieved June 9, 2014, from http://www.businessinsider.com/epa-criticized-for-dropping-fracking-investigation-2013-12

reproductive, metabolic, and neurological disorders, especially when exposures occur in early life. [92] [93] [94]

- December 7, 2013 – Reporting on the second gas leak at a single gas well in one month, the Fort Worth *Star-Telegram* uncovered another inherent risk of fracking for groundwater contamination: Silica sand, which is used as an ingredient in fracking fluid for its ability to prop open the shale fractures, can damage steel pipes as it flows back up the well along with the gas. According to Dan Hill, head of the petroleum engineering department at Texas A&M University, new wells are the most susceptible to sand erosion because "the amount of sand and gas rushing through valves and flow lines is at its greatest when a well first goes into production."[95]

- November 28, 2013 – An Associated Press investigation uncovered nearly 300 oil pipeline spills in North Dakota in the previous ten months, all with no public notification. These were among some 750 "oil field incidents" that had occurred in the state over the same time period, also without public notification. Until the AP inquiry, industry and state officials had kept quiet about one particular "massive spill" that had been accidentally discovered by a wheat farmer. Even small spills can contaminate water sources permanently and take cropland out of production.[96]

- November 26, 2013 – A U.S. Geological Survey report found serious impacts of fracking on watersheds and water quality throughout the Appalachian Basin, as well as issues with radiation and seismic events. As noted in the report, the knowledge of how extraction affects water resources has not kept pace with the technology.[97] [98] Meanwhile, clean fresh water is becoming an increasingly scant resource. A report from the U.S. State

[92] Kassotis, C. D., Tillitt, D. E., Davis, J. W., Hormann, A. M., & Nagel, S. C. (2013). Estrogen and androgen receptor activities of hydraulic fracturing chemicals and surface and ground water in a drilling-dense region. *Endocrinology*. doi: 10.1210/en.2013-1697

[93] Banerjee, N. (2013, December 16). Hormone-disrupting chemicals found in water at fracking sites. *Los Angeles Times*. Retrieved June 11, 2014, from http://articles.latimes.com/2013/dec/16/science/la-sci-fracking-health-20131217

[94] Endocrine Society. (2013, December 16). Fracking chemicals disrupt hormone function. ScienceDaily. Retrieved June 11, 2014 from www.sciencedaily.com/releases/2013/12/131216140428.htm

[95] Hirst, C., & Fuquay, J. (2013, December 7). Second leak reported at east Fort Worth gas well site. *Star-Telegram*. Retrieved June 9, 2014, from http://www.star-telegram.com/2013/12/07/5399740/second-leak-reported-at-east-fort.html?rh=1

[96] MacPherson, J. (2013, October 28). Nearly 300 pipeline spills in North Dakota have gone unreported to the public since January 2012. *Huffington Post*. Retrieved June 9, 2014, from http://www.huffingtonpost.com/2013/10/28/pipeline-spills-north-dakota_n_4170133.html?ncid=edlinkusaolp00000003

[97] Kappel, W. M., Williams, J. H., & Szabo, Z. (2013). Water resources and shale gas/oil production in the Appalachian Basin - Critical issues and evolving developments. *U.S. Geological Survey*. Retrieved June 9, 2014, from http://pubs.usgs.gov/of/2013/1137/pdf/ofr2013-1137.pdf

[98] Mall, A. (2013, November 26). New USGS analysis: Threats to water, wildlife, and health from oil and gas development in the Appalachian basin [Web log post]. Retrieved June 9, 2014, from http://switchboard.nrdc.org/blogs/amall/new_usgs_analysis.html

Department found that the United States will face a serious freshwater shortage by 2030, with demand exceeding supply by 40 percent.[99]

- November 22, 2013 – A U.S. Geological Survey study of pollution from oil production in North Dakota, where horizontal drilling and hydraulic fracturing are heavily used, identified two potential plumes of groundwater contamination covering 12 square miles. The cause was traced to a casing failure in a wastewater disposal well. Drilling companies had incorrectly assumed that, once injected underground, the wastewater would remain contained. According to *EnergyWire*, the development of the Bakken oil formation is "leaving behind an imprint on the land as distinct as the ones left by the receding ice sheets of the ice age."[100]

- September 10, 2013 – Pennsylvania Attorney General Kathleen Kane filed criminal charges against Exxon Mobil Corporation's subsidiary, XTO Energy Corporation, for a spill of 50,000 gallons of toxic drilling wastewater in 2010 that contaminated a spring and a tributary of the Susquehanna River. In July, XTO settled civil charges for the incident without admitting liability by agreeing to pay a $100,000 fine and improve its wastewater management.[101]

- September 10, 2013 – Out of concern for risks posed to drinking water in the nation's capital, George Hawkins, general manager of DC Water, Washington, DC's local water provider, called for a prohibition on horizontal drilling and hydraulic fracturing in the George Washington National Forest until the process can be proven safe.[102] The Potomac River is the source of the District's water supply and has its headwaters in the George Washington National Forest, which sits atop the Marcellus Shale. The general managers of Fairfax Water, provider of drinking water for Fairfax County, Virginia, and the U.S. Army Corps of Engineers have called for a similar prohibition.[103]

- September 3, 2013 – The North Dakota Department of Mineral Resources voiced concern about an increasing number of fracking well blowouts (23 incidents in the past year) that result in spills and public safety threats.[104]

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[99] A freshwater shortage is expected in the US by 2030. (2013, September 8). *MSN Now*. Retrieved June 11, 2014, from http://now.msn.com/freshwater-shortage-in-us-will-reach-a-worrying-stage-by-2030-1#scpshrtu

[100] Vaidyanathan, G. (2013, November 22). Bakken shale: As oil production sets in, pollution starts to migrate -- scientists. *E&E Publishing, LLC*. Retrieved June 9, 2014, from http://www.eenews.net/stories/1059990892

[101] Maykuth, A. (2013, September 13). Shale criminal charges stun drilling industry. *Philly.com*. Retrieved June 9, 2014, from http://articles.philly.com/2013-09-13/news/42012429_1_xto-energy-inc-criminal-charges-attorney-general

[102] Letter from George Hawkins, General Manager, DC Water, to U.S. Secretary of Agriculture, Thomas Vilsack, (Sept. 10, 2013), http://www.washingtoncitypaper.com/blogs/housingcomplex/2013/09/20/dc-water-chief-urges-agriculture-secretary-not-to-allow-fracking-near-d-c/

[103] Wiener, A. (2013, September 20). DC Water Chief urges Agriculture Secretary not to allow fracking near D.C. *Washington City Paper*. Retrieved June 11, 2014, from http://www.washingtoncitypaper.com/blogs/housingcomplex/2013/09/20/dc-water-chief-urges-agriculture-secretary-not-to-allow-fracking-near-d-c/

[104] Sun Staff. (2013, September 3). More blowouts a concern for N.D. *The Jamestown Sun*. Retrieved June 9, 2014, from http://www.jamestownsun.com/content/more-blowouts-concern-nd

- August 28, 2013 – A joint U.S. Geological Survey and U.S. Fish and Wildlife Service study documented a causal link between a fracking wastewater spill and the widespread death of fish in the Acorn Fork, a creek in Kentucky.[105]

- July 25, 2013 – A University of Texas at Arlington study of drinking water found elevated levels of arsenic and other heavy metals in some samples from private drinking water wells located within five kilometers of active natural gas wells in the Barnett Shale.[106]

- July 3, 2013 – *ProPublica* reported that the EPA was wrong to have halted its investigation of water contamination in Wyoming, Texas and Pennsylvania—where high levels of benzene, methane, arsenic, oil, methane, copper, vanadium and other chemicals associated with fracking operations have been documented.[107] Although numerous organizations and health professionals around the country have since called on the agency to resume its investigation, no action has been taken.

- June 6, 2013 – *Bloomberg News* reported,

  > *In cases from Wyoming to Arkansas, Pennsylvania to Texas, drillers have agreed to cash settlements or property buyouts with people who say hydraulic fracturing, also known as fracking, ruined their water according to a review by Bloomberg News of hundreds of regulatory and legal filings. In most cases homeowners must agree to keep quiet. The strategy keeps data from regulators, policymakers, the news media and health researchers, and makes it difficult to challenge the industry's claim that fracking has never tainted anyone's water.*

  Bloomberg quoted Aaron Bernstein, associate director of the Center for Health and the Global Environment at the Harvard School of Public Health, saying that non-disclosure agreements "have interfered with the ability of scientists and public health experts to understand what is at stake here."[108] The EPA also long ago noted how non-disclosure agreements challenge scientific progress and keep examples of drilling harm secret from the public. In a 1987 report, the EPA wrote,

  > *Very often damage claims against oil and gas operators are settled out of court, and information on known damage cases has often been sealed through agreements between landowners and oil companies. This is typical practice, for instance, in*

[105] Papoulias, D., & MacKenzie, T. (2013, August 28). Hydraulic fracturing fluids likely harmed threatened Kentucky fish species. *USGS Newsroom*. Retrieved June 9, 2014, from http://www.usgs.gov/newsroom/article.asp?ID=3677

[106] Fontenot, B. E., Hunt, L. R., Hildenbrand, Z. L., Jr., D. D., Oka, H., Walton, J. L., ... Schug, K. A. (2013). An evaluation of water quality in private drinking water wells near natural gas extraction sites in the Barnett Shale formation. *Environmental Science & Technology, 47*(17), 10032-10040. doi: 10.1021/es4011724

[107] Lustgarten, A. (2013, July 3). EPA's abandoned Wyoming fracking study one retreat of many. *ProPublica*. Retrieved June 9, 2014, from http://www.propublica.org/article/epas-abandoned-wyoming-fracking-study-one-retreat-of-many

[108] Efstathiou, J., Jr., & Drajem, M. (2013, June 5). Drillers silence fracking claims with sealed settlements. *Bloomberg*. Retrieved June 9, 2014, from http://www.bloomberg.com/news/2013-06-06/drillers-silence-fracking-claims-with-sealed-settlements.html

Texas. In some cases, even the records of well-publicized damage incidents are almost entirely unavailable for review. In addition to concealing the nature and size of any settlement entered into between the parties, impoundment curtails access to scientific and administrative documentation of the incident.[109]

- June 3, 2013 – A study by Duke University researchers linked fracking with elevated levels of methane, ethane, and propane in nearby groundwater.[110] Published in *Proceedings of the National Academy of Sciences*, the study included results from 141 northeastern Pennsylvania water wells. Methane levels were, on average, six times higher in drinking water wells closer to drilling sites when compared with those farther away, while ethane was 23 times higher.[111]

- May 19, 2013 – In Pennsylvania, the *Scranton Times-Tribune* released details of an investigation that revealed at least 161 cases of water contamination from fracking between 2008 and the fall of 2012, according to state Department of Environmental Protection records.[112]

- April 2013 – Researchers analyzing publicly available Colorado data found 77 surface spills impacting groundwater in Weld County alone. Samples of these spills often exceeded drinking water maximum contaminant levels (MCLs) for benzene, toluene, ethylbenzene and xylene; for benzene, a known carcinogen, 90% of the samples exceeded the legal limit.[113]

- March 4, 2013 – Researchers at the University of Pittsburgh Graduate School of Public Health analyzed samples of gas drilling wastewater discharged to surface water through wastewater treatment plants. Barium, strontium, bromides, chlorides, and benzene all exceeded levels known to cause human health impacts.[114]

- December 9, 2012 – State data in Colorado showed more than 350 instances of groundwater contamination resulting from more than 2,000 spills from oil and gas operations over the past five years. Further, as the *Denver Post* reported, "Contamination

[109] Environmental Protection Agency. (1987). *Report to Congress: Management of wastes from the exploration, development, and production of crude oil, natural gas, and geothermal energy* (Rep.). 137-138. Washington, D.C.: U.S. Environmental Protection Agency.
[110] Jackson, R. B., Vengosh, A., Darrah, T. H., Warner, N. R., Down, A., Poreda, R. J., ... Karr, J. D. (2013). Increased stray gas abundance in a subset of drinking water wells near Marcellus shale gas extraction. *Proceedings of the National Academy of Sciences*, 110(28), 11250-11255. doi: 10.1073/pnas.1221635110
[111] CBS/AP. (2013, June 25). Methane found in Pa. drinking water near fracked wells. *CBS News*. Retrieved from http://www.cbsnews.com/news/methane-found-in-pa-drinking-water-near-fracked-wells/
[112] Legere, L. (2013, May 19). Sunday Times review of DEP drilling records reveals water damage, murky testing methods. *The Times-Tribune*. Retrieved June 9, 2014, from http://thetimes-tribune.com/news/sunday-times-review-of-dep-drilling-records-reveals-water-damage-murky-testing-methods-1.1491547
[113] Gross, S. A., Avens, H. J., Banducci, A. M., Sahmel, J., Panko, J. M., & Tvermoes, B. E. (2013). Analysis of BTEX groundwater concentrations from surface spills associated with hydraulic fracturing operations. *Journal of the Air & Waste Management Association, 63*(4), 424-432. doi: 10.1080/10962247.2012.759166
[114] Ferrar, K. J., Michanowicz, D. R., Christen, C. L., Mulcahy, N., Malone, S. L., & Sharma, R. K. (2013). Assessment of effluent contaminants from three facilities discharging Marcellus shale wastewater to surface waters in Pennsylvania. *Environmental Science & Technology, 47*(7), 3472-3481. doi: 10.1021/es301411q

of groundwater—along with air emissions, truck traffic and changed landscapes—has spurred public concerns about drilling along Colorado's Front Range."[115]

- May, 2012 – A report by researchers at Natural Resources Defense Council and Carnegie Mellon University found that the options available for dealing with fracking wastewater are inadequate to protect public health and the environment, resulting in increasing quantities of toxic wastewater as an ongoing problem without a good solution.[116]

- January 11, 2012 – The U.S. Geological Survey found that the Marcellus Shale is already highly fractured and that numerous fissures naturally occurring within the formation could potentially provide pathways for contaminants to migrate vertically into water supplies.[117]

- October 17, 2011 – Thomas P. Jacobus, General Manager of the U.S. Army Corps of Engineers' Washington Aqueduct, that provides drinking water to Washington, DC, Arlington County, Virginia, and Falls Church, Virginia, called for a prohibition on horizontal hydraulic fracturing in the George Washington National Forest because of concern that fracking poses risks to drinking water. The Washington Aqueduct—which provides drinking water to Washington, DC, Arlington County, Virginia, and Falls Church, Virginia—is supplied by the Potomac River, which has its headwaters in the George Washington National Forest that sits atop the Marcellus Shale. Jacobus said, "Enough study on the technique [hydraulic fracturing] has been published to give us great cause for concern about the potential for degradation of the quality of our raw water supply…."[118]

- October 11, 2011 – Charles M. Murray, General Manager of Fairfax Water, the water provider for Fairfax County, Virginia, called for a prohibition on horizontal hydraulic fracturing in the George Washington National Forest. "Natural gas development activities have the potential to impact the quantity and quality of Fairfax Water's source water," Murray wrote. "Downstream water users and consumers will bear the economic burden if drinking water sources are contaminated or the quality of our source water supply is degraded."[119]

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[115] Finley, B. (2012, December 9). Drilling spills reaching Colorado groundwater; state mulls test rules. *The Denver Post*. Retrieved June 9, 2014, from http://www.denverpost.com/environment/ci_22154751/drilling-spills-reaching-colorado-groundwater-state-mulls-test#ixzz2EihHU2fg

[116] Hammer, R., & VanBriesen, J. (2012, May). *In fracking's wake: New rules are needed to protect our health and environment from contaminated wastewater* (Rep.). Natural Resources Defense Council. Retrieved June 11, 2014, from http://www.nrdc.org/energy/files/fracking-wastewater-fullreport.pdf

[117] U.S. Geological Survey, New York Water Science Center. (2012, January 11). *Comments on the revised draft supplemental generic environmental impact statement*. (Rep.). Retrieved June 11, 2014, from http://www.ewg.org/sites/default/files/report/ReviseddraftSGEIS_USGScomments_Version3_0.pdf

[118] Jacobus, T. P. (2012, April 25). Draft environmental impact statment for the George Washington National Forest [Letter written October 17, 2011 to K. Landgraf]. Retrieved June 11, 2014, from http://www.fs.usda.gov/Internet/FSE_DOCUMENTS/stelprdb5366331.pdf

[119] Murray, C. M. (n.d.). Draft environmental impact statement for the George Washington National Forest [Letter written October 11, 2013 to K. Landgraf]. Retrieved June 11, 2014, from http://www.svnva.org/wp-content/uploads/fairfax-wash-aquaduct-gwnf-comments.pdf

- September 7, 2011 – In its draft Supplemental Generic Environmental Impact Statement (SGEIS), the NYS DEC acknowledged that "there is questionable available capacity"[120] for New York's public sewage treatment plants to accept drilling wastewater, yet the agency said that it would allow those facilities to accept such waste if the plants meet permitting conditions.[121] The NYS DEC proposed underground injection as one alternative to sewage treatment procession of fracking waste. Although it is a common method of disposal for fracking wastewater,[122] the last significant government study of pollution risks from oil and gas wastewater injection wells occurred in 1989 and found multiple cases of costly groundwater contamination.[123] In subsequent years, studies have continued to link underground injection of drilling wastewater to pollution as well as earthquakes.[124]

- September, 2011 – A team led by Theo Colburn of the Endocrine Disruptor Exchange found that 25 percent of chemicals known to be used in fracking fluids are implicated in cancer, 37 percent could disrupt the endocrine system, and 40 to 50 percent could cause nervous, immune and cardiovascular system problems. The research team also found that more than 75 percent could affect the skin, eyes and respiratory system, resulting in various problems such as skin and eye irritation or flu-like symptoms.[125]

- August 4, 2011 – As reported by *The New York Times*, the EPA had alerted Congress in 1987 about a case of water contamination caused by fracking. Its report documented that

[120] New York State Department of Environmental Conservation. (2011). *Supplemental generic environmental impact statement on the oil, gas and solution mining regulatory program, well permit issuance for horizontal drilling and high-volume hydraulic fracturing to develop the Marcellus shale and other low-permeability gas reservoirs* (6-62, Rep.).

[121]New York State Department of Environmental Conservation. (2011). *Supplemental generic environmental impact statement on the oil, gas and solution mining regulatory program, well permit issuance for horizontal drilling and high-volume hydraulic fracturing to develop the Marcellus shale and other low-permeability gas reservoirs* (6-57 through 6-63, Rep.).

[122]New York State Department of Environmental Conservation. (2011). *Supplemental generic environmental impact statement on the oil, gas and solution mining regulatory program, well permit issuance for horizontal drilling and high-volume hydraulic fracturing to develop the Marcellus shale and other low-permeability gas reservoirs* (6-64, Rep.).

[123] United States Government Accountability Office. (1989, July 5). Drinking water: Safeguards are not preventing contamination from injected oil and gas wastes. Retrieved June 10, 2014, from http://www.gao.gov/products/RCED-89-97

[124] Fountain, H. (2012, January 1). Disposal halted at well after new quake in Ohio. *The New York Times*. Retrieved June 10, 2014, from http://www.nytimes.com/2012/01/02/science/earth/youngstown-injection-well-stays-shut-after-earthquake.html

[125] Colborn, T., Kwiatkowski, C., Schultz, K., & Bachran, M. (2011). Natural gas operations from a public health perspective. *Human and Ecological Risk Assessment: An International Journal, 17*(5), 1039-1056. doi: 10.1080/10807039.2011.605662

a shale gas well hydraulically fractured at a depth of more than 4,200 feet contaminated a water supply only 400 feet from the surface.[126] [127] [128]

- May 17, 2011 – The state of Pennsylvania fined Chesapeake Energy Corp. $900,000 for an incident in which improper cementing and casing in one of the company's gas wells allowed methane to migrate underground and contaminate 16 private drinking water wells in Bradford County.[129]

- May 9, 2011 – A Duke University study documented "systematic evidence for methane contamination of drinking water associated with shale gas extraction." The study showed that methane levels were 17 times higher in water wells near drilling sites than in water wells in areas without active drilling.[130]

- April 18, 2011 – As part of a year-long investigation into hydraulic fracturing and its potential impact on water quality, U.S. Representatives Henry Waxman (D-Calif.), Edward Markey (D-Mass.) and Diana DeGette (D-Colo.) released the second of two reports issued in 2011. Their analysis of hydraulic fracturing fluids used by the 14 leading oil and natural gas service companies between 2005 and 2009 found, among other things, that the companies used more than 650 different products that contained chemicals that are known or possible human carcinogens, regulated under the Safe Drinking Water Act, or listed as hazardous air pollutants under the Clean Air Act. The report also showed that "between 2005 and 2009, the companies used 94 million gallons of 279 products that contained at least one chemical or component that the manufacturers deemed proprietary or a trade secret … in most cases the companies stated that they did not have access to proprietary information about products they purchased 'off the shelf' from chemical suppliers. In these cases, the companies are injecting fluids containing chemicals that they themselves cannot identify."[131] These findings were reported in the New York Times.[132]

  January 2011 – A team of scientists led by a University of Central Arkansas researcher called attention to the threat posed to surface waters by rapidly expanding shale gas

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[126] Urbina, I. (2011, August 4). A tainted water well, and concern there may be more. Retrieved June 11, 2014, from http://www.nytimes.com/2011/08/04/us/04natgas.html

[127] U.S. Environmental Protection Agency. (1987). *Report to Congress: Management of wastes from the exploration, development, and production of crude oil, natural gas, and geothermal energy* (Rep.). 4-22, 4-23. Retrieved June 11, 2014, from http://nepis.epa.gov/Exe/ZyPDF.cgi?Dockey=20012D4P.PDF

[128] Horwitt, D. (2011, August 3). Cracks in the facade. *Environmental Working Group*. Retrieved June 11, 2014, from http://www.ewg.org/research/cracks-façade

[129] Levy, M. (2011, May 18). DEP fines Chesapeake $1 million. *Pressconnects.com*. Retrieved June 9, 2014, from http://www.pressconnects.com/viewart/20110517/NEWS01/105170345/DEP-fines-Chesapeake-1-million

[130] Duke University. (2011). Methane levels 17 times higher in water wells near hydrofracking sites, study finds. *ScienceDaily*. Retrieved June 11, 2014, from http://www.sciencedaily.com/releases/2011/05/110509151234.htm

[131] Waxman, H.A., Markey, E. J., & DeGette, D. (2011, April 18). Committee on Energy & Commerce (U.S.A., Congress, Committee on Energy & Commerce). Retrieved December 9, 2014, from http://democrats.energycommerce.house.gov/sites/default/files/documents/Hydraulic-Fracturing-Chemicals-2011-4-18.pdf.

[132] Urbina, I. (2011, April 17). Chemicals Were Injected Into Wells, Report Says. *The New York Times*. Retrieved December 9, 2014, from http://www.nytimes.com/2011/04/17/science/earth/17gas.html.

development, noting a lack of data collection accompanying the rush to drill. "Gas wells are often close to surface waters that could be impacted by elevated sediment runoff from pipelines and roads, alteration of stream flow as a result of water extraction, and contamination from introduced chemicals or the resulting wastewater."[133] In October, after receiving new information from two companies, the members of Congress updated their findings to show that "between 2005 and 2009, oil and gas service companies injected 32.7 million gallons of diesel fuel or hydraulic fracturing fluids containing diesel fuel in wells in 20 states."[134]

- April 29, 2010 – In 2010, the Colorado Oil and Gas Conservation Commission fined OXY USA a record $390,000 for an incident of pollution, discovered in 2008, when its drilling wastes leaked through an unlined pit, contaminated two springs with benzene and polluted other nearby water sources. In addition, the regulators separately fined OXY USA $257,400 for a nearby case of pollution, also discovered in 2008, in which a torn liner in a pit caused drilling waste fluids to leak out and contaminate two springs with benzene.[135]

- April 22, 2011 – Describing one of many blowouts, the Associated Press reported on a shale gas well in Canton, Pennsylvania that spewed thousands of gallons of chemical-laced water on farmland and into a stream for two consecutive days before being brought under control.[136]

- January 31, 2011 – As part of a year-long investigation into hydraulic fracturing and its potential impact on water quality, U.S. Representatives Henry Waxman (D-Calif.), Edward Markey (D-Mass.) and Diana DeGette (D-Colo.) reported that "between 2005 and 2009, oil and gas service companies injected 32.2 million gallons of diesel fuel or hydraulic fracturing fluids containing diesel fuel in wells in 19 states." Furthermore, revealing apparent widespread violation of the Safe Drinking Water Act, the investigation found that no oil and gas service companies had sought—and no state or federal regulators had issued—permits for the use of diesel fuel in hydraulic fracturing.[137]

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[133] Entrekin, S., Evans-White, M., Johnson, B., & Hagenbuch, E. (2011). Rapid expansion of natural gas development poses a threat to surface waters. *Frontiers in Ecology and the Environment, 9*(9), 503-511. doi: 10.1890/110053

[134] Waxman, H. A., Markey, E. J., & DeGette, D. (2011, October 25). *Committee on Energy & Commerce* (U.S.A., Congress, Committee on Energy & Commerce). Retrieved December 9, 2014, from http://democrats.energycommerce.house.gov/index.php?q=news/reps-waxman-markey-and-degette-report-updated-hydraulic-fracturing-statistics-to-epa.

[135] Webb, D. (2010, April 29). Record fine, second one against Oxy approved. *Grand Junction Sentinel*. Retrieved June 11, 2014, from http://www.gjsentinel.com/news/articles/record-fine-second-one-against-oxy-approved

[136] The Associated Press. (2011, April 22). Crews stop flow of drilling fluid from Pennsylvania well. *Syracuse.com*. Retrieved June 9, 2014, from http://www.syracuse.com/news/index.ssf/2011/04/crews_stop_flow_of_drilling_fl.html

[137] Waxman, H. A., Markey, E. J., & DeGette, D. (2011, January 31). *Committee on Energy & Commerce* (U.S.A., Congress, Committee on Energy & Commerce). Retrieved June 9, 2014, from http://democrats.energycommerce.house.gov/index.php?q=news/waxman-markey-and-degette-investigation-finds-continued-use-of-diesel-in-hydraulic-fracturing-f

- June 5, 2009 – A leaking pipe carrying fracking waste in Washington County, Pennsylvania, polluted a tributary of Cross Creek Lake, killing fish, salamanders, crayfish and aquatic insect life in approximately three-quarters of a mile of the stream.[138]

- April 26, 2009 – Officials in three states linked water contamination and methane leaks to gas drilling. Incidents included a case in Ohio where a house exploded after gas seeped into its water well and multiple cases of exploding drinking water wells in Dimock, PA.[139]

- November 13, 2008 – *ProPublica* reported more than 1,000 cases of drilling-related contamination documented by courts and state and local governments in Colorado, New Mexico, Alabama, Ohio and Pennsylvania.[140]

- December 15, 2007 – In Bainbridge, Ohio, a gas well that was improperly cemented and subsequently fractured by Ohio Valley Energy Systems Corp. allowed natural gas to migrate outside of the well, causing a home to explode. In addition, 23 nearby water wells were contaminated, two of which were located more than 2,300 feet from the drilling site.[141] [142] [143]

Inherent engineering problems that worsen with time

- December 2, 2014 – Problems with structural integrity have been documented in a well at the only hydraulically fractured site in the United Kingdom. Email messages obtained under freedom of information laws reveal that problems with wellbore integrity emerged in April of 2014 and attempts were made to remediate the problem, although nothing was reported at that time to regulators. The drilling company, Cuadrilla Resources, continues to deny that any problems exist with the well, emphasizing that "no leak of fluids" occurred and that "the issue" was resolved during the abandonment process. Cuadrilla had previously been reprimanded for failing to disclose a more minor deformation in the

[138] Pittsburgh Post-Gazette. (2009, June 5). Waste from Marcellus shale drilling in Cross Creek Park kills fish. *Pittsburgh Post-Gazette*. Retrieved June 9, 2014, from http://www.post-gazette.com/washington/2009/06/05/Waste-from-Marcellus-shale-drilling-in-Cross-Creek-Park-kills-fish/stories/200906050136

[139] Lustgarten, A. (2009, April 26). Officials in three states pin water woes on gas drilling. *ProPublica*. Retrieved June 9, 2014, from http://www.propublica.org/article/officials-in-three-states-pin-water-woes-on-gas-drilling-426

[140] Lustgarten, A. (2008, November 13). Buried secrets: Is natural gas drilling endangering U.S. water supplies? *ProPublica*. Retrieved June 9, 2014, from http://www.propublica.org/article/buried-secrets-is-natural-gas-drilling-endangering-us-water-supplies-1113

[141] Ohio Department of Natural Resources Division of Mineral Resources Management. (2008, September 1). *Report on the investigation of the natural gas invasion of aquifers in Bainbridge Township of Geauga County, Ohio*. (Rep.). Retrieved June 9, 2014, from http://www.ohiodnr.com/mineral/bainbridge/tabid/20484/default.aspx

[142] Bair, E. S., Freeman, D. C., & Senko, J. M. (2010, June). *Expert panel technical report, subsurface gas invasion Bainbridge Township, Geauga County, Ohio* (Rep.). Retrieved June 11, 2014, from http://oilandgas.ohiodnr.gov/portals/oilgas/pdf/bainbridge/DMRM%200%20Title%20Page,%20Preface,%20Acknowledgements.pdf

[143] Ohio Dep't of Natural Res., Order Number 2009-17 (Apr. 14, 2009) (see attachments A, B).

well casing. The well was abandoned at the end of last year, following two earthquakes in 2011, which scientists determined to have been caused by fracking at the site.[144]

- August 11, 2014 – Researchers affiliated with multiple universities and with the Los Alamos National Laboratory summarized recent field observations of wellbore-integrity failure, concluding that, because at least some well failures are not identified, reported barrier failure rates of 1-10% of wells and reported rates of groundwater contamination of 0.01-0.1% of wells constitute a "lower bound" for possible environmental problems. Citing hydraulic fracturing, as well as temperature and pressure changes, as operations that can induce pathways for leaks, the authors point out that few studies have considered the very-long-term fate (">50 years") of wellbore systems. They include "whether unconventional resource development alters the frequency of well integrity failures" as a critical topic for future research.[145]

- July 30, 2014 – Based on records obtained from Pennsylvania's Department of Environmental Protection (PA-DEP), Scranton's *Times-Tribune* reported that five natural gas wells in Bradford County have leaked methane for years because of persistent casing and cement problems. In the most recent violation, a PA-DEP inspector found combustible gas flowing through vents connected to the cement between layers of pipe. The department issued a notice of violation for each well, saying combustible gas outside the well's surface casing violates state regulations. Each of the wells has four layers of steel casing, but nothing prevents leaking (stray) methane from flowing into the atmosphere. No evidence of water contamination has yet been seen. None of the wells have produced any gas for sale.[146]

- June 30, 2014 – A study published in *Proceedings of the National Academy of Sciences* by a Cornell University research team projected that over 40 percent of shale gas wells in Northeastern Pennsylvania will leak methane into groundwater or the atmosphere over time. Analyzing more than 75,000 state inspections of more than 41,000 oil and gas wells in Pennsylvania since 2000, the researchers identified high occurrences of casing and cement impairments inside and outside the wells. A comparative analysis showed that newer, unconventional (horizontally fracked) shale gas wells were leaking at six times the rate of conventional (vertical) wells drilled over the same time period. The leak rate for unconventional wells drilled after 2009 was at least six percent, and rising with time. In the state's northeastern counties between 2000-2012, over nine percent of shale gas wells drilled leaked within the first five years.[147] The study also discovered that over

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[144] Bryant, B. (2014, December 2). The only fracked site in the United Kingdom suffered structural failure. *Vice News*. Retrieved from https://news.vice.com/article/the-only-fracking-site-in-the-united-kingdom-suffered-structural-failure

[145] Jackson R.B., Vengosh, A., Carey, J.W., Davies, R.J., Darrah, T.H., O'Sullivan, F. and Pétron, G. (2014). The environmental costs and benefits of fracking. *Annual Review of Environment and Resources* 39, 327–62. doi: 10.1146/annurev-environ-031113-144051

[146] Gibbons, B. (2014, July 30). Five gas wells leaked methane for years. *Times-Tribune*. Retrieved from http://thetimes-tribune.com/news/five-gas-wells-leaked-methane-for-years-1.1727537

[147] Ingraffea, A., Wells, M., Santoro, R., & Shonkoff, S. Assessment and risk analysis of casing and cement impairment in oil and gas wells in Pennsylvania, 2000–2012. *Proceedings of the National Academy of Sciences*. Retrieved July 4, 2014, from http://www.pnas.org/content/early/2014/06/25/1323422111.abstract

8,000 oil and gas wells drilled since 2000 had not received a facility-level inspection. This study helps explain the results of earlier studies that documented elevated levels of methane in drinking water aquifers located near drilling and fracking operations in Pennsylvania and points to compromised structural integrity of well casings and cement as a possible mechanism.

- May 22, 2014 – In a 69-page report, University of Waterloo researchers warned that natural gas seeping from 500,000 wellbores in Canada represents "a threat to environment and public safety" due to groundwater contamination, greenhouse gas emissions and explosion risks wherever methane collects in unvented buildings and spaces. The report found that 10 percent of all active and suspended gas wells in British Columbia now leak methane. Additionally, the report found that some hydraulically fractured shale gas wells in that province have become "super methane emitters" that spew as much as 2,000 kilograms of methane a year.[148] [149]

- May 1, 2014 – Following a comprehensive review of evidence, the Council of Canadian Academies identified inherent problems with well integrity as one of its top concerns about unconventional drilling and fracking. According to one expert panel, "the greatest threat to groundwater is gas leakage from wells from which even existing best practices cannot assure long-term prevention."[150] Regarding their concerns related to well integrity and cement issues, the panel wrote:

  > *Two issues of particular concern to panel members are water resources, especially groundwater, and GHG emissions. Both related to well integrity…. Natural gas leakage from improperly formed, damaged, or deteriorated cement seals is a long-recognized yet unresolved problem …. Leaky wells due to improperly placed cement seals, damage from repeated fracturing treatments, or cement deterioration over time, have the potential to create pathways for contamination of groundwater resources and to increase GHG emissions.*

  They further explain:

  > *Cement may crack, shrink, or become deformed over time, thereby reducing the tightness of the seal around the well and allowing the fluids and gases … to escape into the annulus between casing and rock and thus to the surface…. The challenge of ensuring a tight cement seal [will] be greater for shale gas wells that are subjected to repeated pulses of high pressure during the hydraulic fracturing process than for conventional gas wells. This pressure stresses the casing and therefore the cement that isolates the well from surrounding formations*

[148] Dusseault, M. B., Jackson, R. E., & MacDonal, D. (2014, May 22). *Towards a road map for mitigating the rates and occurrences of long-term wellbore leakage*. *Geofirma*. Retrieved June 10, 2014, from http://www.geofirma.com/Links/Wellbore_Leakage_Study%20compressed.pdf

[149] Nikiforuk, A. (2014, June 5). Canada's 500,000 leaky energy wells: 'Threat to public' *The Tyee*. Retrieved June 10, 2014, from http://www.thetyee.ca/News/2014/06/05/Canada-Leaky-Energy-Wells/

[150] Council of Canadian Academies. (2014, May 1). *Environmental Impacts of Shale Gas Extraction in Canada: the Expert Panel on Harnessing Science and Technology to Understand the Environmental Impacts of Shale Gas Extraction.* Retrieved June 24, 2014, from http://bit.ly/1nNicuf

repeatedly.

- 2013 – According to state inspections of all 6,000 wells drilled in Pennsylvania's Marcellus Shale before 2013, six to ten percent of them leaked natural gas, with the rate of leakage increasing over time. The rate was six percent in 2010 (97 well failures out of 1,609 wells drilled); 7.1 percent in 2011 (140 well failures out of 1,972 wells drilled); and 8.9 percent in 2012 (120 well failures out of 1,346 wells drilled).[151] These data include wells that were cited for leakage violations, and wells that were noted to be leaking by inspectors but which had not been given violations. The New York State DEC forecasts that 50,000 wells could be drilled over the life of the Marcellus Shale play. If they fail at the same rate as wells in Pennsylvania, 4,000 wells would fail and leak in New York almost immediately.[152]

- 2009 – A study published by the Society of Petroleum Engineers of more than 315,000 oil, gas and injection wells in Alberta, Canada, found that 4.5 percent of the wells had unintended gas flow to the surface. In one designated area, officials required testing for gas migration outside the well casings in addition to routine testing for gas leaks within the rings of steel casings (annuli). Within this special testing zone, 15.5 percent of wells (3,205 of 20,725) leaked gas, and the incidence of gas leaks was four times percent higher in horizontal or deviated wells than in vertical wells.[153]

- Autumn 2003 – Schlumberger, one of the world's largest companies specializing in hydraulic fracturing and other oilfield services, reported in its in-house publication, *Oilfield Review*, that more than 40 percent of approximately 15,500 wells in the outer continental shelf area in the Gulf of Mexico were leaking gas. These included actively producing wells, in addition to shut-in and temporarily abandoned wells. In many cases, the gas leaked through the spaces (annuli) between layers of steel casing that drilling companies had injected with cement precisely to prevent such gas leaks. Leakage rates increased dramatically with age: about five percent of the wells leaked immediately; 50 percent were leaking after 15 years; and 60 percent were leaking after about 30 years.[154] Gas leaks pose serious risks including loss of life from explosions and migration of gas and associated contaminants into drinking water supplies. Leaks also allow the venting of raw methane into the atmosphere where it acts as a powerful greenhouse gas.

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[151] Ingraffea, A. R. (2013). Some scientific failings within high volume hydraulic fracturing proposed regulations. Retrieved June 10, 2014, from http://www.psehealthyenergy.org/data/NYS_DEC_Proposed_REGS_comments_Ingraffea_Jan_2013.pdf

[152]New York State Department of Environmental Conservation. (2011). *Supplemental generic environmental impact statement on the oil, gas and solution mining regulatory program, well permit issuance for horizontal drilling and high-volume hydraulic fracturing to develop the Marcellus shale and other low-permeability gas reservoirs* (2-1, Rep.).

[153] Watson, T. L., & Bachu, S. (2009). Evaluation of the potential for gas and CO2 leakage along wellbores, society of petroleum engineers. *SPE Drilling & Completion*, 115-126.

[154] Brufatto, C. (2003). From mud to cement - Building gas wells. *Oilfield Review, 15*(3). Retrieved June 10, 2014, from http://www.slb.com/resources/publications/industry_articles/oilfield_review/2003/or2003aut06_building_gas_wells.aspx

- November 2000 – Maurice Dusseault, a professor at the University of Waterloo in Ontario who specializes in rock mechanics, and two co-authors presented a paper published by the Society of Petroleum Engineers, in which they reported that oil and natural gas wells routinely leak gas through cracks in their cement casings, likely caused by cement shrinkage over time and exacerbated by upward pressure from natural gas. According to their paper, in Alberta, it is common for wells to leak natural gas into aquifers. "Because of the nature of the mechanism, the problem is unlikely to attenuate," they wrote, "and the concentration of the gases in the shallow aquifers will increase with time."[155]

Radioactive releases

- May 8, 2014 – A group of leading medical experts and the American Lung Association of the Northeast detailed research and growing concerns about potential health impacts of radon and radium associated with natural gas production and the Marcellus Shale, in particular. High levels of radiation in the Marcellus Shale could pose health threats if high concentrations of radon and its decay products travel with natural gas, a problem compounded by the short distance Marcellus gas could travel in pipelines to people's homes.[156]

- March 24, 2014 – A team led by toxicology researchers at the University of Iowa identified high levels of radioactivity in fracking wastewater as a significant concern and noted that the testing methods used and recommended by state regulators in the Marcellus Shale region can dramatically underestimate the amount of radioactivity—specifically radium—in fracking wastewater.[157] Results obtained using EPA-recommended protocols can be obscured by a mix of other contaminants present. Regarding the use of EPA protocols with fracking wastewater or other highly saline solutions, Avner Vengosh, a geochemist at Duke University, noted, "People have to know that this EPA method is not updated."[158]

[155] Dusseault, M. B., Gray, M. N., & Nawrocki, P. A. (2000). Why oil wells leak: Cement behavior and long-term consequences. *Society of Petroleum Engineers*. Retrieved June 10, 2014, from http://www.hydrorelief.org/frackdata/references/65704543-Casing-Leaks.pdf

[156] Campbell, J. (2014, May 8). Fracking critics keep pushing for state-backed health study. *Politics on the Hudson.* Retrieved June 9, 2014, from http://polhudson.lohudblogs.com/2014/05/08/fracking-critics-keep-pushing-state-backed-health-study/

[157] Nelson, A. W., May, D., Knight, A. W., Eitrheim, E. S., Mehrhoff, M., Shannon, R., ... Schultz, M. K. (2014). Matrix complications in the determination of radium levels in hydraulic fracturing flowback water from Marcellus shale. *Environmental Science & Technology, 1*(3), 204-208. doi: 10.1021/ez5000379

[158] Kelly, S. (2014, March 24). Research shows some test methods miss 99 percent of radium in fracking waste. *Desmogblog.com*. Retrieved June 9, 2014, from http://www.desmogblog.com/2014/03/23/some-testing-methods-can-miss-99-percent-radium-fracking-waste-new-research-reports

- February, 2014 – The Marcellus Shale is known to have high uranium and radium content. According to Mark Engle, U.S. Geological Survey geochemist, the concentration of radium-226 can exceed 10,000 picoCuries/Liter (pCi/L) in the shale. Radium-226 has a half-life of 1,600 years. Radium and other naturally occurring radioactive materials (NORM) can be released from shale rock during drilling and fracking and can emerge with flowback and produced waters. It can thus enter the ambient environment and become concentrated in the sludge which results from treatment of flowback water, and in river sediment around water treatment facilities. It can also be found in landfills in which sludge and sediment have been disposed. Some radium can be found in drinking water. As stated by Dr. Avner Vengosh, a geochemist at Duke University, "Once you have a release of fracking fluid into the environment, you end up with a radioactive legacy."[159]

- October 2, 2013 – A peer-reviewed study of the impacts of drilling wastewater treated and discharged into a creek by a wastewater facility in western Pennsylvania documented radium levels approximately 200 times greater in sediment samples near the discharge location than in sediment samples collected upstream of the plant or elsewhere in western Pennsylvania. "The absolute levels that we found are much higher than what you allow in the U.S. for any place to dump radioactive material," one of the authors told *Bloomberg News.* The pollution occurred despite the fact that the treatment plant removed a substantial amount of the radium from the drilling wastewater before discharging it. The researchers wrote that the accumulation of radium in sludge removed from the wastewater "could pose significant exposure risks if not properly managed."[160] [161]

- February 2013 – In an analysis of fracking sludge samples from Pennsylvania, researchers "… confirmed the presence of alpha, beta, and gamma radiation in the soil and water in reserve pits located on agricultural land." Total beta radiation exceeded regulatory guideline values by more than 800 percent, and elevated levels of some of the radioactive constituents remained in a vacated pit that had been drained and leveled. It is imperative, the research team concluded, "that we obtain better knowledge of the quantity of radioactive material and the specific radioisotopes being brought to the earth's surface from these mining processes."[162]

- January 11, 2012 – In its review of the New York State DEC's SGEIS on high-volume fracturing, the EPA expressed concerns about the diffusion of responsibility for the

[159] Brown V.J. (Feb 2014). Radionuclides in fracking wastewater. *Enviro. Health Perspect. 122*(2), A50-A55.
[160] Warner, N. R., Christie, C. A., Jackson, R. B., & Vengosh, A. (2013). Impacts of shale gas wastewater disposal on water quality in Western Pennsylvania. *Environmental Science & Technology, 47*(20), 11849-11857. doi: 10.1021/es402165b
[161] Efstathiou, J., Jr. (2013, October 2). Radiation in Pennsylvania creek seen as legacy of fracking. *Bloomberg*. Retrieved June 11, 2014, from http://www.bloomberg.com/news/2013-10-02/radiation-in-pennsylvania-creek-seen-as-legacy-of-frackin.html
[162] Rich, A. L., & Crosby, E. C. (2013). 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). *NEW SOLUTIONS: A Journal of Environmental and Occupational Health Policy, 23*(1), 117-135. doi: 10.2190/NS.23.1.h

ultimate disposal of radioactive wastes generated by treatment or pretreatment of drilling wastewater. The EPA also raised concerns about the lack of analysis of radon and other radiation exposure. "Who is responsible for addressing the potential health and safety issues and associated monitoring related to external radiation and the inhalation of radon and its decay products?" the EPA asked. "Such potential concerns need to be addressed."[163]

- 2012 – Responding to concern about radon in natural gas produced from the Marcellus Shale, the U.S. Geological Survey analyzed ten samples of gas collected near the wellheads of three Pennsylvania gas wells. The agency found radon levels ranging from 1 to 79 picocuries per liter, with an average of 36 and a median of 32. (The highest radon activity reported here would decay to 19.8 pCi/L in approximately a week; by comparison, the EPA's threshold for indoor air remediation is 4 pCi/L.) Asserting they knew of no previous published measurements of radon in natural gas from the Appalachian Basin, which contains the Marcellus Shale, agency scientists concluded that the number of samples "is too small to … yield statistically valid results" and urged "collection and interpretation of additional data."[164]

- September 7, 2011 – The U.S. Geological Survey reported that radium levels in wastewater from oil and gas wells in New York and Pennsylvania, including those in the Marcellus Shale, "have a distinctly higher median … than reported for other formations in the Appalachian Basin, and range to higher values than reported in other basins." The median level of radium found in Marcellus Shale wastewater in New York, 5,490 picocuries per liter, is almost 1,100 times the maximum contaminant level for drinking water, which is five picocuries per liter. In other words, if a million gallons of Marcellus Shale wastewater contaminated with the median level of radium found in New York were to spill into a waterway, 1.1 billion gallons of water would be required to dilute the radium to the maximum legal level.[165] (The EPA's health-based goal for radium in drinking water is zero.) Over time, radium naturally decays into radioactive radon gas. Thus, higher radium levels also suggest that higher levels of radon may also be present in natural gas produced from the Marcellus Shale.

- February 27, 2011 – *The New York Times* reported on the threat to drinking water from Pennsylvania drilling waste due to the presence of chemical contaminants, including high levels of radioactivity. The investigation found that sewage treatment plants were neither testing for nor capable of removing that radioactivity, which was subsequently discharged

[163] Environmental Protection Agency. (2012, January 11). *EPA comments on revised draft NYSDEC revised dSGEIS for horizontal drilling and high-volume hydraulic fracturing to develop the Marcellus shale and other low-permeability gas reservoirs* [Press release]. Retrieved June 10, 2014, from http://www.epa.gov/region2/newsevents/pdf/EPA%20R2%20Comments%20Revised%20dSGEIS%20Enclosure.pdf

[164] Rowan, E. L., & Kraemer, T. F. (2012). *Radon - 222 content of natural gas samples from upper and middle Devonian sandstone and shale reservoirs in Pennsylvania: Preliminary data*. United States Geological Survey. (Rep.). Retrieved June 10, 2014, from http://pubs.usgs.gov/of/2012/1159/ofr2012-1159.pdf

[165] Rowan, E. L., Engle, M. A., Kirby, C. S., & Kraemer, T. F. (2011, September 7). *Radium content of oil- and gas-field produced waters in the northern Appalachian basin (USA): Summary and discussion of data*. (Rep United States Geological Survey. Retrieved June 10, 2014, from http://pubs.usgs.gov/sir/2011/5135/ http://water.epa.gov/drink/contaminants/basicinformation/radionuclides.cfm.

into waterways that supply drinking water. Drillers sent some of this waste to New York State. The article states:

> *In December 2009, these very risks led E.P.A. scientists to advise in a letter to New York that sewage treatment plants not accept drilling waste with radium levels 12 or more times as high as the drinking-water standard. The Times found wastewater containing radium levels that were hundreds of times this standard. The scientists also said that the plants should never discharge radioactive contaminants at levels higher than the drinking-water standard.*[166]

- 2008-2009 – The New York State DEC found that wastewater from 11 of 13 vertical wells drilled in New York's Marcellus Shale in 2008 and 2009 contained radium levels ranging from 400 times to nearly 3,400 times EPA's safe level for radium in drinking water. These figures later informed the 2011 study of radium in drilling wastewater conducted by the U.S. Geological Survey.[167]

Occupational health and safety hazards

- December 4, 2014 – Benzene, a naturally occurring component of crude oil and natural gas, is a known carcinogen, with no known threshold of safety. Although the American Petroleum Institute stated in 1948 that "the only absolutely safe concentration … is zero," the organization since then undertook an intensive campaign to combat strict exposure limits. An investigation by the Center for Public Integrity found that, "[f]or decades, the petrochemical industry spent millions on science seeking to minimize the dangers of benzene. … Taken together, the documents — put in context by interviews with dozens of lawyers, scientists, academics, regulators and industry representatives — depict a 'research strategy' built on dubious motives, close corporate oversight and painstaking public relations."[168]

- November 11, 2014 – University of Wisconsin toxicologist Crispin Pierce documented that super-fine dust drifts from facilities that process silica sand for fracking operations. Pierce and his team detected silica dust in ambient air near frac sand operations at levels that that exceed EPA air quality standards by a factor of four. Occupational exposure to respirable crystalline silica is linked in adult workers to silicosis, lung cancer, and pulmonary tuberculosis. Health threats to the general public from frac sand-related air

[166] Urbina, I. (2011, February 26). Regulation lax as gas wells' tainted water hits rivers. *The New York Times*. Retrieved June 10, 2014, from http://www.nytimes.com/2011/02/27/us/27gas.html?pagewanted=all&_r=0
[167] New York State Department of Environmental Conservation. (2011). *Supplemental generic environmental impact statement on the oil, gas and solution mining regulatory program, well permit issuance for horizontal drilling and high-volume hydraulic fracturing to develop the Marcellus shale and other low-permeability gas reservoirs* (5-133, 5-141, 7-60, Appendix 12, Appendix 13, Rep.).
[168] Lombardi, K. (2014, December 4). Benzene and worker cancers: 'An American tragedy.' The Center for Public Integrity. Retrieved from http://www.publicintegrity.org/2014/12/04/16320/benzene-and-worker-cancers-american-tragedy

pollution have not yet been studied directly. One of the first investigations of silica dust levels in the community environment, the Wisconsin study will appear next year in the *National Journal of Environmental Health*.[169]

- November 11, 2014 – A high-pressure water line ruptured, killing one worker and seriously injuring two others during the hydraulic fracturing of an oil well in Weld County, Colorado.[170]

- October 6, 2014 – Toxicologist Peter Thorne, chair of University of Iowa's Department of Occupational and Environmental Health, warned the Winneshiek County Board of Supervisors about potential community impacts and cancer risk of silica exposure from sand used for fracking operations. Thorne's ongoing investigation, which involves air sampling, risk assessments, and inhalation toxicology studies, focuses on the public health hazards of mining, processing and storing sand. His team has documented spikes in silica particulate matter related to the transport of the silica sand by rail. The study aims to determine if mining poses an "unacceptable exposure" to the public and quantify the level of risk. For silica-exposed workers, the National Institute for Occupational Safety and Health (NIOSH) continues to identify needed heath protections. Thorne noted, "Workers handling materials should be using respirators, but most are not."[171]

- September 25, 2014 – The Civil Society Institute's Boston Action Research, in cooperation with Environmental Working Group and Midwest Environmental Advocates, issued a report on the hazards of silica mining. The report noted that frac sand mining is expanding rapidly in the United States and poses a little-understood threat to public health, the environment, and local economies. Given the pace of the drilling and fracking boom, silica extraction could spread to a dozen other states with untapped or largely untapped sand deposits, including Illinois, Maine, Massachusetts, Michigan, Missouri, New York, North Carolina, South Carolina, Pennsylvania, Tennessee, Vermont and Virginia. The *International Business Times* published a summary of the findings.[172] [173]

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[169] Kremer, R. (2014, November 11). High levels of super-fine dust are detected around Wisconsin frac sand mines. *Wisconsin Public Radio*. Retrieved from http://www.wpr.org/high-levels-super-fine-dust-are-detected-around-wisconsin-frac-sand-mines?utm_content=buffer8947f&utm_medium=social&utm_source=facebook.com&utm_campaign=buffer

[170] Paul, J.. (2014, November 11). Brighton man ID'd as victim in fatal Weld County fracking blast. *The Denver Post.* Retrieved from http://www.denverpost.com/news/ci_26937782/brighton-man-idd-victim-fatal-weld-county-fracking?source=pkg

[171] Strandberg, S. (2014, October 6). U of I researcher informs supervisors about frac-sand impact. *Decorah Newspapers.* Retrieved from http://www.decorahnewspapers.com/Content/Home/Home/Article/U-of-I-researcher-informs-supervisors-about-frac-sand-impact/-2/-2/35735

[172] Chapman, E., Hopkins, L., Jasset, A., Sheldon, S., Smith, G. (2014, September 25). Communities at risk: Frac sand mining in the Upper Midwest--A report by Boston Action Research (a project of Civil Society Institute). Retrieved from http://216.30.191.148/fracsandmining/ and www.bit.ly/fracsandmining

[173] Gallucci, M. (2014, September 25). US oil & gas fracking boom could drive silica sand mining operations in 12 more states, environmental groups say. *International Business Times.* Retrieved from http://www.ibtimes.com/us-oil-gas-fracking-boom-could-drive-silica-sand-mining-operations-12-more-states-1695246

- August 29, 2014 – In a peer-reviewed study, NIOSH partnered with oil and gas operators and service companies to evaluate worker exposures to, and internal uptake of, volatile organic chemicals at six sites in Colorado and Wyoming where wells were being prepared for production. The study found benzene in the urine of wellpad workers. Benzene is "naturally present in flowback fluids and the time spent working around flowback and production tanks … appears to be the primary risk factor for inhalation exposures." In some cases, airborne concentrations of benzene exceeded the NIOSH Recommended Exposure Limit concentrations and, in a few instances, the American Conference of Governmental Industrial Hygienists (ACGIH) Threshold Limit Value, "when workers performed work tasks near a point source for benzene emissions."[174]

- July 29, 2014 – As part of an investigation into the health impacts of drilling and fracking on animal health, veterinarian Michelle Bamberger and Cornell biochemist Robert Oswald, published an interview with a twenty-year oil and gas industry worker about his experiences and worker safety. His account included injuries, 16-hour work days, and fatigue, exposure to chemicals, and inadequate health and safety training. "No one out there tells you about stuff that has latency. That is the last thing they are going to do is tell you that something that you are handling will take you out in 20 years or 10 years or cause you some kind of ailment, or you can potentially drag this home to your family."[175]

- July 14, 2014 – As part of an analysis of safety and research needs associated with drilling and fracking, researchers at the Colorado School of Public Health and the College of Health Sciences at the University of Wyoming documented high injury and on-the-job mortality rates among gas and oilfield workers. The occupational fatality rate was 2.5 times higher than that of the construction industry and seven times higher than that of general industry. By contrast, injury rates were lower than the construction industry, suggesting that injuries are underreported. Researchers documented crystalline silica levels above occupational health standards and identified the existence other hazards, including particulate matter, benzene, noise, and radiation. The team called for exposure assessments for both chemical hazards and physical hazards that lead to occupational illness (noise, radioactivity); screening and surveillance systems to assess incidence and prevalence of occupational illness; industry/academic collaboration to conduct occupational epidemiologic studies; and assessment of the effectiveness of industry interventions to reduce exposures.[176]

- July 2014 – The British labor journal *Hazards*, identified health concerns in the drilling and fracking industry: increased rate of death on the job, toxic releases, silica exposure,

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[174] Esswein, E., Snawder, J., King, B., Breitenstein, M., Alexander-Scott, M., and Kiefer, M. (2014). Evaluation of some potential chemical risks during flowback operations in unconventional oil and gas extraction: Preliminary results. *Journal of Occupational and Environmental Hygiene*, *11*, D174-0184.

[175] Bamberger, M., & Oswald, R. (2014). The shale gas revolution from the viewpoint of a former industry insider. *NEW SOLUTIONS: A Journal of Environmental and Occupational Health Policy.* Early Online View. doi: 10.2190/NS.EOV.1

[176] Witter, R.Z., Tenney, L., Clark, S., and Newman, L.S. (2014). Occupational exposures in the oil and gas extraction industry: State of the science and research recommendations. *American Journal of Industrial Medicine, 57*(7), 847-856. Retrieved from http://onlinelibrary.wiley.com/doi/10.1002/ajim.22316/full

and exposure to hydrocarbons and endocrine disruptors. The union that organizes the construction, rig and transport workers on which fracking would rely, agreed at its July 2014 national conference to lobby for a moratorium on fracking because "(d)elegates want union members to be made aware of the dangers of fracking and be advised not to work on fracking sites."[177]

- June 29, 2014, and August 31, 2014 – An initial report and follow-up analysis in *The Columbus Dispatch* examined fire hazards at well pads. In one notable case, malfunctioning hydraulic tubing allowed a wellpad fire in Monroe County, Ohio to spread rapidly, prompting evacuations. Local firefighters had neither the correct equipment nor did they know the chemicals they were trying to extinguish. One firefighter was treated for smoke inhalation. [178] [179]

- May 19, 2014 – Underscoring the dangerous nature of chemicals used in fracking operations, the National Institute for Occupational Safety and Health reported that at least four gasfield workers have died since 2010 from acute chemical exposures during flowback operations and warned that that flowback operations can "result in elevated concentrations of volatile hydrocarbons in the work environment that could be acute exposure hazards." The agency further noted that such volatile hydrocarbons "can affect the eyes, breathing, and the nervous system and at high concentrations may also affect the heart causing abnormal rhythms."[180] [181]

- May 16, 2013 – A NIOSH study revealed that worker exposure to crystalline silica dust from sand used in fracking operations exceeded "relevant occupational health criteria" at all eleven tested sites, and the magnitude of some exposures exceeded National Institute for Occupational Safety and Health limits by a factor of 10 or more. "[P]ersonal respiratory protection alone is not sufficient to adequately protect against workplace exposures." Inhalation of crystalline silica can cause incurable silicosis, lung cancer, chronic obstructive pulmonary disease, kidney disease and autoimmune diseases.[182] Although community exposures distant from mines are possible, there are no

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[177] O'Neill, R. (editor). (July 2014). Chemicals, dust and deaths and the new rush for oil and gas. *Hazards Magazine*. Special Online Report. Retrieved from http://www.hazards.org/oil/fracking.htm#top

[178] Richards, J. S. (2014, June 29). Glitch sparks smoky fire at gas well. *The Columbus Dispatch.* Retrieved from http://www.dispatch.com/content/stories/local/2014/06/29/glitchsparks-smoky-fire-at-gas-well.html

[179] Arenschield, L. (2014, August 31). Fracking fire points out failings. *The Columbus Dispatch* Retrieved from http://www.dispatch.com/content/stories/local/2014/06/29/glitchsparks-smoky-fire-at-gas-well.html

[180] Snawder, J., Esswein, E., King, B., Breitenstein, M., Alexander-Scott, M., Retzer, K., ... Hill, R. (2014, May 19). Reports of worker fatalities during flowback operations [Web log post]. *NIOSH Science Blog.* Retrieved June 9, 2014, from http://blogs.cdc.gov/niosh-science-blog/2014/05/19/flowback/

[181] Iafolla, R. (2014, May 20). Four fatalities linked to used fracking fluid exposure during 'flowback,' NIOSH reports. *Bloomberg BNA*. Retrieved June 9, 2014, from http://www.bna.com/four-fatalities-linked-n17179890610/

[182] Esswein, E. J., Breitenstein, M., Snawder, J., Kiefer, M., & Sieber, W. K. (2013). Occupational exposures to respirable crystalline silica during hydraulic fracturing. *Journal of Occupational and Environmental Hygiene, 10*(7), 347-356. doi: 10.1080/15459624.2013.788352

federal or state standards for silica in ambient air. A first-ever study on public health risks from frac sand is now in progress.[183]

- May 8, 2014 – A report by the AFL-CIO found that the fracking boom has made North Dakota the most dangerous state for U.S. workers—with a fatality rate five times higher than the national average—and that North Dakota's fatality rate has doubled since 2007. The AFL-CIO called North Dakota "an exceptionally dangerous and deadly place to work." U.S. Secretary of Labor Thomas E. Perez called the rising rate of workplace deaths suffered in the oil and gas sector "unacceptable."[184]

- April 24, 2014 – A University of Texas San Antonio report commissioned by the Methodist Healthcare Ministries found that many oil and gas field workers in the Eagle Ford Shale are uninsured or underinsured and that "the most noticeable health impacts so far are work-related illnesses and injuries: heat exhaustion, dehydration, sleep deprivation, exposure to oil and gas spills and accidents." The study also noted that oil and gas production has put strain on healthcare facilities.[185]

- April 10, 2014 –West Virginia University researcher Michael McCawley reported that some of the nation's highest rates of silicosis are in heavily drilled areas within the Northern Panhandle of West Virginia and southwestern Pennsylvania. A disease that hardens the lungs through inflammation and development of scar tissue, silicosis is entirely attributable to exposure to silica dust, a known occupational hazard at drilling and fracking operations. Two years earlier, the Occupational Safety and Health Administration and the National Institute for Occupational Safety and Health issued a joint "Hazard Alert" to warn fracking workers of the health hazards of exposure to silica dust, including silicosis.[186]

- February 25, 2014 – A year-long investigation by the *Houston Chronicle* found that fracking jobs are deadly, with high fatality rates and high rates of serious injury. Within just one year in Texas, 65 oil and gas workers died, 79 lost limbs, 82 were crushed, 92

[183] University of Iowa Environmental Health Sciences Research Center. (2012). Exposure assessment and outreach to engage the public on health risks from frac sand mining. Retrieved June 10, 2014, from http://cph.uiowa.edu/ehsrc/fracsand.html

[184] Picchi, A. (2014, May 8). The most dangerous U.S. state for workers. *CBS News*. Retrieved June 10, 2014, from http://www.cbsnews.com/news/the-most-dangerous-us-state-for-workers/

[185] Ghahremani, Y. (2014, April 24). Fractured Healthcare: Pumping Resources Back into the Eagle For Shale Communities/Executive Summary: Methodist Healthcare Ministries and Center for Community and Business Research at the University of Texas San Antonio. Retrieved June 20, 2014, from http://www.joomag.com/en/newsstand/fractured-healthcare-pumping-resources-back-into-the-eagle-ford-shale-communities-apr-2014/0368470001398347080

[186] Hicks, I. (2014, April 10). Gas workers risk silica exposure. *The Intelligencer, Wheeling News-Register*. Retrieved June 10, 2014, from http://www.news-register.net/page/content.detail/id/598589/Gas-Workers-at-Risk-Of-Silica-Ex---.html

suffered burns and 675 broke bones. From 2007 to 2012, at least 664 US workers were killed in oil and gas fields.[187][188]

- December 27, 2013 –National Public Radio (NPR) reported spiking rates of fatalities related to oil and gas drilling operations, which had increased more than 100 percent since 2009. NPR noted that in the previous year, 138 workers were killed on the job, making the fatality rate among oil and gas workers nearly eight times higher than the all-average rate of 3.2 deaths for every 100,000 workers across all industries.[189]

- October 30, 2012 – In a policy statement, the American Public Health Association (APHA) asserted that, high-volume horizontal hydraulic fracturing (HVHF) "poses potential risks to public health and the environment, including groundwater and surface water contamination, climate change, air pollution, and worker health." The statement also noted that the public health perspective has been inadequately represented in policy processes related to HVHF.[190] The policy statement added:

  > *[H]ydraulic fracturing workers are potentially exposed to inhalation health hazards from dust containing silica. There may also be impacts on workers and communities affected by the vastly increased production and transport of sand for HVHF. Inhalation of fine dusts of respirable crystalline silica can cause silicosis. Crystalline silica has also been determined to be an occupational lung carcinogen.*

- 2005 – A researcher at Stanford University examined hazards associated with oil and gas extraction from exposure to radiation and determined that inhalation of high-levels of radon gas is a serious concern to workers and those living nearby. "…[G]aseous radon (222Rn) is concentrated in ethane and propane fractions due to the fact that the boiling point of radon lies between those of propane and ethane. Elevated Rn activity concentration values have been measured at several processing plant sites…. It is well known that the radiological impact of the oil and gas-extracting and processing industry is not negligible."[191]

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[187] Olsen, L. (2014, February 22). Houston Chronicle exclusive: Drilling boom, deadly legacy. Retrieved June 10, 2014, from http://www.houstonchronicle.com/news/special-reports/article/Houston-Chronicle-exclusive-Drilling-boom-5259311.php#/0

[188] Hsieh, S. (2014, February 25). Why are so many workers dying in oil fields? Retrieved June 10, 2014, from http://www.thenation.com/blog/178523/why-are-so-many-workers-dying-oil-fields

[189] Schneider, A., & Geewax, M. (2013, December 27). On-the-job deaths spiking as oil drilling quickly expands. Retrieved June 10, 2014, from http://www.npr.org/2013/12/27/250807226/on-the-job-deaths-spiking-as-oil-drilling-quickly-expands

[190] American Public Health Association. (2012, October 30). The environmental and occupational health impacts of high-volume hydraulic fracturing of unconventional gas reserves. Retrieved June 10, 2014, from http://www.apha.org/advocacy/policy/policysearch/default.htm?id=1439

[191] Steinhäusler, F. (2005). Radiological impact on man and the environment from the oil and gas industry: Risk assessment for the critical group. *Nato Science Series: IV: Earth and Environmental Sciences.* DOI: 10.1007/1-4020-2378-2_19. http://rd.springer.com/chapter/10.1007/1-4020-2378-2_19

Public Health Effects, Measured Directly

- October 2, 2014 – According to researchers from the University of Pennsylvania's Center of Excellence in Environmental Toxicology, an increasing number of gas wells in Pennsylvania is significantly correlated with inpatient rates of hospitalization. The research team collected data from seven different insurance providers for three counties; the study's publication is forthcoming.[192]

- September 11, 2014 – In Texas, commercial vehicle accidents have increased more than 50 percent since 2009 when the state's ongoing drilling and fracking boom began, according to an investigation by the *Houston Chronicle* and Houston Public Media News 88.7. "For six decades, highway deaths have dropped steadily all across the United States …. But in Texas all motor vehicle fatalities – and accidents involving commercial trucks – have turned back upward since the state's oil drilling and fracking boom began in 2008." This rising motor vehicle death toll is especially felt in formerly rural counties in the Eagle Ford and Permian Basin, now places of heavy drilling and fracking. A new "Road Check" program finds annually, "… 27 to 30 percent of Texas' commercial trucks shouldn't be operating at all due to potentially life-threatening safety problems like defective brakes, bald tires, inoperable safety lights and unqualified, unfit or intoxicated drivers."[193]

- September 10, 2014 – A Yale University-led study of 492 people found that those who live near gas wells in southwestern Pennsylvania have a higher prevalence of reported skin conditions and upper respiratory conditions than those further away. The conditions were more common in households less than one kilometer from gas wells, compared to those more than two kilometers away. The authors of this study, the largest to date on the link between reported symptoms and natural gas drilling activities, say that their findings are "… consistent with earlier reports of respiratory and dermal conditions in persons living near natural gas wells." They also cite literature demonstrating the biological plausibility of a link between oil and gas extraction activities and both categories of health effects reported.[194]

- August 3, 2014 – Hospitals in the Bakken Shale region reported a sharp rise in ambulance calls and emergency room visits after 2006. "Mercy Medical Center in Williston and the Tioga Medical Center in neighboring Williams County saw their ambulance runs increase by more than 200 percent. Tioga's hospital saw a staggering leap in trauma patients by

[192] Skrapits, E. (2014, October 2). Study: More gas wells in area leads to more hospitalizations. *The Citizen's Voice*. Retrieved from http://citizensvoice.com/news/study-more-gas-wells-in-area-leads-to-more-hospitalizations-1.1763826

[193] Olsen,L. (2014, 11 September). Fatal truck accidents have spiked during Texas' ongoing fracking and drilling boom. *Houston Chronicle.* Retrieved from http://www.houstonchronicle.com/news/article/Fracking-and-hydraulic-drilling-have-brought-a-5747432.php?cmpid=email-premium&cmpid=email-premium&t=1a9ca10d49c3f0c8a9#/0

[194] Rabinowitz, P.M., Slizovskiy, I.B., Lamers, V., Trufan, S.J., Holford, T.R., Dziura, J.D., Peduzzi, P.N., Kane, M.J., Reif, J.S., Weiss, T.R. and Stowe, M.H. (2014). Proximity to natural gas wells and reported health status: Results of a household survey in Washington County, Pennsylvania. *Environmental Health Perspectives.* Advance online publication. http://dx.doi.org/10.1289/ehp.1307732

1,125 percent. Mercy had a 373 percent increase." Drugs (including overdoses of prescription drugs, methamphetamine, and heroin) explain many of the cases, with oilfield related injuries such as "fingers crushed or cut off, extremity injuries, burns and pressure burns" accounting for 50% of the cases in one of the region's hospital emergency rooms.[195]

- May 21, 2014 – Raising questions about possible links to worsening air pollution from the Uintah Basin's 11,200 oil and gas wells, health professionals reported that infant deaths in Vernal, Utah, rose to six times the normal rate over the past three years. Physician Brian Moench said, "We know that pregnant women who breathe more air pollution have much higher rates of virtually every adverse pregnancy outcome that exists …. And we know that this particular town is the center of an oil and gas boom that's been going on for the past five or six years and has uniquely high particulate matter and high ozone."[196] Although it formerly had pristine air quality, Uintah County, Utah received a grade "F" for ozone in the American Lung Association's 2013 State of the Air Report.[197]

- January 28, 2014 – Congenital heart defects, and possibly neural tube defects in newborns, were associated with the density and proximity of natural gas wells within a 10-mile radius of mothers' residences in a study of almost 25,000 births from 1996-2009 in rural Colorado. The researchers note that natural gas development emits several chemicals known to increase risk of birth defects (teratogens).[198]

  January 4, 2014 –Preliminary data from researchers at Princeton University, Columbia University and MIT showed elevated rates of low birthweight among infants born to mothers living near drilling and fracking operations during their pregnancies.[199]

- October, 2013 – A preliminary 2013 Cornell University study of the health impacts of oil and gas extraction on infant health in Colorado found that proximity to wells—linked with air pollutants from fracking operations—was associated with reductions in average birthweight and length of pregnancy as well as increased risk for low birthweight and premature birth.[200] A study by the same author, currently under review, which analyzed births to Pennsylvania mothers residing close to a shale gas well in Pennsylvania from

[195] Bryan, K.J. (2014, August 3). Drugs, oilfield work, traffic pushing more people through doors of Watford City ER. *Bakken Today*. Retrieved from http://www.bakkentoday.com/event/article/id/37101/

[196] S Schlanger, Z. (2014, May 21). In Utah boom town, a spike in infant deaths raises questions. *Newsweek*. Retrieved June 10, 2014, from http://www.newsweek.com/2014/05/30/utah-boom-town-spike-infant-deaths-raises-questions-251605.html

[197] American Lung Association. (2013). American Lung Association state of the air 2013. Retrieved June 10, 2014, from http://www.stateoftheair.org/2013/states/utah/uintah-49047.html

[198] McKenzie, L. M., Guo, R., Witter, R. Z., Savitz, D. A., Newman, L. S., & Adgate, J. L. (2014). Birth outcomes and maternal residential proximity to natural gas development in rural Colorado. *Environmental Health Perspectives, 122*, 412-417. doi: 10.1289/ehp.1306722

[199] Whitehouse, M. (2014, January 4). Study shows fracking is bad for babies. *Bloomberg*. Retrieved June 10, 2014, from http://www.bloombergview.com/articles/2014-01-04/study-shows-fracking-is-bad-for-babies

[200] Hill, E. L. (2013, October). The impact of oil and gas extraction on infant health in Colorado. Retrieved June 10, 2014, from http://www.elainelhill.com/research

2003-2010, also identified increased risk of adverse effects. This includes low birth weight, as well as a 26% increase in APGAR scores under 8 (APGAR—or American Pediatric Gross Assessment Record—is a measure of newborn responsiveness. Scores of less than 8 predict an increase in the need for respiratory support).[201]

- August 26, 2013 – Medical experts at a rural clinic in heavily-drilled Washington County, PA reported case studies of 20 individuals with acute symptoms consistent with exposure to air contaminants known to be emitted from local fracking operations.[202] [203]

- May 2, 2013 – Reports of symptoms commonly linked to exposure to elevated levels of ground-level ozone associated with gas drilling have been documented in shale-heavy states. In Pennsylvania in 2012, a study of more than 100 state residents living near gas facilities found that reported health symptoms closely matched the scientifically established effects of chemicals detected through air and water testing at those nearby sites, and that those negative health effects occurred at significantly higher rates in households closer to the gas facilities than those further away.[204] Indicative of the growing prevalence of such health impacts in the state, a poll showed that two-thirds of Pennsylvanians support a moratorium on fracking because of concern about negative health impacts.[205]

Noise pollution, light pollution and stress

- December 1, 2014 – Range Resources Inc. warned supervisors in Pennsylvania's Donegal Township that a "big burn" natural gas flare will continue for as long as a week and "will produce a continuous noise of as much as 95 decibels at the well pad. Sustained decibel levels between 90 and 95 can result in permanent hearing loss, but workers will be equipped with ear protection." Township supervisor Doug Teagarden expressed concern for residents, saying, "They told us the flare would be double the size of other

[201] Hill, E.L. (2013, December). Shale gas development and infant health: Evidence from Pennsylvania (under review). Retrieved June 23, 2014 from http://www.elainelhill.com/research.
[202] Abrams, L. (2013, August 26). Fracking's real health risk may be from air pollution. *Salon*. Retrieved June 10, 2014, from http://www.salon.com/2013/08/26/frackings_real_health_risk_may_be_from_air_pollution/
[203] Dyrszka, L., Nolan, K., & Steingraber, S. (2013, August 27). *Statement on preliminary findings from the Southwest Pennsylvania Environmental Health Project study* [*Press release*]. Concerned Health Professionals of NY. Retrieved June 10, 2014, from http://concernedhealthny.org/statement-on-preliminary-findings-from-the-southwest-pennsylvania-envir...
[204] Steinzor, N., Subra, W., & Sumi, L. (2013). Investigating links between shale gas development and health impacts through a community survey project in Pennsylvania. *NEW SOLUTIONS: A Journal of Environmental and Occupational Health Policy, 23*(1), 55-83. doi: 10.2190/NS.23.1.e
[205] Phillips, S. (2013, May 14). Poll shows support for a drilling moratorium in Pennsylvania. *StateImpact*. Retrieved June 10, 2014, from http://stateimpact.npr.org/pennsylvania/2013/05/14/poll-shows-support-for-a-drilling-moratorium-in-pennsylvania/

well flares, and the noise will be like a siren on a firetruck …. There are houses within a couple of hundred yards of the well pad, and those folks are going to hear it."[206]

- November 6, 2014 –Sakthi Karunanithi, Director of Public Health in Lancashire, UK, reported on a Health Impact Assessment (HIA) of the two proposed shale gas exploration sites in Lancashire. Karunanithi's study determined that key risks to the health and wellbeing of the residents who live near the two proposed sites in Lancashire include stress and anxiety from uncertainty that could lead to "poor mental wellbeing," and noise-related health effects due to continuous drilling. The HIA also noted a lack of public trust and confidence.[207] [208]

- September 2014 – The Ohio Shale Country Listening Project, a collaborative effort to solicit, summarize, and share the perspectives and observations of those directly experiencing the shale gas build out in eastern Ohio, found that the more shale gas wells a community has, the less popular the oil and gas industry becomes. Many residents reported that they had not experienced the economic benefits promised by the oil and gas industry. They complained of increased rents and costs of gas and groceries, an influx of out-of-state workers, more vehicular accidents, road destruction from large trucks, and damaged landscape and cropland. Locals reported feeling less secure and more financially strapped.[209]

- June 20, 2014 – In its discussion of "Oil and Gas Drilling/Development Impacts," the U.S. Office of Indian Energy and Economic Development detailed noise pollution from bulldozers, drill rigs, diesel engines, vehicular traffic, blasting, and flaring of gas. "If noise-producing activities occur near a residential area, noise levels from blasting, drilling, and other activities could exceed the EPA guidelines. The movement of heavy vehicles and drilling could result in frequent-to-continuous noise …. Drilling noise would occur continuously for 24 hours per day for one to two months or more depending on the depth of the formation."[210] Exposure to chronic noise can be deadly. The World Health Organization has documented the connection between environmental noise and health effects, including cardiovascular disease, cognitive impairment, sleep disturbance, and

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[206] Hopey, D. (2014, December 1). Gas flare to light up part of Washington County. *Pittsburgh Post Gazette.* Retrieved from http://powersource.post-gazette.com/powersource/companies-powersource/2014/12/01/Gas-flare-to-light-up-part-of-Washington-County/stories/201411250224

[207] Karunanithi, S. (2014, November 6). Potential health impacts of the proposed shale gas exploration sites in Lancashire. *Reported at a meeting of the Lancashire County Council Cabinet, Thursday, 6th November, 2014 at 2.00 pm in Cabinet Room 'B' - County Hall, Preston, Item 9 on the agenda(1-68).* Retrieved from http://council.lancashire.gov.uk/documents/b11435/Potential%20Health%20Impacts%20of%20the%20Proposed%20Shale%20Gas%20Exploration%20Sites%20in%20Lancashire%2006th-Nov-2014%2014.pdf?T=9

[208] Dunkley, E. (2014, November 7). Fracking in Lancashire 'may affect mental health', report finds. *BBC NEWS Lancashire.* Retrieved from http://www.bbc.com/news/uk-england-lancashire-29944212

[209] Ohio Organizing Collaborative (OOC)'s Communities United for Responsible Energy (CURE), with support from the Ohio Environmental Council (OEC), FracTracker.org, and Laborers Local 809 of Steubenville. (2014, September). Ohio Shale Country Listening Project. Retrieved from http://carrollconcernedcitizens.org/uploads/2014_Shale_Report__small_.pdf

[210] Oil and Gas Drilling/Development Impacts. (n.d.). *Oil and gas drilling/development impacts*. Retrieved June 20, 2014, from http://teeic.indianaffairs.gov/er/oilgas/impact/drilldev/index.htm

tinnitus. At least one million "healthy life years" are lost every year from traffic-related noise in the western part of Europe.[211]

- February 24, 2014 – In a review of the health effects from unconventional gas extraction published in the journal *Environmental Science & Technology*, leading researchers noted, "Noise exposure is a significant hazard due to the presence of multiple sources, including heavy equipment, compressors, and diesel powered generators. Loud continuous noise has health effects in working populations. It is likely that exposure to noise is substantial for many workers, and this is potentially important for health because drilling and servicing operations are exempt from some sections of the Occupational Safety and Health Administration noise standard." They noted that research should investigate stressors such as noise and light in the context of drilling and fracking operations in order to understand the overall effect of chemical and physical stressors together.[212]

  May 30, 2014 – *The Denver Post* reported that in order to help meet Colorado's noise limits for fracking operations in suburban neighborhoods (and partially block the glare of floodlights), Encana Oil and Gas erected 4-inch-thick polyvinyl walls up to 32 feet high and 800 feet long. Residents said that the plastic walls do not completely solve the problem.[213]

- October 25, 2013 – An analysis of well location and census data by the *Wall Street Journal* revealed that at least 15.3 million Americans now live within a mile of a well that has been drilled since 2000. According to this investigation, the fracking boom has ushered in "unprecedented industrialization" of communities across wide swaths of the nation and, with it, "24/7" industrial noise, stadium lighting, earth-moving equipment, and truck traffic.[214]

- April 16, 2013 – In a presentation on oil field light pollution for a conference on "Sustainable Environment and Energy: Searching for Synergies," Roland Dechesne of the Royal Astronomical Society of Canada described problems of "light trespass," glare, and poorly-aimed fixtures in oil fields in Alberta. He described resulting "mass waterfowl mortality" linked to artificial illumination and other biochemical impacts of light pollution on wildlife, as well as the possibility of these effects on humans, including circadian disruption, melatonin suppression and possible resulting hormonally-linked

[211] Rodier, G. (2011, June 1). Burden of disease from environmental noise - Quantification of healthy life years lost in Europe. *WHO*. Retrieved June 20, 2014, from http://www.who.int/quantifying_ehimpacts/publications/e94888/en/
[212] Adgate, J. L., Goldstein, B. D., & McKenzie, L. M. (2014). Potential public health hazards, exposures and health effects from unconventional natural gas development [Abstract]. *Environmental Science & Technology*. doi: 10.1021/es404621d
[213] Finley, B. (2014, May 29). Oil and gas industry building giant walls to try to ease impact. *The Denver Post*. Retrieved June 20, 2014, from http://www.denverpost.com/ci_25859469/oil-and-gas-industry-building-giant-walls-try
[214] Gold, R. and McGinty T. (2014, Oct. 25). Energy boom puts wells in America's backyards. *The Wall Street Journal.* Retrieved June 21, 2014, from http://online.wsj.com/news/articles/SB10001424052702303672404579149432365326304.

diseases.[215] Known to have ecological impacts, outdoor light pollution from drilling and fracking operations may also be linked to artificial light-associated health effects documented in humans, including breast cancer.[216]

- April, 2013 – Led by the University of Pittsburgh Graduate School of Public Health, a study of community members living in proximity to Marcellus Shale drilling in Pennsylvania found adverse impacts to mental health, with stress the most frequently-reported symptom. At least half of all respondents in each set of interviews reported these specific stressors, including: being taken advantage of; health concerns; concerns/complaints ignored; corruption; denied information or provided with false information. Many also reported the desire to move or leave community, estrangement from community, and financial damages. Researchers noted that stress can result in direct health impacts.[217] Notably, mounting evidence indicates that chronic stress magnifies individuals' susceptibility to effects of pollution; for children, this interactive effect can begin during prenatal life.[218]

- September 7, 2011 – A study by researchers at Boise State University and Colorado State University at Fort Collins modeled the potential impacts of compressor station noise from oil and gas operations on Mesa Verde National Park in Colorado. The study found the sound of 64 compressors outside Mesa Verde elevated the sound level within the park by 34.8 decibels on average, and by 56.8 decibels on the side of the park located closest to the compressors. According to the EPA, 55 decibels is the highest "safe noise level" to avoid damage to the human ear.[219]

Earthquakes and seismic activity

- October 23, 2014 – Researchers from the U.S. Geological Survey and the Global Seismological Services in Golden, Colorado, linked a 2011 magnitude 5.3 earthquake in Colorado, which damaged the foundations of several homes, to underground disposal of

[215] Dechesne, R. (2013). Limiting oil field light pollution for safety and the environment. Sustainable Environment and Energy CPANS 2013 Conference. Retrieved June 20, 2014, from http://www.cpans.org/assets/Uploads/Presentations/NewFolder/Session-46Roland-Dechesne.pdf

[216] Chepesiuk, R. (2009). Missing the dark: Health effects of light pollution. *Environ Health Perspect*. *117*(1): A20–A27.

[217] Ferrar, K.J., Kriesky, J., Christen, C.L., Marshall, L.P., Malone, S.L., Sharma, R.K., Michanowicz. D.R., Goldstein, B.D. (2013). Assessment and longitudinal analysis of health impacts and stressors perceived to result from unconventional shale gas development in the Marcellus Shale region. *Int J Occup Environ Health*. *19*(2),104-112. doi: 10.1179/2049396713Y.0000000024.

[218] Cooney, C.M. (2011). Stress–pollution interactions: An emerging issue in children's health research. *Environ Health Perspect 119*, a430-a435. http://dx.doi.org/10.1289/ehp.119-a430

[219] Barber, J.R., C.L. Burdett, S.E. Reed, K.A. Warner, C. Formichella, K.R. Crooks, D.M. Theobald, and K.M. Fristrup (2011). Anthropogenic noise exposure in protected natural areas: estimating the scale of ecological consequences. *Landscape Ecology 26*(9),1281-1295.

fracking wastewater. The study determined that the earthquake ruptured an 8 to 10 kilometer-long segment of normal faults–an unexpectedly long length for a magnitude 5.3 earthquake–suggesting that wastewater disposal may have triggered a low stress drop.[220] Lead author Bill Barnhart, a U.S. Geological Survey geophysicist, told *Reuters*, "We saw a big increase in seismicity starting in 2001, including magnitude 5 earthquakes, in many locations in the basin, and that coincided with a surge in gas production and injection of wastewater."[221]

- September 23, 2014 – Youngstown State University geologist Ray Beiersdorfer described increased seismic activity in Youngstown, Ohio in a essay that explores how that fracking and fracking-related processes are causing "earthquake epidemics" across the United States.[222]

- September 15, 2014 – Researchers at the National Energy Technology Laboratory teamed up with researchers from industry and academia to publish data and analysis from a closely watched project that involved field monitoring of the induced fracturing of six horizontal Marcellus Shale gas wells in Greene County, Pennsylvania. Touted in earlier media reports as demonstrating that, during short-term follow-up, fracking chemicals injected into these six wells did not spread to overlying aquifers[223], the study's most notable finding is striking documentation of fractures from three of the six wells extending vertically to reach above an overlying rock layer previously thought to create an impenetrable "frac barrier" (that is, an upper barrier to fracture growth). In one case, a fracture extended vertically 1,900 feet, a surprisingly far distance. No pre-existing fault had been detected at this location, suggesting that small "pre-existing fractures or small-offset (sub-seismic) faults may have focused the energy of hydraulic fractures on certain areas…." Perhaps because of the extremely small sample size and a design focused primarily on monitoring for potential gas and fluid migration, the study's analysis includes no discussion of the seismic relevance of extremely long, vertical induced fractures.[224]

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[220] Barnhart, W. D., H. M. Benz, G. P. Hayes, J. L. Rubinstein, and E. Bergman (2014), Seismological and geodetic constraints on the 2011 Mw5.3 Trinidad, Colorado earthquake and induced deformation in the Raton Basin, *J. Geophys. Res. Solid Earth*, *119*, 7923–7933, doi:10.1002/2014JB011227. Retrieved from http://onlinelibrary.wiley.com/doi/10.1002/2014JB011227/abstract

[221] Zuckerman, L. (2014, October 29). Gas wastewater likely triggered 2011 quake in Colorado: USGS. *Reuters.* Retrieved from http://www.reuters.com/article/2014/10/29/us-usa-earthquake-colorado-idUSKBN0II2NP20141029

[222] Beiersdorfer, R. (2014, September 23). View: On fracking, earthquakes and Indian Point. *Journal Online.* Retrieved from http://www.lohud.com/story/opinion/contributors/2014/09/23/view-geologist-warns-fracking-ties-earthquakes/16100755/

[223] Begos, K. (2014, July 19). DOE study: Fracking chemicals didn't taint water. *Associated Press*. Retrieved from http://bigstory.ap.org/article/ap-study-finds-fracking-chemicals-didnt-spread

[224] Hammack, R., Harbert, W., Sharma, S., et al. (2014). An evaluation of fracture growth and gas/fluid migration as horizontal Marcellus Shale gas wells are hydraulically fractured in Greene County, Pennsylvania. *NETL-TRS-3-2014: EPAct Technical Report Series. US Dept of Energy, National Energy Technology Laboratory*: Pittsburgh PA. Retrieved from http://www.netl.doe.gov/File%20Library/Research/onsite%20research/publications/NETL-TRS-3-2014_Greene-County-Site_20140915_1_1.pdf

- September 15, 2014 – Scientists from the U.S. Geological Society ascribed causality to wastewater injection wells from coal-bed methane production for increases in seismic activity in New Mexico and Colorado and, in particular, for an earthquake that measured magnitude 5.3 in Colorado in 2011, the second largest earthquake to date for which there is clear evidence that the earthquake sequence was induced by fluid injection.[225]

- September 6, 2014 – The Ohio Department of Natural Resources suspended operations at two deep-injection wells for fracking wastewater near Warren in northeastern Ohio after discovering evidence that the operation possibly caused a 2.1-magnitude earthquake. The injection well operator, American Water Management Services, had recently received permission to increase pressures at the site of the wells. In 2012, Governor John Kasich had halted disposal of fracking wastewater surrounding a well site in the same region after a series of earthquakes were tied to a deep-injection well. The company that ran that well has disputed the link. The state placed seismic-monitoring devices in the Warren area under protocols adopted after the series of earthquakes in nearby Youngstown.[226]

- September 1, 2014 – Explaining the need for increased seismic monitoring, Andrew Beaton, director of the Alberta Geological Survey (AGS), stated that over a long period of time, stresses increase in and around an injection well bore. Seismic movement can be caused if the rate of injection is too fast or if there is a geological feature, such as a fault or fracture in nearby areas. Although Albertans in rural areas have been reporting for years that they can feel tremors under their feet near oil and gas activity, especially around areas of fracking, the Alberta Energy Regulator noted that deep well injections have been shown to create more of an earthquake hazard then hydraulic fracturing. Alberta experienced 819 earthquakes between 1918 and 2009. In comparison, Saskatchewan recorded 13 in the same time and British Columbia recorded more than 1,200 earthquakes in 2007 alone. There are currently 24 seismic monitors in Alberta, which are tied into other networks, such as those belonging to Environment Canada, University of Calgary and University of Alberta.[227]

- August 26, 2014 – In a first-of-its-kind lawsuit, a resident of Prague, Oklahoma, sued two energy companies after rocks fell from her chimney and injured her leg during an earthquake of greater than magnitude 5. The lawsuit claims that underground injection of fracking wastewater conducted by New Dominion LLC, based in Oklahoma City, and Spess Oil Company, based in Cleveland, Oklahoma, is causing shifts in fault lines

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[225] Rubinstein, J.L., Ellsworth, W.L., Arthur McGarr, A. and Benz, H.M. (2014), The 2001-present induced earthquake sequence in the Raton Basin of Northern New Mexico and Southern Colorado [abstract]. *Bulletin of the Seismological Society of America*. Retrieved September 15, 2014 from http://www.bssaonline.org/content/104/5/2162.abstract?stoc

[226] Smyth, J.C. (2014, September 6). Ohio halts injections at two wells for fracking wastewater after quake. *Associated Press*. Retrieved from http://www.dispatch.com/content/stories/local/2014/09/06/ohio-halts-2-wells-for-fracking-wastewater-after-quake.html

[227] Maclean, R. (2014, September 1). Earthquake hazard linked with deep well injection in Alberta: Deep well disposal of oilfield waste over time leads to increased earthquake risk. *CBC News*. Retrieved from http://www.cbc.ca/news/canada/calgary/earthquake-hazard-linked-with-deep-well-injection-in-alberta-1.2751963

resulting in earthquakes.[228]

- July 31, 2014 – William Ellsworth, a research geophysicist at the U.S. Geological Survey Earthquake Science Center, reported that the U.S. Geological Survey is developing a hazard model that takes induced earthquakes into account. In addition, residents of Oklahoma, where a sharp spike in earthquake activity has been noted over the past decade, are showing an increased interest in obtaining earthquake insurance.[229]

- July 3, 2014 – Using data from the Oklahoma Corporation Commission, a team of researchers led by Katie Keranen, a geophysics professor at Cornell University, found that a steep rise in earthquakes in Oklahoma can be explained by fluid migration from wastewater disposal wells. Moreover, injected fluids in high-volume wells triggered earthquakes over 30 kilometers (over 18 miles) away. All of the wells analyzed were operated in compliance with existing regulations. Similar mechanisms may function in other states with high volumes of underground injection of wastewater from unconventional oil and gas production.[230] Reporting on the study and the increase in earthquakes across the United States and the link to fracking and wastewater disposal, the *Associated Press* noted that some states, including Ohio, Oklahoma and California, have introduced new rules compelling drillers to measure the volumes and pressures of their injection wells as well as to monitor seismicity during fracking operations.[231]

- July 1, 2014 – Seismologists linked the emergence of a giant sinkhole that formed in August 2012 near Bayou Corne in southeast Louisiana to tremors (earthquakes) caused by high-pressure pulses of either natural gas or water charged with natural gas. The surges of natural gas that caused the explosive tremors (earthquakes) may have weakened the salt cavern and caused its collapse. Alternatively, part of the salt cavern may have collapsed, causing a nearby gas pocket to give off surges of gas, later followed by the complete collapse of the salt cavern. These findings help illuminate the role of pressurized fluids in triggering seismic events.[232]

- June 24, 2014 – Following two earthquakes within a one-month period, the Colorado Oil and Gas Conservation Commission directed High Sierra Water Services to stop disposing

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[228] Rangel, L. (2014, August 26). Prague resident files lawsuit against two Okla. energy companies following earthquake injury. *Newschannel 4 (kfor.com)*. Retrieved from http://kfor.com/2014/08/26/prague-resident-files-lawsuit-against-two-okla-energy-companies-following-earthquake-injury/

[229] Eaton, J. (2014, July 31). Oklahoma grapples with earthquake spike—and evidence of industry's role: Spike in seismic activity is linked with oil and gas wastewater disposal. *National Geographic*. Retrieved from http://news.nationalgeographic.com/energy/2014/07/140731-oklahoma-earthquake-spike-wastewater-injection/

[230] Keranen, K.M., Weingarten, M., Abers, G.A., Bekins, B.A., and Ge, S. (2014). Sharp increase in central Oklahoma seismicity since 2008 induced by massive wastewater injection. *Science*, *345*(6195), 448-451 doi: 10.1126/science.1255802.

[231] Schmall, E. and Jouzapavicius, J. (2014, July 14). States with fracking see surge in earthquake activity. *Associated Press*. Retrieved from http://www.huffingtonpost.com/2014/07/14/fracking-earthquake_n_5585892.html

[232] Nayak, A. and Dreger, D. (2014, July 1). Moment tensor inversion of seismic events associated with the sinkhole at Napoleonville Salt Dome, Louisiana. Bulletin of Seismological Society of America. Retrieved from http://www.seismosoc.org/society/press_releases/BSSA_104-4_Nayak_and_Dreger_Press_Release.pdf

wastewater into one of its Weld County injection wells. Monitoring by a team of seismologists from the University of Colorado had picked up evidence of continuing low-level seismic activity near the injection site, including a 2.6-magnitude event less than a month following a 3.4 magnitude earthquake that shook the Greeley area on May 31, 2014.[233]

- May 2, 2014 – The U.S. Geological Survey and Oklahoma Geological Survey jointly issued an official earthquake warning for Oklahoma, pointing out that the number of earthquakes in the state has risen 50 percent since just October—when the two agencies had issued a prior warning. The advisory stated that this dramatic increase in the frequency of small earthquakes "significantly increases the chance for a damaging quake in central Oklahoma." Injection wells used for the disposal of liquid fracking waste have been implicated as the presumptive cause of the earthquake swarm. According to the Oklahoma Geological Survey, about 80 percent of the state of Oklahoma is closer than ten miles from an injection well.[234] Since the joint earthquake advisory was released in May, the number of earthquakes in Oklahoma has continued to rise. During the first four months of 2014, Oklahoma had experienced 109 earthquakes of magnitude 3 or higher on the Richter scale. By mid-June, the number of earthquakes had topped 200, exceeding the frequency of earthquakes in California.[235]

- May 2, 2014 – At the annual meeting of the Seismological Society of America, leading geologists warned that the risks and impacts of earthquakes from fracking and injection wells are even more significant than previously thought, pointing out that such earthquakes could occur tens of miles away from wells themselves, including quakes greater than 5.0 magnitude on the Richter scale. Justin Rubinstein, a research geophysicist at the U.S. Geological Survey said, "This demonstrates there is a significant hazard. We need to address ongoing seismicity."[236] Seismologist Gail Atkinson reported, "We don't know how to evaluate the likelihood that a [fracking or wastewater] operation will be a seismic source in advance."[237]

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[233] Tomasic, J. (2014, June 24). Colorado drilling regulators halt injection-well activity in reaction to Greeley quake. *Colorado Independent*. Retrieved from http://www.coloradoindependent.com/147934/colorado-drilling-regulators-halt-injection-well-activity-in-reaction-to-greeley-quake (see also Baker, B. (2014, June 24). Colorado regulators halt fracking wastewater injection operation after earthquake strikes area for second time in a month. *Ecowatch*. Retrieved from http://ecowatch.com/2014/06/24/colorado-wastewater-injection-earthquake/)

[234] Geological Survey Joint Statement. (2014, May 2). Record number of Oklahoma tremors raises possibility of damaging earthquakes. United States Geological Survey. Retrieved June 23, 2014, from http://earthquake.usgs.gov/regional/ceus/products/newsrelease_05022014.php

[235] Branson-Potts, H. (2014, June 17). Oklahoma coming to terms with unprecedented surge in earthquakes. *Los Angeles Times*. Retrieved June 23, 2014, from http://www.latimes.com/nation/la-na-oklahoma-earthquakes-20140618-story.html#page=1

[236] Walsh, B. (2014, May 1). The seismic link between fracking and earthquakes. *Time*. Retrieved June 9, 2014, from http://time.com/84225/fracking-and-earthquake-link/

[237] Kiger, P. J. (2014, May 2). Scientists warn of quake risk from fracking operations. *National Geographic*. Retrieved June 9, 2014, from http://news.nationalgeographic.com/news/energy/2014/05/140502-scientists-warn-of-quake-risk-from-fracking-operations/

- April 11, 2014 – State geologists reported a link between fracking and a spate of earthquakes in Ohio, prompting the Ohio Department of Natural Resources to place a moratorium on drilling in certain areas and to require greater seismic monitoring.[238]

- April 3, 2014 – Researchers in Mexico linked earthquakes to fracking in the Eagle Ford Shale. They also noted a statistical correlation between seismic activity and fracking, particularly in Nuevo Leon, which registered at least 31 quakes between 3.1 and 4.3 on the Richter scale.[239]

- April, 2014 – Researchers from the University of Alberta and the Alberta Geological Survey published a study in the *Journal of Geophysical Research* that found waste-water injection in Alberta is highly correlated with spikes seismic activity between October, 2006 and March, 2012.[240] On November 13, 2014, *CBC News* reported on a more recent increase in earthquakes, which may also be linked to injection wells.[241]

- March 7, 2014 – U.S. Geological Survey researchers published a study confirming that Oklahoma's damaging 5.7 magnitude earthquake in 2011 was caused by fracking wastewater injection.[242] The author of the study, seismologist Elizabeth Cochran with the U.S. Geological Survey, noted, "Even if wastewater injection only directly affects a low-hazard fault, those smaller events could trigger an event on a larger fault nearby."[243]

- January 30, 2014 – A U.S. Geological Survey research team linked the rise in earthquakes in Colorado to fracking wastewater injection wells and announced that a study will be published in six to nine months.[244]

- December 12, 2013 – *The New York Times* detailed the growing link between fracking wastewater injection wells and earthquakes, as well as between fracking itself and earthquakes, with a focus on Oklahoma and a recent magnitude 4.5 earthquake there. As

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[238] Dave, P. (2014, April 12). Ohio finds link between fracking and sudden burst of earthquakes. *Los Angeles Times*. Retrieved June 9, 2014, from http://www.latimes.com/nation/nationnow/la-na-nn-ohio-finds-link-fracking-earthquakes-20140411-story.html#axzz2yrnpHW1h

[239] Godoy, E. (2014, April 3). Fracking, seismic activity grow hand in hand in Mexico. *Inter Press Service*. Retrieved June 9, 2014, from http://www.ipsnews.net/2014/04/fracking-seismic-activity-grow-hand-hand-mexico/

[240] Schultz, R., V. Stern, and Y. J. Gu (2014). An investigation of seismicity clustered near the Cordel Field, west central Alberta, and its relation to a nearby disposal well. *J. Geophys. Res. Solid Earth, 119,* 3410–3423, doi:10.1002/2013JB010836

[241] Trynacity, K., Siekierska, A. (2014, November 13). Fracking linked to Alberta earthquakes, study indicates. *CBC News.* Retrieved from http://www.cbc.ca/news/canada/edmonton/fracking-linked-to-alberta-earthquakes-study-indicates-1.2829484

[242] Sumy, D. F., Cochran, E. S., Keranen, K. M., Wei, M., & Abers, G. A. (2013). Observations of static Coulomb stress triggering of the November 2011 M5.7 Oklahoma earthquake sequence [Abstract]. *Journal of Geophysical Research: Solid Earth, 119*(3), 1904-1923. doi: 10.1002/2013JB010612

[243] Oskin, B. (2014, March 07). Wastewater injection triggered Oklahoma's earthquake cascade. *Live Science*. Retrieved June 9, 2014, from http://www.livescience.com/43953-wastewater-injection-earthquake-triggering.html

[244] McClurg, L. (2014, January 30). Earthquakes in southern Colorado linked to oil and gas production. *Colorado Public Radio*. Retrieved June 9, 2014, from http://www.cpr.org/news/story/earthquakes-southern-colorado-linked-oil-and-gas-production#sthash.UVvw0JWe.UQwWtYJS.dpuf

The New York Times noted, "Oklahoma has never been known as earthquake country, with a yearly average of about 50 tremors, almost all of them minor. But in the past three years, the state has had thousands of quakes. This year has been the most active, with more than 2,600 so far, including 87 last week …. State officials say they are concerned, and residents accustomed to tornadoes and hail are now talking about buying earthquake insurance."[245]

- November 19, 2013 – *Reuters* reported that a series of Oklahoma earthquakes in September of 2013 damaged several homes, and that more scientists in a number of states are concerned about earthquakes related to oil and gas development. Seismologist Austin Holland with the University of Oklahoma said, "This is a dramatic new rate of seismicity."[246]

- July 19, 2013 – A study from the Lamont-Doherty Earth Observatory linked 109 earthquakes in Youngstown, Ohio to fracking wastewater disposal.[247][248]

- July 11, 2013 – A study in *Science* by Columbia University's Lamont-Doherty Earth Observatory showed that deep-well injection of fracking waste can stress geological faults in ways that make them vulnerable to slipping. The research shows that distant natural earthquakes triggered swarms of smaller earthquakes on critically stressed faults. The researchers wrote, "The fluids [in wastewater injection wells] are driving the faults to their tipping point …. Areas with suspected anthropogenic earthquakes are more susceptible to earthquake-triggering from natural transient stresses generated by the seismic waves of large remote earthquakes."[249]

- April 2013 – A group of British researchers stated that hydraulic fracturing itself was the likely cause of at least three earthquakes powerful enough to be felt by human beings at the surface. The researchers proposed that increases in the fluid pressure in fault zones were the causal mechanism for these three known instances of "felt seismicity" in the United States, Canada and the United Kingdom. The largest of these earthquakes was a magnitude 3.8 in the Horn River Basin, Canada.[250]

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[245] Fountain, H. (2013, December 12). Experts eye oil and gas industry as quakes shake Oklahoma. *The New York Times*. Retrieved June 9, 2014, from http://www.nytimes.com/2013/12/13/science/earth/as-quakes-shake-oklahoma-scientists-eye-oil-and-gas-industry.html

[246] Gillam, C. (2013, November 19). In Oklahoma, water, fracking - and a swarm of quakes. *Reuters*. Retrieved June 9, 2014, from http://www.reuters.com/article/2013/11/19/us-usa-earthquakes-fracking-oklahoma-idUSBRE9AI12W20131119

[247] Kim, W. (2013). Induced seismicity associated with fluid injection into a deep well in Youngstown, Ohio. *Journal of Geophysical Research: Solid Earth, 118*(7), 3506-3518. doi: 10.1002/jgrb.50247

[248] Chameides, B. (2013, September 5). Fracking waste wells linked to Ohio earthquakes. *Scientific American*. Retrieved June 9, 2014, from http://www.scientificamerican.com/article/fracking-waste-wells-linked-to-ohio-earthquakes/

[249] Begley, S. (2013, July 11). Study raises new concern about earthquakes and fracking fluids. *Reuters*. Retrieved June 9, 2014, from http://www.reuters.com/article/2013/07/11/us-science-fracking-earthquakes-idUSBRE96A0TZ20130711

[250] Davies, R., Foulger, G., Bindley, A., & Styles, P. (2013). Induced seismicity and hydraulic fracturing for the recovery of hydrocarbons. *Marine and Petroleum Geology, 45*, 171-185. doi: 10.1016/j.marpetgeo.2013.03.016.

- March 27, 2013 – Scientists from the University of Oklahoma, Columbia University and the U.S. Geological Survey linked a 2011 swarm of earthquakes in Oklahoma to fracking waste disposal in that state.[251] This included a magnitude 5.7 earthquake—the largest ever triggered by wastewater injection—that injured two people, destroyed 14 homes, and was felt across 17 states.[252]

- December 14, 2012 – At a 2012 American Geophysical Union meeting, scientists presented data and concluded that some U.S. states, including Oklahoma, Texas and Colorado, have experienced a significant rise in seismic activity coinciding with a boom in gas drilling, fracking and wastewater disposal. Scientists further found that Oklahoma has seen a significant increase in earthquakes linked to wastewater injection, that a 5.3 earthquake in New Mexico was linked to wastewater injection, and that earthquakes were increasingly common within two miles of injection wells in the Barnett Shale region of Texas. Art McGarr, a researcher at the U.S. Geological Survey Earthquake Science Center, concluded that, "The future probably holds a lot more in induced earthquakes as the gas boom expands."[253]

- November 30, 2012, January 11, 2012, December 22, 2009 – In three sets of comments on proposed fracking guidelines and regulations, citing scientific reports linking oil and gas infrastructure to seismic activity, the NYC DEP raised serious concerns about the impacts of potential seismic activity from fracking-related activities on New York City's water supply infrastructure.[254] [255] [256] The NYC DEP has consistently raised concerns that seismic activity surrounding New York City's aquifers and watershed infrastructure could threaten the city's drinking water supply. For instance, DEP wrote that,

> *Given the similar geological mechanisms, the City has further investigated the risk that seismic activity from shale gas drilling poses to our tunnels and, based on that investigation, has concluded that the proposed protections do not go far*

[251] Drajem, M., & Efstathiou, J., Jr. (2013, March 26). Quake tied to oil-drilling waste adds pressure for rules. *Bloomberg*. Retrieved June 9, 2014, from http://www.bloomberg.com/news/2013-03-26/oklahoma-earthquake-in-2011-tied-to-wastewater-wells-in-fracking.html

[252] Behar, M. (2013, March/April). Fracking's latest scandal? Earthquake swarms. *Mother Jones*. Retrieved June 9, 2014, from http://www.motherjones.com/environment/2013/03/does-fracking-cause-earthquakes-wastewater-dewatering?page=1

[253] Leber, J. (2012, December 14). Studies link earthquakes to wastewater from fracking. *MIT Technology Review*. Retrieved June 9, 2014, from http://www.technologyreview.com/news/508151/studies-link-earthquakes-to-wastewater-from-fracking/

[254] New York City Department of Environmental Protection. (2009, December 22). *New York City comments on: Draft supplemental generic environmental impact statement on the oil, gas and solution mining regulatory program - Well permit issuance for horizontal drilling and high-volume hydraulic fracturing to develop the Marcellus Shale and other low-permeability gas reservoirs* (Rep.). Retrieved June 9, 2014, from http://www.nyc.gov/html/dep/pdf/natural_gas_drilling/nycdep_comments_final_12-22-09.pdf

[255] New York City Department of Environmental Protection. (2012, January 11). *Comments on the revised draft supplemental generic environmental impact statement*. (Rep.). Retrieved June 11, 2014, from http://www.nyc.gov/html/dep/pdf/natural_gas_drilling/nycdep_comments_on_rdsgeis_for_hvhf_20120111.pdf

[256] New York City Department of Environmental Protection. (2012, November 30). *Comments on the revised high-volume hydraulic fracturing regulations* (Rep.). Retrieved June 9, 2014, from http://www.nyc.gov/html/dep/pdf/natural_gas_drilling/revised_high_volume_hydraulic_fracturing_regulations_comments_letter_010713.pdf

> *enough to protect the integrity of the tunnels. Seismic activity from natural gas drilling can be divided into two categories: hydraulic fracturing microseismicity and small induced earthquakes.* [257]

NYC DEP went on to discuss cases in Blackpool, England and Oklahoma, concluding that,

> *The Blackpool earthquakes and probably the Oklahoma earthquakes demonstrate that hydraulic fracturing fluids can reach a nearby fault and can trigger a seismic event. It should be noted that the natural gas wells in both of these cases were vertical, not horizontal, and neither well directly intercepted a fault. Nevertheless, the earthquakes generated were several miles away from the well. Horizontal wells, in contrast, have an even greater chance of directly intercepting a fault and, the distance from a well pad in which HVHF could reactivate a fault is therefore greater.... Thus, the RDSGEIS conclusion that induced seismic activity is not a significant impact is not supported by the evidence.*[258]

- September 6, 2012 – The British Columbia Oil and Gas Commission determined that fracking itself causes earthquakes, pointing to the results of a probe into 38 seismic events near fracking operations in the Horn River Basin. The report noted that no quakes had been recorded in the area prior to April, 2009, before fracking activities began. The report recommended that the link between fracking and seismic activity be further examined.[259]

- March 29, 2012 – The U.S. Geological Survey found that between 2001 and 2011, there was a six-fold increase in earthquakes greater than magnitude 3.0 in the middle of the United States that "are almost certainly manmade." The agency reported that the increase appears to be linked to oil and gas production and deep injection of drilling wastewater.[260] [261]

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[257]New York City Department of Environmental Protection. (2012, November 30). *Comments on the revised high-volume hydraulic fracturing regulations* (Rep.). 7. Retrieved June 9, 2014, from http://www.nyc.gov/html/dep/pdf/natural_gas_drilling/revised_high_volume_hydraulic_fracturing_regulations_comments_letter_010713.pdf

[258] New York City Department of Environmental Protection. (2012, November 30). *Comments on the revised high-volume hydraulic fracturing regulations* (Rep.). 28. Retrieved June 9, 2014, from http://www.nyc.gov/html/dep/pdf/natural_gas_drilling/revised_high_volume_hydraulic_fracturing_regulations_comments_letter_010713.pdf

[259] The Canadian Press. (2012, September 06). Fracking causes minor earthquakes, B.C. regulator says. *CBC News*. Retrieved June 9, 2014, from http://www.cbc.ca/news/canada/british-columbia/fracking-causes-minor-earthquakes-b-c-regulator-says-1.1209063

[260] Ellsworth, W. (2011, April 18). Are seismicity rate changes in the midcontinent natural or manmade? Retrieved June 9, 2014, from http://www2.seismosoc.org/FMPro?-db=Abstract_Submission_12&-sortfield=PresDay&-sortorder=ascending&-sortfield=Special+Session+Name+Calc&-sortorder=ascending&-sortfield=PresTimeSort&-sortorder=ascending&-op=gt&PresStatus=0&-lop=and&-token.1=ShowSession&-token.2=ShowHeading&-recid=224&-format=%2Fmeetings%2F2012%2Fabstracts%2Fsessionabstractdetail.html&-lay=MtgList&-find

[261] Soraghan, M. (2012, March 29). 'Remarkable' spate of man-made quakes linked to drilling, USGS team says. *E&E Publishing, LLC*. Retrieved June 11, 2014, from http://www.eenews.net/stories/1059962190

- July 31, 2011 – Numerous earthquakes in Arkansas motivated the Arkansas Oil and Gas Commission to shut down a disposal well and enact a permanent moratorium on future disposal wells in a nearly 1,200 square-mile area of the Fayetteville Shale.[262]

- March 10, 2010 – In Texas, a 2008-2009 swarm of earthquakes in the Dallas-Fort Worth area, where the Barnett Shale is being developed, was linked to produced water disposal wells.[263]

- June 12, 2009 – *The Wall Street Journal* reported that earthquakes shook Cleburne, Texas, a small town at the epicenter of fracking activity, including a number of earthquake clusters in the Dallas-Fort Worth area. The U.S. Geological Survey noted that more earthquakes were detected during that period of fracking activity than in the previous 30 years combined.[264]

Abandoned and active oil and natural gas wells (as pathways for gas and fluid migration)

- December 8, 2014 – A Princeton University team found that abandoned oil and gas wells in Pennsylvania, left over from prior decades of conventional drilling, leak significantly more methane than previously thought. Between 300,000 and 500,000 abandoned oil and gas wells are located in Pennsylvania, and many go unchecked and unmonitored for leaks. Based on direct measurements of methane flow from 19 such wells, most of which were a half century old or older, the researchers estimated that the methane leaks from abandoned wells alone could account for between 4 and 7 percent of human-caused methane emissions in the state. Based on these measurements of positive methane flow from decades-old wells, the study concluded that "cumulative emissions from these abandoned wells may be significantly larger than the cumulative leakage associated with oil and gas production, which has a shorter lifetime of operation." Further, methane flow rates from plugged wells measured in this study were not consistently lower than unplugged wells and indeed were sometimes higher, even though wells are plugged for the precise purpose of limiting the escape of gases. The authors noted that an estimated three million abandoned oil and gas wells are scattered across the United States and likely represent "the second largest potential contribution to total US methane emissions above

[262] Zilk, C. (2011, July 31). Permanent disposal-well moratorium issued. *Arkansas Online*. Retrieved June 9, 2014, from http://www.arkansasonline.com/news/2011/jul/31/permanent-disposal-well-moratorium-issued-20110731/
[263] Frohlich, C., Hayward, C., Stump, B., & Potter, E. (2011). The Dallas-Fort Worth Earthquake Sequence: October 2008 through May 2009. *Bulletin of the Seismological Society of America, 101*(1), 327-340. doi: 10.1785/0120100131
[264] Casselman, B. (2009, June 12). Temblors rattle Texas town. *The Wall Street Journal*. Retrieved from http://online.wsj.com/news/articles/SB124476331270108225

US Environmental Protection Agency estimates." In the United States, no regulatory requirements for monitoring methane leaks from abandoned wells exist.[265] [266]

- December 1, 2013 – An analysis of reports from the NY DEC found that three-quarters of the state's abandoned oil and gas wells were never plugged. New York State has approximately 48,000 such wells; many of their locations remain unknown.[267]

- Aug. 4, 2011 – A report from the U.S. EPA to Congress in 1987—and discovered by *The New York Times*—concluded that abandoned natural gas wells may have served as a pathway for hydraulic fracturing fluids to migrate underground from a shale gas well to a water well in West Virginia. In noting that the water well was polluted due to hydraulic fracturing and that such contamination was "illustrative" of contamination from oil and natural gas drilling, the report suggested that additional cases of groundwater contamination from hydraulic fracturing may exist.[268]

- April 4, 2011 – *ProPublica* reported that abandoned wells have caused problems across the nation including contamination of drinking water in Colorado, Kentucky, Michigan, New York, Texas and other states. *ProPublica* also found that a draft report from the Pennsylvania DEP described a 2008 incident in Pennsylvania in which a person died in an explosion triggered by lighting a candle in a bathroom after natural gas had seeped into a septic system from an abandoned well. The same draft report documented at least two dozen additional cases in which gas leaked from old wells, and three in which gas from new wells migrated into old wells, seeping into water supplies and requiring the evacuation of homes.[269]

- May 20, 2010 – The British Columbia Oil and Gas Commission issued a safety advisory after hydraulic fracturing caused a large "kick," or unintentional entry of fluid or gas, into a nearby gas well. The commission reported that it knew of 18 incidents in British Columbia and one in Western Alberta in which hydraulic fractures had entered nearby gas wells. "Large kicks resulted in volumes up to 80 cubic meters [about 100 cubic yards] of fluids produced to surface. Invading fluids have included water, carbon dioxide, nitrogen, sand, drilling mud, other stimulation fluids and small amounts of gas." These cases occurred in horizontal wells with a distance between wellbores of up to 2,300 feet.

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[265] Kang, M., Kanno, C.M., Reid M.C, Zhang, X., Mauzerall, D.L., Celia, M.A., Chen, Y., and Onstott, T.C. (2014, December 8). Direct measurements of methane emissions from abandoned oil and gas wells in Pennsylvania. *Proceedings of the Natural Academy of Sciences*, electronic version ahead of print. doi: 10.1073/pnas.1408315111

[266] Magill, B. (2014, June 19). Derelict oil wells may be major methane emitters. Climate Central. Retrieved from http://www.climatecentral.org/news/abandoned-oil-wells-methane-emissions-17575

[267] Bishop, R. E. (2014). Historical analysis of oil and gas well plugging in New York: Is the regulatory system working? *NEW SOLUTIONS: A Journal of Environmental and Occupational Health Policy, 21,* 103-116. Retrieved June 16, 2014, from http://baywood.metapress.com/media/16ut607yqg1yrw9ydad3/contributions/b/0/4/7/b047j34r87552325.pdf

[268] Urbina, I. (2011, August 4). A tainted water well, and concern there may be more. Retrieved June 11, 2014, from http://www.nytimes.com/2011/08/04/us/04natgas.html

[269] Kusnetz, N. (2011, April 4). Danger in honeycomb of old wells. *Pittsburgh Post-Gazette*. Retrieved June 11, 2014, from http://www.post-gazette.com/nation/2011/04/04/Danger-in-honeycomb-of-old-wells/stories/201104040149

The Commission wrote, "It is recommended that operators cooperate through notifications and monitoring of all drilling and completion operations where fracturing takes place within 1000m [3,280 feet] of well bores existing or currently being drilled." Such communication between active wells raises the potential that similar communication can occur between active wells and abandoned wells.[270]

- 2010 – The NY DEC cautioned that "abandoned wells can leak oil, gas and/or brine; underground leaks may go undiscovered for years. These fluids can contaminate ground and surface water, kill vegetation, and cause public safety and health problems." As the agency reported, "DEC has at least partial records on 40,000 wells, but estimates that over 75,000 oil and gas wells have been drilled in the State since the 1820s. Most of the wells date from before New York established a regulatory program. Many of these old wells were never properly plugged or were plugged using older techniques that were less reliable and long-lasting than modern methods."[271] The NY DEC published similar comments in 2008 and 2009.

- January 2009 – Drilling industry consultant M.C. Vincent wrote an article published by the Society of Petroleum Engineers in which he reported that fractures from hydraulically fractured wells can intersect with nearby wells:

  > *Contrary to common expectations, there are numerous examples of fractures intersecting offset wells [existing oil or natural gas wells near the well being fractured] but subsequently providing little or no sustained hydraulic connection between the wells. There is an understandable reluctance to publish reports documenting the intersection of adjacent wellbores with hydraulic fractures. Such information could unnecessarily alarm regulators or adjacent leaseholders who may infer that well spacing or fracture treatments are allowing unexpected capture of reserves.*[272]

  Vincent added, "Although computing tools have improved, as an industry we remain incapable of fully describing the complexity of the fracture, reservoir, and fluid flow regimes." The article's findings raise the possibility that there could be similar communications between existing fracked wells that are fractured and abandoned wells and that operators cannot accurately predict how these will interact.

- 2005 – M.K. Fisher, vice president of Business Management at Pinnacle, a service of Halliburton that specializes in hydraulic fracturing, reported in an article published by the Society of Petroleum Engineers that a single fracture produced during a fracking operation in the Texas Barnett Shale had unexpectedly spread 2,500 feet laterally in two

[270] British Columbia Oil & Gas Commission. (2010, May 20). Safety advisory: communication during fracture stimulation. Retrieved July 3, 2014, from https://www.bcogc.ca/node/5806/download
[271] New York State Department of Environmental Conservation. (2014). New York oil, gas and mineral resources annual reports. Retrieved June 11, 2014, from http://www.dec.ny.gov/pubs/36033.html
[272] Vincent, M. (2009, January 19). Examining our assumptions – Have oversimplifications jeopardized our ability to design optimal fracture treatments? Lecture presented at Society of petroleum engineers hydraulic fracturing technology conference in The Woodlands, Texas.

directions. He also described fractures in the Barnett Shale as "extremely complex."[273] These findings raise the possibility that well communication over very large distances could occur due to fractures that spread "unexpectedly."

- October 1999 – The U.S. Department of Energy reported that there were approximately 2.5 million abandoned oil and gas wells in the U.S.[274]

- Early 1990s – An underground waste disposal well in McKean County, Pennsylvania, contaminated groundwater when the wastewater traveled up a nearby abandoned, unmapped and unplugged oil well. Owners of private water wells that were contaminated in the incident eventually had to be connected to a public water system.[275]

- July 1989 –In the past, the investigative agency for Congress, the U.S. General Accounting Office [now the Government Accountability Office] studied oil and natural gas underground injection disposal wells and found serious cases of contamination. The agency reported that, in several cases, wastewater from oil and natural gas operations had migrated up into abandoned oil and natural gas wells, contaminating underground water supplies. The GAO found that "if these abandoned wells are not properly plugged—that is, sealed off —and have cracked casings, they can serve as pathways for injected brines [waste fluids from natural gas and oil drilling] to enter drinking water …. Because groundwater moves very slowly, any contaminants that enter it will remain concentrated for long periods of time, and cleanup, if it is technically feasible, can be prohibitively costly."[276]

- December 1987 – The EPA submitted a report to Congress on oil and natural gas wastes in which the agency cautioned:

> *… [T]o avoid degradation of ground water and surface water, it is vital that abandoned wells be properly plugged. Plugging involves the placement of cement over portions of a wellbore to permanently block or seal formations containing hydrocarbons or high-chloride waters (native brines). Lack of plugging or improper plugging of a well may allow native brines or injected wastes [from a waste fluid disposal well] to migrate to freshwater aquifers or to come to the surface through the wellbore. The potential for this is highest where brines*

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[273] Fisher, M., Wright, C., Davidson, B., Steinsberger, N., Buckler, W., Goodwin, A., & Fielder, E. (2005). Integrating fracture-mapping technologies to improve stimulations in the Barnett Shale. *SPE Production & Facilities, 20*(2). doi: 10.2118/77441-PA

[274] United States Department of Energy, Office of Fossil Energy. (1999, October 5). *Environmental benefits of advanced oil and gas exploration and production technology*. (Rep.). Retrieved June 11, 2014, from http://www.netl.doe.gov/kmd/cds/disk25/oilandgas.pdf

[275] Hopey, D. (2012, January 3). Wastewater disposal wells under scrutiny following Irvin leak. *Pittsburgh Post-Gazette*. Retrieved June 11, 2014, from http://www.post-gazette.com/news/environment/2012/01/03/Wastewater-disposal-wells-under-scrutiny-following-Irvin-leak.html

[276] United States Government Accountability Office. (1989, July 5). Drinking water: Safeguards are not preventing contamination from injected oil and gas wastes. Retrieved June 10, 2014, from http://www.gao.gov/products/RCED-89-97. (2, 4, Rep.).

originate from a naturally pressurized formation such as the Coleman Junction formation found in West Texas …. Proper well plugging is essential for protection of ground water and surface water in all oil and gas production areas.[277]

While the EPA did not address the potential for contamination through abandoned wells as a result of hydraulic fracturing, both hydraulic fracturing and underground injection disposal wells require underground injection of fluid under pressure, raising the potential that there is a similar risk of groundwater contamination when hydraulic fracturing occurs near abandoned wells.

- 1985 – In an investigation of 4,658 complaints due to oil and natural gas production, the Texas Department of Agriculture found that "when a water well is experiencing an oilfield pollution problem (typically, high chlorides), the pollution source is often difficult to track down. The source could be a leak in the casing of a disposal well, leakage behind the casing due to poor cement bond, old saltwater evaporation pits, or, most often, transport of contaminants through an *improperly plugged abandoned well*" (emphasis in original). The agency found more than a dozen confirmed or suspected cases in which pollutants had migrated up abandoned wells and contaminated groundwater. In one case, drilling wastewater migrated up an abandoned well a half mile away from where the wastewater was injected underground for disposal.[278]

- November 1978 – In a report later cited by the EPA in its 1987 report to Congress (cited above), the state of Illinois Environmental Protection Agency found that oil and natural gas wastes injected underground could migrate through abandoned oil and natural gas wells and contaminate groundwater. The agency wrote, "In old production areas, abandoned wells may pose a serious threat to ground water quality. Unplugged or improperly plugged wells provide possible vertical communication between saline and fresh water aquifers."[279]

Flood risks

- June 20, 2014 –*The Coloradoan* reported that Noble Energy storage tanks damaged by spring flooding in Colorado dumped 7,500 gallons of crude oil, fracking chemicals, and fracking wastewater into the Poudre River, which is both a National Heritage area and a

[277] U.S. Environmental Protection Agency. (1987). *Report to Congress: Management of wastes from the exploration, development, and production of crude oil, natural gas, and geothermal energy* (Rep.). Retrieved June 11, 2014, from http://nepis.epa.gov/Exe/ZyPDF.cgi?Dockey=20012D4P.PDF. (III-47, Rep.),
[278] Texas Department of Agriculture, Department of Natural Resources. (1985). *Agricultural land and water contamination: From injection wells, disposal pits, and abandoned wells used in oil and gas production* (pp. 5, 12-15). Austin, TX: Dept. of Agriculture, Office of Natural Resources.
[279] Illinois Environmental Protection Agency, Water Quality Management Planning. (1978). *Illinois oil field brine disposal assessment* (pp. 44-45, Rep.).

habitat for Colorado's only self-sustaining population of wild trout. Recent high river flows had undercut the bank where the oil tank was located, which caused the tank to drop and break a valve.[280]

- September 2013 – An extraordinary flood that struck the Front Range of Colorado killed ten people, forced the evacuation of 18,000 more, destroyed more than 1850 homes, and damaged roads, bridges, and farmland throughout the state. More than 2650 oil and gas wells and associated facilities were also affected, with 1614 wells lying directly within the flood impact zone. Many of these storm-damaged facilities and storage tanks leaked uncontrollably. In a later accounting, Matt Lepore, director of the Colorado Oil and Gas Conservation Commission, estimated the flooding had resulted in the release to the environment of 48,250 gallons of oil or condensate and 43,479 gallons of fracking wastewater from 50 different spill sites across the state. In Colorado, more than 20,850 oil and gas wells lie within 500 feet of a river, stream, or other drainage. According to Commissioner Lepore, setback requirements that keep drilling and fracking operations away from residential areas inadvertently encourage operators to drill in unoccupied floodplains. At the same time, oil and gas operators prefer locations close to supplies of water for use in fracking. These twin factors result in a clustering of drilling and fracking operations in low-lying areas prone to catastrophic flooding.[281]

- 2004-2013 – In at least six of the last ten years (2004, 2005, 2006, 2009, 2011 and 2013), several counties where shale gas drilling is most likely to occur in New York State have experienced serious flooding. These include the counties of Albany, Broome, Cattaraugus, Chautauqua, Chenango, Delaware, Erie, Greene, Madison, Orange, Otsego, Schoharie, Sullivan and Ulster. In at least five of the past 10 years (2004, 2005, 2006, 2009 and 20011), floods have exceeded 100-year levels in at least some of the

[280] Handy, R. (2014, June 20). Crude oil spills into Poudre near Windsor. *The Coloradoan.* Retrieved June 23, 2014, from http://www.coloradoan.com/story/news/local/2014/06/20/crude-oil-spills-poudre-near-windsor/11161379/

[281] Lepore, M. (2014, March). "Lessons Learned" in the front range flood of September 2013: a staff report to the commissioners of the Colorado Oil and Gas Conservation Commission. Retrieved July 7, 2012, from the Colorado Oil and Gas Conservation Commission website: http://cogcc.state.co.us/Announcements/Hot_Topics/Flood2013/FinalStaffReportLessonsLearned20140314.pdf

counties.[282] [283] [284] [285] [286] [287] [288]

- February 7, 2013 – In its 2012 annual report to investors, oil and natural gas drilling company Noble Energy stated, "Our operations are subject to hazards and risks inherent in the drilling, production and transportation of crude oil and natural gas, including … flooding which could affect our operations in low-lying areas such as the Marcellus Shale."[289]

- September 7, 2011 – The NYS DEC's draft shale gas drilling plan recommended that drilling be prohibited within 100-year floodplains but acknowledged that many areas in the Delaware and Susquehanna River basins that were affected by flooding in 2004 and 2006 were located outside of officially designated flood zones.[290] In 2004, 2005, 2006, 2009 and 2011, flooding in New York exceeded 100-year levels in at least some of the counties where drilling and fracking may occur.

- 1992 – In its Generic Environmental Impact Statement (GEIS) for oil and natural gas drilling, the New York State DEC raised concerns that storage tanks holding drilling wastewater, spent hydraulic fracturing fluid or other contaminants could be damaged by flooding and leak. At the time, the GEIS called for at least some of these tanks to be properly secured.[291] However, if horizontal high-volume hydraulic fracturing (HVHF) is approved, shale gas operations will require many more storage tanks for fracking fluids

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[282] Brooks, L. T. (2005). *Flood of September 18-19, 2004 in the upper Delaware River basin, New York* (Rep.). Retrieved June 11, 2014, from United States Geological Survey website: http://ny.water.usgs.gov/pubs/of/of051166/
[283] Suro, T. P., & Firda, G. D. (2006). *Flood of April 2–3, 2005, Neversink River basin, New York* (Rep.). Retrieved June 11, 2014, from United States Geological Survey website: http://pubs.usgs.gov/of/2006/1319/
[284] Suro, T. P., Firda, G. D., & Szabo, C. O. (2009). *Flood of June 26–29, 2006, Mohawk, Delaware and Susquehanna River basins, New York* (Rep.). Retrieved June 11, 2014, from United States Geological Survey website: http://pubs.usgs.gov/of/2009/1063/pdf/ofr2009-1063.pdf
[285] Szabo, C. O., Coon, W. F., & Niziol, T. A. (2010). *Flash floods of August 10, 2009, in the villages of Gowanda and Silver Creek, New York* (Rep.). Retrieved June 11, 2014, from United States Geological Survey website: http://pubs.usgs.gov/sir/2010/5259/pdf/SIR%202010-5259.pdf
[286] Szabo, L. (2011, September 8). *Remnants of Tropical Storm Lee cause record flooding in the Susquehanna River basin* (Rep.). Retrieved June 11, 2014, from United States Geological Survey website: http://ny.water.usgs.gov/leeindex.html
[287]Giordano, S. (2013, January 29). Several eastern counties in central New York under water after heavy flooding. *Syracuse Post-Standard*. Retrieved June 11, 2014, from http://www.syracuse.com/news/index.ssf/2013/06/several_eastern_counties_in_ce.html
[288] New York State Department of Environmental Conservation. (2011). *Supplemental generic environmental impact statement on the oil, gas and solution mining regulatory program, well permit issuance for horizontal drilling and high-volume hydraulic fracturing to develop the Marcellus shale and other low-permeability gas reservoirs* (2-32, 33, Rep.).
[289] Noble Energy, Annual Report (Form 10-K) (Feb. 7, 2013) at 42.
[290] New York State Department of Environmental Conservation. (2011). *Supplemental generic environmental impact statement on the oil, gas and solution mining regulatory program, well permit issuance for horizontal drilling and high-volume hydraulic fracturing to develop the Marcellus shale and other low-permeability gas reservoirs* (ES-22, 2-32, 33, Rep.).
[291] New York State Department of Environmental Conservation. (2011). *Supplemental generic environmental impact statement on the oil, gas and solution mining regulatory program, well permit issuance for horizontal drilling and high-volume hydraulic fracturing to develop the Marcellus shale and other low-permeability gas reservoirs* (8-42, 8-43, 9-35, Rep.).

and wastewater than conventional drilling operations anticipated by the DEC twenty years ago. In 1992, the agency anticipated that oil and gas wells in the state would require between 20,000 and 80,000 gallons of fracking fluid.[292] As of 2011, the agency anticipated that HVHF shale gas wells will require between 2.4 and 7.8 million gallons of fluid.[293]

Threats to agriculture and soil quality

- October 14, 2014 – State documents obtained by the Center for Biological Diversity show that almost three billion gallons of fracking wastewater have been illegally dumped into central California aquifers that supply drinking water and farming irrigation. The California Water Board confirmed that several oil companies used at least nine of 11 injection wells that connect with high-quality water sources for disposal of fracking wastewater, which included high levels of arsenic, thallium, and nitrates. The California Division of Oil, Gas and Geothermal Resources has shut down 11 oil field injection wells and is scrutinizing almost 100 others for posing a "danger to life, health, property, and natural resources." At least one farming company has sued oil producers in part for contaminating groundwater that farms use for irrigation.[294]

- September 6, 2014 – *Al Jazeera America* examined the challenges that North Dakota farmers are facing in light of wastewater spills from oil and gas development. Notably, in heavily drilled Bottineau County, some levels of chloride, from sites where an estimated 16,800 to 25,200 gallons of wastewater had seeped into the ground, were so high that they exceeded the levels measurable with the North Dakota Department of Health's test strips. State records, testimonies from oil workers and various residents, and the decades-long failure of contaminated fields to produce crops indicate that wastewater spills are a significant hazard in the current fracking boom.[295]

- August 6, 2014 – The Pennsylvania Department of Environmental Protection found that leaks of fracking wastewater from three impoundments contaminated soil and

[292] New York State Department of Environmental Conservation. (1992). *Generic environmental impact statement on the oil, gas and solution mining regulatory program* (Rep.). Retrieved June 11, 2014, from http://www.dec.ny.gov/docs/materials_minerals_pdf/dgeisv1ch8.pdf (9-26, Rep.).
[293] New York State Department of Environmental Conservation. (2011). *Supplemental generic environmental impact statement on the oil, gas and solution mining regulatory program, well permit issuance for horizontal drilling and high-volume hydraulic fracturing to develop the Marcellus shale and other low-permeability gas reservoirs* (ES-8, Rep.).
[294] Dechert, S. (2014, October 14). Fracking wastewater spoils California drinking, farm supplies. *Clean Technica*. Retrieved from http://cleantechnica.com/2014/10/14/fracking-wastewater-spoils-california-drinking-farm-supplies/
[295] Gottesdiener, L. (2014, September 6). In shadow of oil boom, North Dakota farmers fight contamination. *Al Jazeera America*. Retrieved from http://america.aljazeera.com/articles/2014/9/6/north-dakota-wastewaterlegacy.html

groundwater. The findings prompted the state to issue a violation and increase monitoring and testing.[296]

- August 5, 2014 – Michelle Bamberger, a veterinarian and researcher, and Robert Oswald, a professor of molecular medicine at Cornell University, published a book that describes their research into the impacts of drilling and fracking on agriculture and animal health. They detail results of 24 case studies from six gas drilling states, including follow-up on cases they previously published in the peer-reviewed literature, raising numerous concerns about the effects of drilling and fracking on agriculture and the health of animals.[297]

- August 1, 2014 – At least 19,000 gallons of hydrochloric acid spilled during completion of a fracking well on an alfalfa farm in Kingfisher County, Oklahoma. The Oklahoma Corporation Commission reported concerns about rain pushing chemical runoff into a nearby creek that flows into the town of Hennessey's water system. The company planned to pay for the alfalfa crop for six years. The landowner and a neighbor were pursuing litigation.[298]

- May 4, 2014 – In an analysis of state data from Colorado, the *Denver Post* reported that fracking related to oil and gas drilling is putting soil quality and farmlands at risk due to significant amounts of toxic fluids penetrating the soil. According to the *Denver Post* 578 spills were reported in 2013, which means that, on average in the state, a gallon of toxic liquid penetrates soil every eight minutes. Eugene Kelly, professor of Soil and Crop Sciences at Colorado State University, said that the overall impact of the oil and gas boom "is like a death sentence for soil."[299]

- November 28, 2012 – In conjunction with the Food & Environment Reporting Network, *The Nation* reported that serious risks to agriculture caused by fracking are increasing across the country and linked these concerns to risks to human health.[300]

- January, 2012 – A study of gas drilling's impacts on human and animal health concluded that the drilling process may lead to health problems. The study reported and analyzed a number of case studies, including dead and sick animals in several states that had been exposed to drilling or hydraulic fracturing fluids, wastewater, or contaminated ground or

[296] Hopey, D. (2014, August 6). State: Fracking waste tainted groundwater, soil at three Washington County sites. *Pittsburgh Post-Gazette.* Retrieved from http://www.post-gazette.com/local/washington/2014/08/06/Pa-finds-tainted-water-soil-at-three-Washington-County-shale-sites/stories/201408050198

[297] Bamberger, M. and Oswald, R. (2014). The real cost of fracking: How America's shale gas boom Is threatening our families, pets, and food. Boston: Beacon Press.

[298] Passoth, K. (2014, August 1). Major oil field spill in Kingfisher Co. *KOCO.com Oklahoma City*. Retrieved from http://www.koco.com/news/major-oil-field-spill-in-kingfisher-county/27236612

[299] Finley, B. (2014, May 4). Colorado faces oil boom "death sentence" for soil, eyes microbe fix. *The Denver Post*. Retrieved June 11, 2014, from http://www.denverpost.com/environment/ci_25692049/colorado-faces-oil-boom-death-sentence-soil-eyes

[300] Royte, E. (2012, November 28). Fracking our food supply. *The Nation*. Retrieved June 11, 2014, from http://www.thenation.com/article/171504/fracking-our-food-supply

surface water.[301] The researchers cited 24 cases in six states where animals and their owners potentially affected by gas drilling. In one case a farmer separated 96 head of cattle into three areas, one along a creek where fracking wastewater was allegedly dumped and the remainder in fields without access to the contaminated creek; the farmer found that, of the 60 head exposed to the creek, 21 died and 16 failed to produce, whereas the unexposed cattle experienced no unusual health problems. In another case, a farmer reported that of 140 head of cattle that were exposed to fracking wastewater, about 70 died, and there was a high incidence of stillborn and stunted calves in the remaining cattle.[302]

- January 2011 – U.S. Forest Service researchers reported dramatic negative effects on vegetation caused by the drilling and fracking of a natural gas well in an experimental forest in northeastern West Virginia.[303] In June 2008, the researchers found browning of foliage near the well pad, a lack of ground foliage and that many trees nearby had dropped their foliage. They attributed these impacts to the loss of control of the well bore on May 29, 2008, which caused an aerial release of materials from the well. Trees showed no apparent symptoms the following summer.[304] However, the researchers also found "dramatic impacts on vegetation" where drilling and fracking wastewater had been sprayed on the land as a disposal technique following completion of the well. Just after the spraying of approximately 60,000 gallons of wastewater at the first disposal site, the Forest Service researchers found 115 damaged trees and other evidence of harm. This figure grew to 147 trees almost a year later.[305] At a second site, where about 20,000 gallons of wastewater was sprayed, the damage was less dramatic, yet the researchers still found "considerable leaf browning and mortality of young northern red oak seedlings."[306]

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[301] Bamberger, M., & Oswald, R. E. (2012). Impacts of gas drilling on human and animal health. *New Solutions: A Journal of Environmental and Occupational Health Policy, 22*(1), 51-77. doi: 10.2190/NS.22.1.e

[302] Ramanujan, K. (2012, March 7). Study suggests hydrofracking is killing farm animals, pets. *Cornell Chronicle*. Retrieved June 11, 2014, from http://www.news.cornell.edu/stories/2012/03/reproductive-problems-death-animals-exposed-fracking

[303] Adams, M., Edwards, P. J., Ford, W. M., Johnson, J. B., Schuler, T. M., Thomas-Van Gundy, M., & Wood, F. (2011, January). *Effects of development of a natural gas well and associated pipeline on the natural and scientific resources of the Fernow experimental forest* (Rep.). Retrieved June 11, 2014, from United States Department of Agriculture website: http://www.fs.fed.us/nrs/pubs/gtr/gtr_nrs76.pdf. (1-4, Rep.).

[304] Adams, M., Edwards, P. J., Ford, W. M., Johnson, J. B., Schuler, T. M., Thomas-Van Gundy, M., & Wood, F. (2011, January). *Effects of development of a natural gas well and associated pipeline on the natural and scientific resources of the Fernow experimental forest* (Rep.). Retrieved June 11, 2014, from United States Department of Agriculture website: http://www.fs.fed.us/nrs/pubs/gtr/gtr_nrs76.pdf. (10-11, Rep.).

[305] Adams, M., Edwards, P. J., Ford, W. M., Johnson, J. B., Schuler, T. M., Thomas-Van Gundy, M., & Wood, F. (2011, January). *Effects of development of a natural gas well and associated pipeline on the natural and scientific resources of the Fernow experimental forest* (Rep.). Retrieved June 11, 2014, from United States Department of Agriculture website: http://www.fs.fed.us/nrs/pubs/gtr/gtr_nrs76.pdf . (11-15, Rep.)

[306] Adams, M., Edwards, P. J., Ford, W. M., Johnson, J. B., Schuler, T. M., Thomas-Van Gundy, M., & Wood, F. (2011, January). *Effects of development of a natural gas well and associated pipeline on the natural and scientific resources of the Fernow experimental forest* (Rep.). Retrieved June 11, 2014, from United States Department of Agriculture website: http://www.fs.fed.us/nrs/pubs/gtr/gtr_nrs76.pdf. (15, Rep.).

The researchers concluded that the spraying of the drilling fluids resulted in an "extreme" dose of chlorides to the forest.[307]

- May 2010 – Pennsylvania's Department of Agriculture quarantined 28 cows in Tioga County after the animals wandered through a spill of drilling wastewater and may have ingested some of it. The Department was concerned that beef eventually produced from the cows could be contaminated as a result of any exposure. In May 2011, only ten yearlings were still quarantined, but the farmer who owned the cows, Carol Johnson, told National Public Radio that of 17 calves born to the quarantined cows in the spring of 2011, only six survived, and many of the calves that were lost were stillborn. "They were born dead or extremely weak. It's highly unusual," she said, continuing, "I might lose one or two calves a year, but I don't lose eight out of eleven."[308]

- March 2010 – A Pennsylvania State Extension analysis of dairy farms in the state found a decline in the number of dairy cows in areas of the state where fracking was prevalent. Pennsylvania counties that had both more than 10,000 dairy cows and more than 150 Marcellus Shale wells experienced a 16-percent decline in dairy cows between 2007 and 2010.[309]

- April 28, 2009 – Seventeen cows in Caddo Parish, Louisiana died within one hour after apparently ingesting hydraulic fracturing fluids spilled at a well that was being fractured. "It seemed obvious the cattle had died acutely from an ingested toxin that had drained from the 'fracking' operation going on at the property," Mike Barrington, a state veterinarian said in a document obtained from the state Department of Environmental Quality by the *New Orleans Times-Picayune*.[310] [311]

- August, 1977 – A paper in the *Journal of Arboriculture* describes how natural gas leaks in soil can damage plants and crops. The paper notes that vegetation dies in the vicinity of natural gas leaks. Due to the oxidation of methane by methane-consuming bacteria, gas leaks drive down the oxygen concentration to extremely low levels and cause carbon

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[307] Adams, M., Edwards, P. J., Ford, W. M., Johnson, J. B., Schuler, T. M., Thomas-Van Gundy, M., & Wood, F. (2011, January). *Effects of development of a natural gas well and associated pipeline on the natural and scientific resources of the Fernow experimental forest* (Rep.). Retrieved June 11, 2014, from United States Department of Agriculture website: http://www.fs.fed.us/nrs/pubs/gtr/gtr_nrs76.pdf. (17, Rep.).

[308] Phillips, S. (2011, September 27). Burning questions: Quarantined cows give birth to dead calves. *StateImpact*. Retrieved June 11, 2014, from http://stateimpact.npr.org/pennsylvania/2011/09/27/burning-questions-quarantined-cows-give-birth-to-dead-calves/

[309] Penn State Extension. (2010, March). *Pennsylvania dairy farms and Marcellus shale, 2007–2010* (Rep.). Retrieved June 11, 2014, from Penn State website: http://cce.cornell.edu/EnergyClimateChange/NaturalGasDev/Documents/PA%20Dairy%20Farms%20and%20Marcellus%202007%20to%202010.pdf

[310] Schleifstein, M. (2011, March 27). Haynesville natural gas field is the most productive in the U.S. *The Times-Picayune*. Retrieved June 11, 2014, from http://www.nola.com/politics/index.ssf/2011/03/haynesville_natural_gas_field.html.

[311] KSLA. (2009, April 28). Cows in Caddo Parish fall dead near gas well. *KSLA News*. Retrieved June 11, 2014, from http://www.ksla.com/Global/story.asp?S=10268585

dioxide concentration to rise. The resulting low oxygen concentration is the greatest contributing factor in the death of trees and other vegetation near natural gas leaks.[312]

Threats to the climate system

- October 23, 2014 – Adding to the debate about natural gas and climate change, a multi-center, international research team used a sophisticated, integrated approach to the global energy-economy-climate systems question and found no climate benefit to natural gas over other fossil fuels. As summarized by the editor of *Nature*, "The development of hydraulic fracturing technologies has led to rapid growth in the use natural gas as an energy source. Some evidence has suggested that this growing adoption of natural gas might lead to a reduced greenhouse gas burden and consequent mitigation of climate change. This collaboration between five energy–climate modelling teams show that instead — under a scenario of abundant natural gas availability — increased consumption will have little or no impact on climate change." The authors concluded, "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."[313]

- October 6, 2014 – Utilizing satellite data for the Bakken and Eagle Ford formations, scientists from Germany, the United Kingdom, and the University of Maryland confirmed that higher "top-down" estimates of fugitive methane leaks from oil and gas fields (which are obtained via tall tower flask samples, aircraft measurements and road surveys) are more accurate than lower "bottom-up" estimates (which are obtained by summing emissions from different types of known sources at sites provided by participating utility companies). According to "bottom-up" estimates, the average U.S. leakage rate ranges from 1.2 – 2.0 percent. But satellite data show much higher leakage rates: 10.1 percent (± 7.3 percent) and 9.1 percent (± 6.2 percent), for the Bakken and Eagle Ford formations respectively. These higher estimates indicate that current inventories likely underestimate fugitive emissions and call into question any immediate climate benefit from switching from coal to natural gas. Similar results were seen for the Marcellus shale region, but as a result of technical and geographical limitations, the authors declined to quantify their results, pending future studies with enhanced equipment.[314]

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[312] Davis, S.H.,Jr. (1977). The effect of natural gas on trees and other vegetation. *Journal of Arboriculture 3*(8),153-154.

[313] McJeon, H., Edmonds, J., Bauer, N., Clarke, L., Fisher, B., Flannery, B., Hilaire, J., Krey, V., Marangoni, G., Mi, R., Riahi,K., Rogner, H., & Tavoni, M. (2013). Limited impact on decadal-scale climate change from increased use of natural gas. *Nature, 514,* 482–485. doi:10.1038/nature13837.

[314] Schneising, O., Burrows, J.P., Dickerson, R.R., Buchwitz, M. Reuter, M., and Bovensmann, H. (2014). Remote sensing of fugitive methane emissions from oil and gas production in North American tight geologic formations. *Earth's Future 2*(10), 548–558. doi: 10.1002/2014EF000265

- September 24, 2014 – According to a paper published by scientists from the University of California and Stanford University, "… without strong limits on [greenhouse gas] 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." The study builds on previous research by examining natural gas in a range of supply curves, with a tested economic model, and across three different types and levels of climate policy. Researchers found that abundant natural gas, even with low rates of methane leakage, does little to reduce – and may increase – greenhouse gases. They conclude that, "… delaying deployment of renewable energy technologies, may actually exacerbate the climate change problem in the long term."[315]

- September 2, 2014 – Analyzing the level of greenhouse gas emissions attributable to electricity from natural-gas-fired power plants and coal-fired power plants, economist Chris Busch and physicist Eric Gimon conclude that, over short time frames and at high rates of leakage, natural gas offers little benefit compared to coal and could exacerbate global warming. Although Busch and Gimon acknowledge that natural gas offers some reductions in greenhouse gas emissions over longer time frames, they point out that such reductions are not large enough for natural gas to play an expanded role in efforts to manage emissions. They conclude that under the best of circumstances, natural gas-fired electric power offers a modest benefit toward abating climate change, while if poorly developed (i.e., with extensive methane leaks, estimated by these authors to be on the order of 4% or higher), or if used to displace energy efficiency or renewable energy, natural gas could seriously contribute to increased greenhouse gas emissions.[316]

- August 5, 2014 – A Climate Central piece appearing in *Scientific American* outlined the natural gas-related factors that threaten any ability to achieve climate goals through President Obama's proposed Clean Power Plan. "No one has any idea how much methane is leaking from our sprawling and growing natural gas system. This is a major problem, because without a precise understanding of the leak rate natural gas could actually make climate change worse." Referring to an interactive Climate Central tool that runs various methane leakage scenarios, the article notes that, "… even with modest leak rates and a fairly aggressive transition, we could still end up with little or no climate benefits by 2030 after an enormous financial and political investment in natural gas."[317]

- July 25, 2014 – A report released as part of the U.S. EPA's Office of Inspector General's "products associated with climate change," determined that "EPA has placed little focus and attention on reducing methane emissions from pipelines in the natural gas distribution sector." The report notes that in 2012, the EPA said methane leaks from

[315] Shearer, C., Bistline, J., Inman, M., and Davis, S.J. (2014). The effect of natural gas supply on US renewable energy and CO2 emissions. *Environmental Research Letters, 9.* doi:10.1088/1748-9326/9/9/094008

[316] Busch, C. and Gimon, E. (2014). Natural gas versus coal: Is natural gas better for the climate. *The Electricity Journal, 27*(7), 97-111.

[317] Climate Central. (2014, August 5). Methane leak rate proves key to climate change goals. *Scientific American.* Retrieved from http://www.scientificamerican.com/article/methane-leak-rate-proves-key-to-climate-change-goals/

pipelines "accounted for more than 13 million metric tons of carbon dioxide equivalent emissions," are almost 100 percent methane, and are more than 10 percent of total methane emissions from natural gas systems. The report also noted that the EPA has not done a comprehensive analysis of the emissions factors it uses since a 1996 study that has a "high level of uncertainty," and the agency does not have the partnerships in place to begin controlling methane leaks, such as with the Pipeline and Hazardous Materials Safety Administration.[318]

- May 15, 2014 – A recent review of existing data on lifecycle emissions of methane from natural gas systems concluded that, as a strategy for addressing climate change, natural gas is a "bridge to nowhere." The review found that, over a 20-year time frame, natural gas is as bad as or worse than coal and oil as a driver of climate change.[319] Referencing this review and other recent studies, *Bloomberg Business News* reported that the EPA has underestimated the impact of methane leakage resulting from the production transmission, and distribution of natural gas and is using outdated estimates of methane's potency compared to more recent estimates from the Intergovernmental Panel on Climate Change (IPCC).[320]

- April 25, 2014 – A reassessment of the heat-trapping potential of greenhouse gases revealed that current methods of accounting underestimate the climate-damaging impact of methane pollution from all sources, including drilling and fracking operations.[321]

- April 14, 2014 – A study from researchers at Purdue University, NOAA, Cornell University, University of Colorado at Boulder and Pennsylvania State University, published in *Proceedings of the National Academy of Sciences* found very high levels of methane emissions above many wells being drilled at fracking sites in Pennsylvania. Levels were 100 to 1,000 times above the estimates of federal regulators, who have always assumed very low methane emissions as wells are drilled.[322] [323]

- February 26, 2014 – The United Nations' top environmental official—Achim Steiner, who heads the UN Environmental Programme (UNEP)—argued that the shale gas rush is

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[318] U.S. Environmental Protection Agency Office of Inspector General. (2014, July 25). Improvements needed in EPA efforts to address methane emissions from natural gas distribution pipelines. Report No. 14-P-0324. Retrieved from http://www.epa.gov/oig/reports/2014/20140725-14-P-0324.pdf

[319] Howarth, R. W. (2014). A bridge to nowhere: Methane emissions and the greenhouse gas footprint of natural gas [Abstract]. *Energy Science & Engineering*. doi: 10.1002/ese3.35

[320] Childers, A. (2014, May 9). EPA underestimates fracking's impact on climate change. *Bloomberg*. Retrieved June 10, 2014, from http://www.bloomberg.com/news/2014-05-09/epa-underestimates-fracking-s-impact-on-climate-change.html

[321] Edwards, M.R. and Trancik, J.E. (2014). Climate impacts of energy technologies depend on emissions timing. *Nature Climate Change 4*, 348-352. doi: 10.1038/NCLIMATE2204

[322] Caulton, D. R., Shepson, P. B., Santoro, R. L., Sparks, J. P., Howarth, R. W., Ingraffea, A. R., ... Miller, B. R. (2014). Toward a better understanding and quantification of methane emissions from shale gas development. *Proceedings of the National Academy of Sciences of the United States of America*. doi: 10.1073/pnas.1316546111

[323] Banjeree, N. (2014, April 14). EPA drastically underestimates methane released at drilling sites. *Los Angeles Times*. Retrieved June 10, 2014, from http://www.latimes.com/science/sciencenow/la-sci-sn-methane-emissions-natural-gas-fracking-20140414,0,2417418.story

'a liability' in efforts to slow climate change and that a switch from coal to natural gas is delaying critical energy transition to renewables.[324]

- February 13, 2014 – A major study in *Science* by Stanford University, Massachusetts Institute of Technology and the U.S. Department of Energy found that methane leaks negate any climate benefits of natural gas as a fuel for vehicles, and that the EPA is significantly underestimating methane in the atmosphere.[325] Lead author Adam R. Brandt told *The New York Times*, "Switching from diesel to natural gas, that's not a good policy from a climate perspective."[326] This study also concluded that the national methane leakage rate is likely between 3.6 and 7.2 percent of production.

- January 15, 2014 – The *Guardian* reported that even a new a study by BP found that "Shale gas … will not cause a decline in greenhouse gases" and will do little to cut carbon emissions.[327]

- December 30, 2013 – An analysis of fracking-related truck transportation in the Susquehanna River Basin, Pennsylvania found that greenhouse gas emissions from frack water and waste hauling operations were 70–157 metric tons of CO_2 equivalent per gas well.[328]

- November 11, 2013 – In a letter to California Governor Jerry Brown, twenty of the nation's top climate scientists warned that pro-fracking policies will worsen climate disruption and harm California's efforts to be a leader in reducing greenhouse gas emissions. The letter called on Governor Brown to place a moratorium on fracking.[329] On November 21, 2013, a group of Governor Brown's former policy and campaign advisors

[324] Goldenberg, S. (2014, February 26). Achim Steiner: Shale gas rush 'a liability' in efforts slow climate change. *The Guardian*. Retrieved June 10, 2014, from http://www.theguardian.com/environment/2014/feb/26/achim-steiner-shale-gas-rush-climate-change-energy

[325] Brandt, A. R., Heath, G. A., Kort, E. A., O'Sullivan, F., Petron, G., Jordaan, S. M., ... Harriss, R. (2014). Methane leaks from North American natural gas systems. *Energy and Environment, 343*(6172), 733-735. doi: 10.1126/science.1247045

[326] Davenport, C. (2014, February 13). Study finds methane leaks negate benefits of natural gas as a fuel for vehicles. *The New York Times*. Retrieved June 10, 2014, from http://www.nytimes.com/2014/02/14/us/study-finds-methane-leaks-negate-climate-benefits-of-natural-gas.html?smid=tw-share

[327] Harvey, F., & Macalister, T. (2014, January 16). BP study predicts greenhouse emissions will rise by almost a third in 20 years. *The Guardian*. Retrieved June 10, 2014, from http://www.theguardian.com/business/2014/jan/15/bp-predicts-greenhouse-emissions-rise-third?CMP=twt_gu

[328] Gilmore, K. R., Hupp, R. L., & Glathar, J. (2014). Transport of Hydraulic Fracturing Water and Wastes in the Susquehanna River Basin, Pennsylvania. *Journal of Environmental Engineering, 140*. doi: 10.1061/(ASCE)EE.1943-7870.0000810

[329] Rogers, P. (2013, November 12). Top climate scientists call for fracking ban in letter to Gov. Jerry Brown. *San Jose Mercury News.* Retrieved June 10, 2014, from http://www.mercurynews.com/ci_24509392/top-climate-scientists-call-fracking-ban-letter-gov

made a similar request in light of concerns about the effects of fracking on climate change and water pollution.[330]

- October 18, 2013 – A team of researchers from multiple institutions including Harvard, the University of Michigan and NOAA reported that methane emissions due to drilling activities in the south-central U.S. may be almost five times greater than reported by the world's most comprehensive 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 percent," the authors wrote.[331] As *The New York Times* reported, "The analysis also said that methane discharges in Texas and Oklahoma, where oil and gas production was concentrated at the time, were 2.7 times greater than conventional estimates. Emissions from oil and gas activity alone could be five times greater than the prevailing estimate."[332]

- October 18, 2013 – A major study spearheaded by Stanford University's Energy Modeling Forum concluded that fracking and the shale gas revolution will have no long-term climate benefit. The study brought together a working group of about 50 experts and advisors from companies, government agencies and universities, and modeling teams from 14 organizations. The study also found that build-out of infrastructure for fracking and natural gas will discourage efforts to conserve energy and boost efficiency. The study did not examine methane leaks in order to weigh in on the short-term climate impacts of natural gas.[333]

- October 11, 2013 – As reported in the *Guardian*, key climate scientists argued that the growth in fracking across the United States is hurting the United States' credibility on climate change.[334]

- October 2, 2013 – Updated measurements from the IPCC determined that methane is even worse for the climate than previously thought. The IPCC determined that methane is

[330] McNary, S. (2013, November 21). Former advisors to Gov. Brown request fracking ban. *Southern California Public Radio*. Retrieved June 10, 2014, from http://www.scpr.org/blogs/politics/2013/11/21/15248/former-advisors-to-gov-brown-request-fracking-ban/

[331] Miller, S. M., Wofsy, S. C., Michalak, A. M., Kort, E. A., Andrews, A. E., Biraud, S. C., ... Sweeney, C. (2013). Anthropogenic emissions of methane in the United States. *Proceedings of the National Academy of Sciences, 110*(50), 20018-20022. doi: 10.1073/pnas.1314392110

[332] Wines, M. (2013, November 25). Emissions of methane in U.S. exceed estimates, study finds. *The New York Times*. Retrieved June 10, 2014, from http://www.nytimes.com/2013/11/26/us/emissions-of-methane-in-us-exceed-estimates-study-finds.html?_r=0

[333] Huntington, H. (2013). Changing the game? Emissions and market implications of new natural gas supplies. *Energy Modeling Forum, 1*. Retrieved June 10, 2014, from https://emf.stanford.edu/publications/emf-26-changing-game-emissions-and-market-implications-new-natural-gas-supplies.

[334] Magill, B. (2013, October 11). Fracking hurts US climate change credibility, say scientists. *The Guardian*. Retrieved June 10, 2014, from http://www.theguardian.com/environment/2013/oct/11/fracking-us-climate-credibility-shale-gas

34 times more potent as a greenhouse gas in the atmosphere than CO2 over a 100-year timeframe, and 86 times more potent over a 20-year timeframe.[335]

- September 27, 2013 – The IPCC formally embraced an upper limit on greenhouse gases for the first time, warning that the world will exceed those levels and face irreversible climatic changes in a matter of decades unless steps are taken soon to reduce emissions. The IPCC reported that humanity faces a "carbon budget"—a limit on the amount of greenhouse gases that can be produced by industrial activity before irreversible, damaging consequences—of burning about a trillion metric tons of carbon. The world is on track to hit that by around 2040 at the current rate of energy consumption.[336]

- August 12, 2013 – A *New Scientist* review of the science on fracking and global warming concluded that fracking could accelerate climate change rather than slow it.[337]

- May 28, 2013 – A research team led by Jeff Peischl, an associate scientist at NOAA's Cooperative Institute for Research in Environmental Sciences, estimated that the methane leak rate from Los Angeles-area oil and gas operations was about 17 percent.[338] [339]

- May, 2013 – A group of scientists and journalists studying climate change, led by Eric Larson, a scientist with Princeton University and Climate Central, reported that the often-purported 50 percent climate advantage of natural gas over coal is unlikely to be achieved over the next three to four decades given methane leaks and other factors.[340] The 50 percent claim is based on the fact that natural gas produces half as much carbon dioxide when burned than coal, but it ignores the significant greenhouse gas impacts of methane leakage that occurs throughout the life-cycle of natural gas production, transmission and distribution.

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[335] Romm, J. (2013, October 2). More bad news for fracking: IPCC warns methane traps much more heat than we thought. *Climate Progress*. Retrieved June 10, 2014, from http://thinkprogress.org/climate/2013/10/02/2708911/fracking-ipcc-methane/

[336] Gillis, J. (2013, September 27). U.N. climate panel endorses ceiling on global emissions. *The New York Times*. Retrieved June 10, 2014, from http://www.nytimes.com/2013/09/28/science/global-climate-change-report.html?pagewanted=all

[337] Pearce, F. (2013, August 12). Fracking could accelerate global warming. *New Scientist*. Retrieved June 10, 2014, from http://www.newscientist.com/article/dn24029-fracking-could-accelerate-global-warming.html#.UpEWqsQ3uSo

[338] Peischl, J., Ryerson, T. B., Brioude, J., Aikin, K. C., Andrews, A. E., Atlas, E., ... Parrish, D. D. (2013). Quantifying sources of methane using light alkanes in the Los Angeles basin, California. *Journal of Geophysical Research: Atmospheres, 118*(10), 4974-4990. doi: 10.1002/jgrd.50413

[339] Ogburn, S. (2014, May 15). Solving the Case of California's Extra Methane. *Scientific American Global RSS*. Retrieved July 3, 2014, from http://www.scientificamerican.com/article/solving-the-case-of-californias-extra-machine/

[340] Larson, E. D. (2013). Natural gas & climate change. *Climate Central*. Retrieved June 10, 2014, from http://assets.climatecentral.org/pdfs/NaturalGas-and-ClimateChange.pdf

- January 2, 2013 – A NOAA study found methane emissions from oil and gas fields in Utah to be as high as nine percent of production. These levels are considered extremely damaging to the climate.[341]

- November, 2012 – A review by the United Nations Environment Programme found that emissions from fracking, as well as other non-conventional natural gas extraction methods, could increase global warming in the short term and be comparable to coal over a 100-year timeframe.[342]

- November, 2012 – The International Energy Agency found that a large natural gas boom—even with improvements in place to reduce leakage—would eventually lead to greenhouse gas concentrations of 650 parts per million and a global temperature rise of 3.5 degrees Celsius, far exceeding the 2 degree Celsius limit which is critical to avoid the most severe effects of climate change.[343]

- May 29, 2012 – The *Guardian* summarized a special report on natural gas by the International Energy Agency: "A 'golden age of gas' spurred by a tripling of shale gas from fracking and other sources of unconventional gas by 2035 will stop renewable energy in its tracks if governments do not take action."[344]

- February, 2012 – A study found that the carbon dioxide emitted from the burning of natural gas —even neglecting the impacts of methane leakage—contributes significantly to greenhouse gas emissions that are driving climate change.[345]

- February 7, 2012 – A NOAA study of Colorado gas fields measured methane emissions of about four percent, a significant percentage that could be very damaging to the climate.[346]

- December 29, 2011 – As reported by *The New York Times,* levels of methane in the atmosphere have been steadily rising since 2007—coinciding with the onset of the fracking boom and posing a serious threat to the Earth's climate.[347]

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[341] Tollefson, J. (2013). Methane leaks erode green credentials of natural gas. *Nature, 493*(7430), 12-12. doi: 10.1038/493012a

[342] Global Environmental Alert Service. (2012). Gas fracking: Can we safely squeeze the rocks? United Nations Environmental Programme. Retrieved June 10, 2014, from http://www.unep.org/pdf/UNEP-GEAS_NOV_2012.pdf

[343], World Energy Outlook 2012, (November 2012). *Golden Rules for a Golden Age of Natural Gas—World Energy Outlook Special Report on Unconventional Gas*, International Energy Agency. Retrieved July 9, 2014, from http://www.iea.org/publications/freepublications/publication/name,27408,en.html

[344] Harvey, F. (2012, May 29). 'Golden age of gas' threatens renewable energy, IEA warns. *The Guardian*. Retrieved June 10, 2014, from http://www.theguardian.com/environment/2012/may/29/gas-boom-renewables-agency-warns

[345] Myhrvold, N. P., & Caldeira, K. (2012). Greenhouse gases, climate change and the transition from coal to low-carbon electricity. *Environmental Research Letters, 7*(1). doi: 10.1088/1748-9326/7/1/014019

[346] Tollefson, J. (2012, February 7). Air sampling reveals high emissions from gas field. *Nature*. Retrieved June 10, 2014, from http://www.nature.com/news/air-sampling-reveals-high-emissions-from-gas-field-1.9982

[347] Gillis, J. (2011, December 29). The puzzle of rising methane. *The New York Times*. Retrieved June 10, 2014, from http://green.blogs.nytimes.com/2011/12/29/the-puzzle-of-rising-methane/

- October, 2011 – A study from the National Center for Atmospheric Research concluded that substituting the use of natural gas for coal will increase rather than decrease the rate of global warming for many decades.[348]

- July 6, 2011 – According to the U.S. Energy Information Administration and other research, significant amounts of methane are leaking from aging gas pipelines and infrastructure.[349]

- April, 2011 – A comprehensive analysis of the greenhouse gas footprint of natural gas from shale formations found that between 3.6 percent to 7.9 percent of the methane from natural gas production wells escapes into the atmosphere, rather than being combusted, thereby undermining any climate benefits of gas over coal as a source of energy.[350] [351]

Inaccurate jobs claims, increased crime rates, threats to property value and mortgages and local government burden

- October 30, 2014 – The *New York Times* profiled the profound impact heavy drilling has had on Glasscock County, Texas, including its farming community. Farmers described increases in trash, traffic accidents, clashes around farmers selling groundwater to drillers, and economic detriment. In many cases, acres of farmland around a drill site "will probably never be suitable for fertile farming again," and farmers are "at the mercy" of what drillers want to pay. The county itself receives revenue, but "… most of that additional money is being used to repair roads damaged by oil field truck activity. Overall, the gains from drilling are not viewed as worth the drawbacks in a county long dominated by cotton farming."[352]

- September 11, 2014 – An editor for the *Washington Post* examined jobs and manufacturing data in Youngstown, Ohio, to demonstrate that drilling and fracking are not resulting in a revitalization of the Rust Belt as some proponents and a prominent *New York Times* story asserted. The *Post* determined that in Youngstown, Ohio, the manufacturing sector has lost jobs by the tens of thousands in the last twenty years and

[348] Wigley, T. M. (2011). Coal to gas: The influence of methane leakage. *Climatic Change, 108*(3), 601-608. doi: 10.1007/s10584-011-0217-3
[349] McKenna, P. (2011, July 6). Thousands of gas leaks under Boston and San Francisco. *New Scientist*. Retrieved June 10, 2014, from http://www.newscientist.com/article/mg21128203.800-thousands-of-gas-leaks-under-boston-and-san-francisco.html#.UpEbbMQ3uSp
[350] Howarth, R. W., Santoro, R., & Ingraffea, A. (2011). Methane and the greenhouse-gas footprint of natural gas from shale formations. *Climatic Change, 106*(4), 679-690. doi: 10.1007/s10584-011-0061-5
[351] Howarth, R. W., Santoro, R., & Ingraffea, A. (2012). Venting and leaking of methane from shale gas development: Response to Cathles et al. *Climatic Change, 113*(2), 537-549. doi: 10.1007/s10584-012-0401-0
[352] Batheja, A. (2014, October 30). A county resents oil drilling, despite the money it brings in. *The New York Times*. Retrieved from http://www.nytimes.com/2014/10/31/us/a-county-resents-oil-drilling-despite-the-money-it-brings-in.html?ref=earth&_r=1

the oil and gas industry has created approximately two thousand jobs since the recession ended. Six years ago, there were 13,000 more jobs in the Youngstown metro area than there were this past summer.[353]

- September 6, 2014 – In Williams County, North Dakota, in the Bakken shale, increases in crime have corresponded with the flow of oil. The infusion of cash has attracted career criminals who deal in drugs, violence and human sex trafficking. The *Williston Herald* portrayed, in a "reader's discretion advised" article, the rapid rise of "index crimes"—"violent crimes that result in the immediate loss of an individual's property, health or safety, such as murder, larceny and rape." With fewer than 100 law enforcement personnel, "[c]rime in Williams County has risen in kind with the county's population, but funding, staffing and support training for law enforcement has not."[354]

- September, 2014 – An article in the magazine *Governing: The States and Localities* described the social, environmental, health and safety, and economic burdens endured by localities from fracking. "In addition, fracking, in many cases, negatively impacts property values, which in turn depresses property tax revenue. For property owners who own the rights to the oil and gas on their land, the effects of drilling can be offset by royalty payments. But localities have no revenue offset if properties lose value."[355]

- August 26, 2014 – The U.S. Justice Department Office of Violence Against Women awarded three million dollars to five rural and tribal communities to prosecute crimes of violence against women and provide services to victims of sexual assault, domestic violence and stalking in the Bakken Region of North Dakota and Montana.[356] Rationale documented by tribal leaders, law enforcement and the FBI included, "rapid development of trailer parks and modular housing developments often referred to as 'man camps;' abrupt increase in cost of living, especially housing; rapid influx of people, including transients, in a previously rural and stable community; constant fear and perception of danger; and a lost way of life. Local and tribal officials and service providers reported that these changes have been accompanied by a rise in crime, including domestic and sexual violence."[357]

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[353] Tankersley, J. (2014, September 11). Fracking hasn't restored the Rust Belt's lost jobs. *The Washington Post*. Retrieved from http://www.washingtonpost.com/news/storyline/wp/2014/09/11/fracking-hasnt-restored-the-rust-belts-lost-jobs/

[354] Bell, T. (2014, September 6). Modernized slavery. *Williston Herald.* Retrieved from http://www.willistonherald.com/news/modernized-slavery/article_84e257d8-3615-11e4-a4f8-001a4bcf887a.html

[355] Shafroth, F.. (2014, September). Fracking's financial losers: local governments. *Governing: The States and Localities.* Retrieved from http://www.governing.com/columns/public-money/gov-frackings-financial-losers.html

[356] U.S. Department of Justice. (2014, August 26). Associate Attorney General West announces $3 million in grants to address violence against women in rural and tribal communities in the Bakken Region. *Justice News*. Retrieved from http://www.justice.gov/opa/pr/associate-attorney-general-west-announces-3-million-grants-address-violence-against-women

[357] U.S. Department of Justice. (2014). OVW Fiscal Year 2014 Violence Against Women Bakken Region Initiative: Enhanced response to victims application guidelines. Retrieved from http://www.justice.gov/sites/default/files/ovw/legacy/2014/04/25/fy2014-initative-for-the-bakken-region-enhanced-services-for-victims.pdf

- May 27, 2014 – A *Bloomberg News* analysis of 61 shale drilling companies found that the economic picture of shale oil and gas is unstable. Shale debt has almost doubled over the last four years while revenue has gained just 5.6 percent. For the 61 companies in their analysis, *Bloomberg News* reported: "In a measure of the shale industry's financial burden, debt hit $163.6 billion in the first quarter." Further, *Bloomberg News* noted that drillers are caught in a bind because they must keep borrowing to pay for exploration needed to "offset steep production declines typical of shale wells …. For companies that can't afford to keep drilling, less oil coming out means less money coming in, accelerating the financial tailspin."[358]

- May 5, 2014 – An Associated Press analysis found that traffic fatalities have spiked in heavily drilled areas of six states whereas most other roads in the nation have become safer even as population has grown. In North Dakota drilling counties, for instance, traffic fatalities have increased 350 percent.[359]

- April 16, 2014 – A comprehensive article in the *Albany Law Review* concluded that the risks inherent with fracking are not covered by homeowner's insurance, not fully insured by the oil and gas industry and threaten mortgages and property value.[360]

- April 2014 – A report by the Multi-State Shale Research Collaborative, "Assessing the Impacts of Shale Drilling: Four Community Case Studies," documented economic, community, government and human services impact of fracking on four rural communities. The study found that fracking led to a rapid influx of out-of-state workers and, although some new jobs were created, these were accompanied by additional costs for police, emergency services, road damage, and social services. In addition, increased rents, and a shortage of affordable housing accompanied the fracking boom. Unemployment rose after one county's "boom" ended and, in another county, stayed above the state average throughout. [361]

- March 27, 2014 – A report by researchers at Rand Corp. determined that each shale gas well in Pennsylvania causes between $5,400 and $10,000 in damage to state roads. The report did not calculate damage to local roads, which is also significant. Researchers used

[358] Loder, A. (2014, May 27). Shakeout threatens shale patch as frackers go for broke. *Bloomberg*. Retrieved June 10, 2014, from http://www.bloomberg.com/news/2014-05-26/shakeout-threatens-shale-patch-as-frackers-go-for-broke.html

[359] Begos, K., & Fahey, J. (2014, May 5). AP impact: Deadly side effect to fracking boom. *Associated Press*. Retrieved June 10, 2014, from http://bigstory.ap.org/article/ap-impact-deadly-side-effect-fracking-boom-0

[360] Radow, E.L. (2014). At the intersection of Wall Street and Main: Impacts of hydraulic fracturing on residential property interests, risk allocation, and implications for the secondary mortgage market. *Albany Law Review, 77*(2), 673-704.

[361] Multi-State Shale Research Collaborative. (2014, April 10). *Assessing the impacts of shale drilling county case studies* (Rep.). Retrieved June 10, 2014, from https://docs.google.com/viewer?a=v&pid=sites&srcid=ZGVmYXVsdGRvbWFpbnxtdWx0aXN0YXRlc2hhbGV8Z3g6NGU4MjIyNWU5ZjFhZjM4Yg

estimates of truck trips that are significantly below the number estimated for New York by the NYS DEC.[362] [363]

- February 15, 2014 – *The Los Angeles Times* detailed steep increases in crime that have accompanied fracking in parts of the Eagle Ford Shale in Texas, including sexual assaults and thefts.[364]

- February 14, 2014 –Pennsylvania landowners with fracking leases rallied in Bradford County against gas companies for precipitous drops in royalty payments.[365]

- December 20, 2013 – The National Association of Realtors' *RealtorMag* summarized a growing body of research showing that fracking and gas drilling threaten property values, including a University of Denver survey and a *Reuters* analysis.[366]

- December 12, 2013 – A *Reuters* analysis discussed how oil and gas drilling has made making some properties "unsellable" and researched the link between drilling and property value declines. The analysis highlighted a Duke University working paper that finds shale gas drilling near homes can decrease property values by an average of 16.7 percent if the house depends on well water.[367]

- December 10, 2013 – Pennsylvania's *The Daily Review* reported that more gas companies are shifting costs to leaseholders and that royalty payments are drastically shrinking. The story quoted Bradford County commissioner Doug McLinko saying that some gas companies "are robbing our landowners" and that the problem of royalty payments being significantly reduced by deductions for post-production costs "is widespread throughout our county."[368]

- November 30, 2013 – *The New York Times* reported striking increases in crime in Montana and North Dakota where the oil and gas boom is prevalent, as well as challenges

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[362] Cusick, M. (2014, March 27). Report finds each Marcellus gas well costs thousands in road damage. *StateImpact*. Retrieved June 10, 2014, from http://stateimpact.npr.org/pennsylvania/2014/03/27/report-finds-each-marcellus-gas-well-costs-thousands-in-road-damage/

[363] Abramzon, S., Samaras, C., Curtright, A., Litovitz, A., & Burger, N. (2014). Estimating the consumptive use costs of shale natural gas extraction on Pennsylvania roadways. *Journal of Infrastructure Systems*. Retrieved June 10, 2014, from http://ascelibrary.org/doi/abs/10.1061/%28ASCE%29IS.1943-555X.0000203

[364] Hennessy-Fiske, M. (2014, February 15). Fracking brings oil boom to south Texas town, for a price. Retrieved June 10, 2014, from http://www.latimes.com/nation/la-na-texas-oil-boom-20140216%2C0%2C7621618.story#ixzz30Iw9FXoz.

[365] Marshall, J. (2014, February 14). Landowners rally for royalties from gas companies. Retrieved June 10, 2014, from http://www.wbng.com/news/local/Landowners-rally-for-245596511.html

[366] Daily Real Estate News. (2013, December 20). 'Fracking' sparks concern over nearby home values. *National Association of Realtors*. Retrieved June 10, 2014, from http://realtormag.realtor.org/daily-news/2013/12/20/fracking-sparks-concern-over-nearby-home-values#.UrmdIlPmVu8.twitter

[367] Conlin, M. (2013, December 12). Gas drilling is killing property values for some Americans. *Reuters*. Retrieved June 10, 2014, from http://www.businessinsider.com/drilling-can-make-some-properties-unsellable-2013-12#ixzz2nMgFv8FU

[368] Loewenstein, J. (2013, December 10). Shrinking royalty checks. *Thedailyreview.com*. Retrieved June 10, 2014, from http://thedailyreview.com/news/shrinking-royalty-checks-1.1598195

faced by local residents from the influx of out-of-area workers and the accompanying costs. The *New York Times* reported, "'It just feels like the modern-day Wild West,' said Sgt. Kylan Klauzer, an investigator in Dickinson, in western North Dakota. The Dickinson police handled 41 violent crimes last year, up from seven only five years ago."[369]

- November 21, 2013 – The Multi-State Shale Research Collaborative released a six-state collaborative report demonstrating that the oil and gas industry has greatly exaggerated the number of jobs created by drilling and fracking in shale formations. The report found that far from the industry's claims of 31 direct jobs created per well, only four jobs are created for each well. It also demonstrated that almost all of the hundreds of thousands of 'ancillary' jobs that the drilling industry claims are related to shale drilling existed before such drilling occurred. As Frank Mauro, executive director of the Fiscal Policy Institute put it, "Industry supporters have exaggerated the jobs impact in order to minimize or avoid altogether taxation, regulation, and even careful examination of shale drilling."[370]

- November 12, 2013 – *The American Banker* reported that the "Fracking Boom Gives Banks Mortgage Headaches," with a number of financial institutions refusing to make mortgages on land where oil and gas rights have been sold to an energy company. The article stated that the uniform New York state mortgage agreement used by Fannie Mae and Freddie Mac requires that homeowners not permit any hazardous materials to be used or located on their property. Fracking is therefore a problem because it is just such a hazardous activity with use of hazardous materials.[371]

- September 25, 2013 – A report found that fracking is linked to significant road damage, increased truck traffic, crime, and strain on municipal and social services. Data from the past ten years on the social costs of fracking including truck accidents, arrests, and higher rates of sexually transmitted diseases are all causes for alarm.[372]

- September 12, 2013 – In a feature titled "Pa. fracking boom goes bust," *The Philadelphia Inquirer* presented data from the independent Keystone Research Center detailing "flat at best" job growth and declines in production and royalty payments.[373]

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[369] Healy, J. (2013, November 30). As oil floods plains towns, crime pours in. *The New York Times*. Retrieved June 10, 2014, from http://www.nytimes.com/2013/12/01/us/as-oil-floods-plains-towns-crime-pours-in.html?smid=tw-share&_r=0

[370] Campbell, J. (2013, November 21). Report: Industry-backed studies exaggerate fracking job estimates. *Politics on the Hudson*. Retrieved June 10, 2014, from http://polhudson.lohudblogs.com/2013/11/21/report-industry-backed-studies-exaggerate-fracking-job-estimates/

[371] Peters, A. (2013, November 12). Fracking boom gives banks mortgage headaches. *American Banker*. Retrieved June 10, 2014, from http://www.americanbanker.com/issues/178_218/fracking-boom-gives-banks-mortgage-headaches-1063561-1.html

[372] Gibbons, B. S. (2013, September 25). Environmental groups calculate social cost of natural gas boom. *The Times-Tribune*. Retrieved June 10, 2014, from http://thetimes-tribune.com/news/environmental-groups-calculate-social-cost-of-natural-gas-boom-1.1558186

[373] Bunch, W. (2013, September 12). Pa. fracking boom goes bust. *Philly.com*. Retrieved June 10, 2014, from http://articles.philly.com/2013-09-12/news/41974274_1_fracking-boom-penn-state-marcellus-center-marcellus-shale

- August 22, 2013 – A University of Denver study in the *Journal of Real Estate Literature* found a 5 percent to 15 percent reduction in bid value for homes near gas drilling sites. [374]

- August 21, 2013 – *The Atlantic Cities* and *MSN Money* reported that fracking operations may be damaging property values and may impair mortgages or the ability to obtain property insurance.[375] [376]

- August 13, 2013 – A *ProPublica* investigative analysis found that Chesapeake Energy is coping with its financial difficulties in Pennsylvania by shifting costs to landowners who are now receiving drastically reduced royalty payments.[377]

- August 4, 2013 – In a survey of West Virginia landowners with shale wells on their property, more than half reported problems including damage to the land, decline in property values, truck traffic and lack of compensation by the oil and gas company.[378]

- May 24, 2013 – Pennsylvania Department of Transportation Secretary Allen D. Biuhler, P.E., and Pennsylvania State Police Commissioner Frank Pawlowski said that gas drilling has led to increases in truck traffic, traffic violations, crime, demand for social services, and the number of miles of roads that are in need of repairs. They noted that drilling companies that committed to repairing roads have not kept pace with the roads they damage. Police Commissioner Pawlowski reported that 56 percent of 194 trucks checked were over the legal weight limit and 50 percent were also cited for safety violations.[379]

- May 4, 2013 – Pennsylvania's *Beaver County Times* asked "What boom?" in pointing to Keystone Research Center data showing that the number of jobs numbers created by shale gas extraction do not add up to what the gas industry claims, noting that unemployment has increased and the state actually fell to 49th in the nation for job creation.[380]

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[374] Downing, B. (2013, April 22). Survey says home values hurt by fracking at drill sites. *Ohio.com*. Retrieved June 10, 2014, from http://www.ohio.com/blogs/drilling/ohio-utica-shale-1.291290/survey-says-home-values-hurt-by-fracking-at-drill-sites-1.422838

[375] Drouin, R. (2013, August 19). How the fracking boom could lead to a housing bust. *Citylab*. Retrieved June 10, 2014, from http://www.theatlanticcities.com/politics/2013/08/how-fracking-boom-could-lead-housing-bust/6588/

[376] Notte, J. (2013, August 21). Fracking leaves property values tapped out. *MSN Money*. Retrieved June 10, 2014, from http://money.msn.com/now/post--fracking-leaves-property-values-tapped-out

[377] Lustgarten, A. (2013, August 13). Unfair share: How oil and gas drillers avoid paying royalties. *ProPublica*. Retrieved June 10, 2014, from http://www.propublica.org/article/unfair-share-how-oil-and-gas-drillers-avoid-paying-royalties

[378] Collins, A. R. & Nkansah, K. (2013, August 4). *Divided rights, expanded conflict: The impact of split estates in natural gas production* [Scholarly project]. Retrieved June 10, 2014, from http://ageconsearch.umn.edu/bitstream/150128/2/Collins_Nkahsah_Split%20estate.pdf

[379] PR Newswire. (2014, May 24). Increased gas drilling activities bringing new challenges to local governments in Pennsylvania. *PR Newswire*. Retrieved June 10, 2014, from http://www.prnewswire.com/news-releases/increased-gas-drilling-activities-bringing-new-challenges-to-local-governments-in-pennsylvania-94774764.html

[380] Morgan, R. (2013, May 4). Beaver County Times: What boom? Industry pundits claim thousands of jobs will be created, but numbers don't quite add up. *Keystone Research Center*. Retrieved June 10, 2014, from http://keystoneresearch.org/media-center/media-coverage/beaver-county-times-what-boom-industry-pundits-claim-thousands-jobs-will

- April 2, 2013 – *The New York Times* reported that manufacturing jobs resulting from an abundance of shale gas have not appeared. "The promised job gains, other than in the petrochemical industry, have been slow to materialize," the *New York Times* reported. The article suggested that increased automation has made it unlikely that manufacturers will add many jobs.[381]

- March 19, 2013 – The *Wall Street Journal* reported that the shale gas boom has not had a big impact on U.S. manufacturing because lower energy prices are only one factor in a company's decision on where to locate factories, and not always the most important factor. "Cheap energy flowing from the U.S. shale-gas boom is often touted as a 'game changer' for manufacturing," the *Journal* reported. "Despite the benefits of lower energy costs, however, the game hasn't changed for most American manufacturers."[382]

- February, 2013 – A peer-reviewed analysis of industry-funded and independent studies on the economics of fracking found that it is unlikely that fracking will lead to long-term economic prosperity for communities. The analysis noted that shale gas development brings a number of negative externalities including the potential for water, air and land contamination; negative impacts on public health; wear and tear on roads and other infrastructure; and costs to communities due to increased demand for services such as police, fire departments, emergency responders, and hospitals.[383]

- November 16, 2012 – A Duke University study showed a drop in home values near fracking for properties that rely on groundwater. [384]

- September 27, 2012 – *The New York Times* reported that the prospect of fracking has hindered home sales in the Catskills and raised concerns about drops in property values, according to real estate agents and would-be buyers.[385]

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[381] Schwartz, N. D. (2013, April 01). Rumors of a cheap-energy jobs boom remain just that. *The New York Times*. Retrieved June 11, 2014, from http://www.nytimes.com/2013/04/02/business/economy/rumors-of-a-cheap-energy-jobs-boom-remain-just-that.html?_r=0

[382] Hagerty, J. R. (2013, March 19). Shale-gas boom alone won't propel U.S. industry. *The Wall Street Journal*. Retrieved June 10, 2014, from http://online.wsj.com/news/articles/SB10001424127887324392804578362781776519720

[383] Barth, J. M. (2013). The Economic Impact of Shale Gas Development on State and Local Economies: Benefits, Costs, and Uncertainties. *NEW SOLUTIONS: A Journal of Environmental and Occupational Health Policy, 23*(1), 85-101. doi: 10.2190/NS.23.1.f

[384] Muoio, D. (2012, November 16). Duke researchers show dip in home value caused by nearby fracking. *The Chronicle*. Retrieved June 10, 2014, from http://www.dukechronicle.com/articles/2012/11/16/duke-researchers-show-dip-home-value-caused-nearby-fracking

[385] Navarro, M. (2012, September 27). Gas drilling jitters unsettle Catskills sales. *The New York Times*. Retrieved June 10, 2014, from http://www.nytimes.com/2012/09/30/realestate/fracking-fears-hurt-second-home-sales-in-catskills.html?pagewanted=1

- August 17, 2012 – A study by the state agencies, the Montana All Threat Intelligence Center and the North Dakota State and Local Intelligence Center, found that crime rose by 32 percent since 2005 in communities at the center of the oil and gas boom.[386]

- October 30, 2011 – A comprehensive article in the *New York State Bar Association Journal* concluded that the risks inherent with fracking threaten mortgages.[387]

- October 26, 2011 – The Associated Press reported that areas with significant fracking activity, including Pennsylvania, Wyoming North Dakota and Texas, are "seeing a sharp increase in drunken driving, bar fights and other hell-raising."[388]

- October 19, 2011 – A *New York Times* investigation found that fracking can create conflicts with mortgages, and that "bankers are concerned because many leases allow drillers to operate in ways that violate rules in landowners' mortgages," and further that "[f]earful of just such a possibility, some banks have become reluctant to grant mortgages on properties leased for gas drilling. At least eight local or national banks do not typically issue mortgages on such properties, lenders say."[389]

- September 7, 2011 – The NYS DEC estimated that 77 percent of the workforce on initial shale gas drilling projects would consist of transient workers from out of state. Not until the thirtieth year of shale gas development would 90 percent of the workforce be comprised of New York residents.[390]

- August 15, 2011 – The *Pittsburgh Post-Gazette* reported that increases in crime followed the Pennsylvania gas drilling boom, noting, for instance, that drunken driving arrests in Bradford County were up 60 percent, DUI arrests were up 50 percent in Towanda, and criminal sentencing was up 35 percent in 2010.[391]

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[386] Montana All Threat Intelligence Center, & North Dakota State and Local Intelligence Center. (2012, August 17). *Impact of population growth on law enforcement in the Williston Basin region* (Rep.). Retrieved June 10, 2014, from http://www.ag.nd.gov/reports/JOINTPRODUCTFINAL.pdf

[387] Radow, E. N. (2011). Homeowners and gas drilling leases: Boon or bust? *New York State Bar Association Journal, 83*(9). Retrieved June 10, 2014, from http://www.s-oacc.org/resources/NYSBA_Journal_nov-dec2011_lead_article_with_reprint_info.pdf

[388] Levy, M. (2011, October 26). Towns see crime, carousing surge amid gas boom. *Associated Press*. Retrieved June 10, 2014, from http://news.yahoo.com/towns-see-crime-carousing-surge-amid-gas-boom-135643480.html

[389] Urbina, I. (2011, October 19). A rush to sign leases for gas runs into mortgage restriction. *The New York Times*. Retrieved June 11, 2014, from http://www.nytimes.com/2011/10/20/us/rush-to-drill-for-gas-creates-mortgage-conflicts.html?_r=2&hp&

[390] New York State Department of Environmental Conservation. (2011). *Supplemental generic environmental impact statement on the oil, gas and solution mining regulatory program, well permit issuance for horizontal drilling and high-volume hydraulic fracturing to develop the Marcellus shale and other low-permeability gas reservoirs* (6-233, 234, Rep.).

[391] Needles, Z. (2011, August 15). Must crime follow Pennsylvania's gas drilling boom? *Pittsburgh Post-Gazette*. Retrieved June 10, 2014, from http://www.post-gazette.com/stories/business/legal/must-crime-follow-pennsylvanias-gas-drilling-boom-310373/

- July 26, 2011 – A New York State Department of Transportation document estimated that fracking in New York could result in the need for road repairs and reconstruction costing $211 million to $378 million each year.[392]

- June 20, 2011 – A Keystone Research Center study found that the gas industry's claim of 48,000 jobs created between 2007 and 2010 as a result of natural gas drilling in Pennsylvania is a far cry from the actual number of only 5,669 jobs—many of which were out-of-state hires.[393]

- May 9, 2011 – A study in the *Journal of Town & City Management* found that shale gas development can impose "significant short- and long-term costs" to local communities. The study noted that shale gas development creates a wide range of potential environmental hazards and stressors, all of which can adversely impact regional economies, including tourism and agriculture sectors.[394]

- November 30, 2010 – The *Dallas Morning News* featured a story, "Drilling Can Dig into Land Value," reporting that the Wise County Central Appraisal District Appraisal Review Board found that a drilling company had caused an "extraordinary reduction" in property value, by 75 percent.[395]

- November 28, 2010 – The Texas *Wise County Messenger* reported that some landowners near fracking operations experience excessive noise, exposure to diesel fumes, and problems with trespassing by workers.[396]

Inflated estimates of oil and gas reserves and profitability

- August 29, 2014 – Andrew Nikiforuk, a Canadian energy analyst, reported on diminishing returns and higher-cost, higher-risk nature of fossil fuel extraction by fracking. Nikiforuk wrote, "Most of the world's oil and gas firms are now pursuing extreme hydrocarbons because the cheap and easy stuff is gone …. That means industry will spend more good money chasing poor quality resources. They will inefficiently mine

[392] Reilly, S. (2011, July 26). Document estimates fracking's toll on N.Y. roads. *Pressconnects.com*. Retrieved June 10, 2014, from http://www.pressconnects.com/article/20110726/NEWS01/107260384/Document-estimates-fracking-s-toll-N-Y-roads

[393] Herzenberg, S. (2011). Drilling deeper into job claims. Keystone Research Center. Retrieved June 10, 2014, from http://keystoneresearch.org/sites/keystoneresearch.org/files/Drilling-Deeper-into-Jobs-Claims-6-20-2011_0.pdf

[394] Christopherson, S. & Rightor, N. (2011). How shale gas extraction affects drilling localities: Lessons for regional and city policy makers. *Journal of Town & City Management, 2*(4), 1-20. Retrieved June 10, 2014, from http://www.greenchoices.cornell.edu/downloads/development/shale/Economic_Effects_on_Drilling_Localities.pdf

[395] Heinkel-Wolfe, P. (2010, September 18). Drilling can dig into land value. *Dallas News*. Retrieved June 10, 2014, from http://www.dallasnews.com/incoming/20100918-Drilling-can-dig-into-land-value-9345.ece

[396] Evans, B. (2010, November 28). Rising volume: 'Fracking' has bolstered economies, but noise still echoes around drilling. *WCMessenger.com*. Retrieved June 10, 2014, from http://www.wcmessenger.com/2010/news/rising-volume-fracking-has-bolstered-economies-but-noise-still-echoes-around-drilling/

and frack ever larger land bases at higher environmental costs for lower energy returns."[397]

- July 29, 2014 – According to the US Energy Information Administration, energy companies are incurring increasing debt and selling assets to continue drilling in shale. "Based on data compiled from quarterly reports, for the year ending March 31, 2014, cash from operations for 127 major oil and natural gas companies totaled $568 billion, and major uses of cash totaled $677 billion, a difference of almost $110 billion. This shortfall was filled through a $106 billion net increase in debt and $73 billion from sales of assets...."[398]

- July, 2014 – Researchers at the Washington, DC-based Environmental Law Institute and Washington & Jefferson College in Pennsylvania collaborated to produce a report designed in part to help communities avoid the "boom and bust" cycles of extractive industries. Authors warned, "While resource extraction has long been regarded as an economic benefit, a body of academic literature suggests that long term growth based chiefly on resource extraction is rare." Confounding factors include transience of the workforce, localized inflation, widening disparities in royalties and impact fee disbursement, commodity price volatility, and communities overspending on infrastructure.[399]

- June 19, 2014 – Energy analyst Deborah Lawrence Rogers outlined the spiraling debt and severe deterioration of the assets of five major shale gas drillers over the last five years. She concluded that, "This is not sustainable. It could be argued that it is not even moral. It is a failed business model of epic proportion. While companies could make the argument at one time that this was a short term downtrend, that no longer holds water because this pattern is long term."[400]

- April 10, 2014 – A report by a petroleum geologist and petroleum engineer concluded the 100-year supply of shale gas is a myth, distinguished between what is technically recoverable and economically recoverable shale gas, and asserted that at current prices, New York State has no economically recoverable shale gas.[401]

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[397] Nikiforuk, A. (2014, August 29). A big summer story you missed: soaring oil debt returns diminish as energy companies resort to higher-cost, higher-risk hydrocarbons. *The Tyee.* Retrieved from http://thetyee.ca/Opinion/2014/08/29/Soaring-Oil-Debt-Summer/

[398] US Energy Information Administration. (2014, July 29). As cash flows flatten, major energy companies increase debt, sell assets. *Today in Energy.* Retrieved from http://www.eia.gov/todayinenergy/detail.cfm?id=17311

[399] Environmental Law Institute and Washington & Jefferson College. (2014, July). Getting the boom without the bust: Guiding Southwestern Pennsylvania through shale gas development. Retrieved from http://www.eli.org/sites/default/files/eli-pubs/getting-boom-final-paper-exec-summary-2014-07-28.pdf

[400] Rogers, D.L. (2014, June 19). Huge CAPEX = free cash flow? Not in shales. *Energy Policy Forum.* Retrieved from http://energypolicyforum.org/2013/06/19/huge-capex-free-cash-flow-not-in-shales/

[401] Labyrinth Consulting Services, Inc., Berman, A., and Pittinger, L. (2014). Resource Assessment of Potentially Producible Natural Gas Volumes From the Marcellus Shale, State of New York. Retrieved from: http://www.lwvny.org/

- February 28, 2014 – The chief of the International Energy Agency reported that there is only a decade left in the US shale oil and gas boom, noting that the growth would not last and that production would soon flatten out and go down.[402]

- December 18, 2013 – A University of Texas study in *Proceedings of the National Academy of Sciences* found that fracking well production drops sharply with time, which undercuts the oil and gas industry's economic projections.[403] In an interview about the study with *StateImpact NPR* in Texas, Tad Patzek, chair of the Department of Petroleum and Geosystems Engineering at University of Texas at Austin, noted that fracking "also interferes now more and more with daily lives of people. Drilling is coming to your neighborhood, and most people abhor the thought of having somebody drilling a well in their neighborhood."[404]

- August 18, 2013 – *Bloomberg News* reported that low gas prices and disappointing wells have led major companies to devalue oil and gas shale assets by billions of dollars.[405]

- October 21, 2012 – *The New York Times* reported that many gas drilling companies overproduced natural gas backed by creative financing and now "are committed to spending far more to produce gas than they can earn selling it." "We are all losing our shirts today," said Exxon CEO Rex Tillerson in the summer of 2012.[406]

- July 13, 2012 – The *Wall Street Journal* reported that ITG Investment Research, at the request of institutional investors, evaluated the reserves of Chesapeake Energy Corp.'s shale gas reserves in the Barnett and Haynesville formations and found them to be only 70 percent of estimates by Chesapeake's engineering consultant for the company's 2011 annual report. Chesapeake and its consultant defended their figures.[407]

- August 23, 2011 – The U.S. Geological Survey cut the government's estimates of natural gas in the Marcellus Shale from 410 trillion cubic feet to 84 trillion cubic feet, equivalent to a reduction from approximately 16 years of U.S. consumption at current levels of natural gas use, to approximately 3.3 years of consumption. The U.S. Geological

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[402] Unger, D. J. (2014, February 28). IEA chief: Only a decade left in US shale oil boom. *The Christian Science Monitor*. Retrieved June 10, 2014, from http://www.csmonitor.com/Environment/Energy-Voices/2014/0228/IEA-chief-Only-a-decade-left-in-US-shale-oil-boom

[403] Patzek, T. W., Male, F., & Marder, M. (2013). Gas production in the Barnett Shale obeys a simple scaling theory. *Proceedings of the National Academy of Sciences, 110*(49), 19731-19736. doi: 10.1073/pnas.1313380110

[404] Buchele, M. (2013, December 18). New study shows how gas production from "fracked" wells slows over time. *StateImpact*. Retrieved June 10, 2014, from http://stateimpact.npr.org/texas/2013/12/18/new-study-shows-how-gas-production-from-fracked-wells-slows-over-time/

[405] Monks, M., Penty, R., & De Vynck, G. (2013, August 18). Shale grab in U.S. stalls as falling values repel buyers. *Bloomberg*. Retrieved June 10, 2014, from http://www.bloomberg.com/news/2013-08-18/shale-grab-in-u-s-stalls-as-falling-values-repel-buyers.html

[406] Krauss, C., & Lipton, E. (2012, October 20). After the boom in natural gas. *The New York Times*. Retrieved June 10, 2014, from http://www.nytimes.com/2012/10/21/business/energy-environment/in-a-natural-gas-glut-big-winners-and-losers.html?pagewanted=all

[407] Wirz, M. (2013, July 13). Chesapeake reserve doubted. *The Wall Street Journal*. Retrieved June 10, 2014, from http://online.wsj.com/news/articles/SB10001424052702303644004577523411723501548

Survey's updated estimate was for natural gas that is technically recoverable, irrespective of economic considerations such as the price of natural gas or the cost of extracting it.[408]

- June 26-27, 2011 – As reported in two *New York Times* stories, hundreds of emails, internal documents, and analyses of data from thousands of wells from drilling industry employees combined with documents from federal energy officials raised concerns that shale gas companies were overstating the amount of gas in their reserves and the profitability of their operations.[409] [410] [411] The *New York Times*' public editor criticized the stories, but offered no evidence that the major findings were wrong.[412] The *New York Times*' news editors publicly defended both stories against the public editor's criticism.[413] [414]

Disclosure of serious risks to investors

A snapshot of the dangers posed by natural gas drilling and fracking pose can be found in an annual Form 10-K that oil and natural gas companies are required to disclose annually to the U.S. Securities and Exchange Commission (SEC). Federal law requires that companies offering stock to the public disclose in their Form 10-K, among other things, the "most significant factors that make the offering speculative or risky."[415]

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[408] United States Geological Survey. (2011, August 23). USGS releases new assessment of gas resources in the Marcellus shale, Appalachian Basin. *USGS Newsroom*. Retrieved June 10, 2014, from http://www.usgs.gov/newsroom/article.asp?ID=2893&from=rss_home#.Uok0mGRO_GA.

[409] Urbina, I. (2011, June 25). Insiders sound an alarm amid a natural gas rush. *The New York Times*. Retrieved June 10, 2014, from http://www.nytimes.com/2011/06/26/us/26gas.html?pagewanted=all

[410] U.S. Energy Information Administration. (2014, May 30). U.S. Natural Gas Summary. Retrieved June 10, 2014, from http://www.eia.gov/dnav/ng/ng_sum_lsum_dcu_nus_a.htm

[411] Urbina, I. (2011, August 24). Geologists sharply cut estimate of shale gas. *The New York Times*. Retrieved June 10, 2014, from http://www.nytimes.com/2011/08/25/us/25gas.html

[412] Brisbane, A. S. (2011, July 16). Clashing views on the future of natural gas. *The New York Times*. Retrieved June 10, 2014, from http://www.nytimes.com/2011/07/17/opinion/sunday/17pubed.html?gwh=7D408242717755A0E06B0D265498E177&gwt=pay&assetType=opinion&_r=0

[413] Brisbane, A. S. (2011, July 17). Times editors respond to my shale gas column. *The New York Times*. Retrieved June 10, 2014, from http://publiceditor.blogs.nytimes.com/2011/07/17/times-editors-respond-to-my-shale-gas-column/

[414] Brisbane, A. S. (2011, July 30). Times editors respond to column on redactions. *The New York Times*. Retrieved June 10, 2014, from http://publiceditor.blogs.nytimes.com/2011/07/30/times-editors-respond-to-column-on-redactions/

[415] See 17 C.F.R. § 229.503(c) (companies must disclose the "most significant" risks); 17 C.F.R. § 230.405 ("the term material, when used to qualify a requirement for the furnishing of information as to any subject, limits the information required to those matters to which there is a substantial likelihood that a reasonable investor would attach importance in determining whether to purchase the security registered"); 17 C.F.R. § 240.10b-5 (it is illegal "to make any untrue statement of a material fact or to omit to state a material fact . . . in connection with the purchase or sale of any security); 17 C.F.R. 249.310 (requiring Form 10-K, "for annual and transition reports pursuant to sections 13 or 15(d) of the Securities Exchange Act of 1934.")

In a review of the most recent Form 10-Ks available on the SEC's website, oil and natural gas companies routinely warned of drilling's serious risks. In the words of Exxon Mobil Corp.'s subsidiary XTO Energy Corp., these included "hazards and risks inherent in drilling"[416]; or in the language of Range Resources Corp., "natural gas, NGLs [natural gas liquids] and oil operations are subject to many risks."[417]

Such hazards and risks include leaks, spills, explosions, blowouts, environmental damage, property damage, injury and death. Chesapeake Energy Corporation, which has been interested in drilling in New York, has stated that "horizontal and deep drilling activities involve greater risk of mechanical problems than vertical and shallow drilling operations."[418] Companies want to use horizontal drilling and fracking to extract shale gas in New York State.

The companies also routinely warn of inadequate insurance to cover drilling harms. XTO Energy Corporation, which holds thousands of acres of natural gas leases in New York, states that "we are not fully insured against all environmental risks, and no coverage is maintained with respect to any penalty or fine required to be paid by us."[419]

Houston-based Noble Energy provides a representative example of the risks that at least several drilling companies include in their annual reports. Noble states:

> *Our operations are subject to hazards and risks inherent in the drilling, production and transportation of crude oil and natural gas, including:*
>
> - *injuries and/or deaths of employees, supplier personnel, or other individuals;*
> - *pipeline ruptures and spills;*
> - *fires, explosions, blowouts and well cratering;*
> - *equipment malfunctions and/or mechanical failure on high-volume, high-impact wells;*
> - *leaks or spills occurring during the transfer of hydrocarbons from an FPSO to an oil tanker;*
> - *loss of product occurring as a result of transfer to a rail car or train derailments;*
> - *formations with abnormal pressures and basin subsidence;*
> - *release of pollutants;*
> - *surface spillage of, or contamination of groundwater by, fluids used in hydraulic fracturing operations;*
> - *security breaches, cyber attacks, piracy, or terroristic acts;*
> - *theft or vandalism of oilfield equipment and supplies, especially in areas of increased activity such as the DJ Basin and Marcellus Shale;*
> - *hurricanes, cyclones, windstorms, or "superstorms," such as Hurricane Sandy which occurred in 2012, which could affect our operations in areas such as the Gulf Coast, deepwater Gulf of Mexico, Marcellus Shale, Eastern Mediterranean or offshore China;*

[416] XTO Energy Corp., Annual Report (Form 10-K) (Feb. 25, 2010) at 25.
[417] Range Resources, Corp., Annual Report (Form 10-K) (Feb. 27, 2013) at 23.
[418] Chesapeake Energy Corp., Annual Report (Form 10-K) (Mar. 1, 2013) at 21.
[419] XTO Energy Corp., Annual Report (Form 10-K) (Feb. 25, 2010) at 17.

- *winter storms and snow which could affect our operations in the Rocky Mountain areas;*
- *unseasonably warm weather, which could affect third party gathering and processing facilities, such as occurred in the Rocky Mountain areas during 2012;*
- *volcanoes which could affect our operations offshore Equatorial Guinea;*
- *flooding which could affect our operations in low-lying areas such as the Marcellus Shale;*
- *harsh weather and rough seas offshore the Falkland Islands, which could limit certain exploration activities; and*
- *other natural disasters.*

Any of these can result in loss of hydrocarbons, environmental pollution and other damage to our properties or the properties of others.[420]

Noble has language similar to that found in other companies' annual reports about inadequate insurance and adds, "coverage is generally limited or not available to us for pollution events that are considered gradual."[421]

The risks identified by Noble and other drilling companies are not just hypothetical. Many, if not all of these risks have become realities as illustrated in the other sections of this compendium.

Medical and scientific calls for more study and more transparency

- December 5, 2014 – A team of medical and scientific researchers, including from the Institute for Health and Environment at the State University of New York (SUNY) at Albany, reviewed the scientific evidence that both adult and early life – including prenatal – exposure to chemicals from fracking operations can result in adverse reproductive health and developmental effects. These include: endocrine-disrupting chemicals potentially increasing risk for reproductive problems, breast cancer, abnormal growth and developmental delays, and changes in immune function; benzene, toluene and xylene (BTX chemicals) increasing risk for impaired sperm quantity and quality in men and menstrual and fertility problems in women; and heavy metals increasing the risk of miscarriage and/or stillbirths. Potential exposures occur through both air and water. Based on their review, the authors concluded, "Taken together, there is an urgent need for the following: 1) biomonitoring of human, domestic and wild animals for these chemicals; and 2) systematic and comprehensive epidemiological studies to examine the

[420] Noble Energy, Annual Report (Form 10-K) (Feb. 7, 2013) at 41-42.
[421] Noble Energy. Annual Report (Form 10-K) (Feb 7, 2013) at 41-42.

potential for human harm."[422] Lead author Susan Nagel said in an accompanying interview, "We desperately need biomonitoring data from these people. What are people actually exposed to? What are the blood levels of people living in these areas? What are the levels in the workers?"[423]

- September 15, 2014 – Researchers led by University of Rochester's Environmental Health Sciences Center conducted interviews in New York, North Carolina, and Ohio to evaluate community health concerns about unconventional natural gas development. They identified many areas where more study is needed, including baseline measures of air quality, ongoing environmental monitoring, and health impact assessments. They noted that other areas where data are lacking involve the assessment of drilling and fracking impacts on vulnerable populations such as very young children, and the potential consequences of interactions between exposures resulting from shale gas extraction operations. Researchers suggested incorporating the input of potentially affected community members into the development of the research agenda.[424]

- July 21, 2014 – An independent assessment report by Scientists for Global Responsibility and the Chartered Institute of Environmental Health reviewed current evidence across a number of issues associated with shale gas extraction by hydraulic fracturing, including environmental and public health risks, drawing on academic research. Among the report's conclusions: there are major shortcomings in regulatory oversight regarding local environmental and public health risks; there is a large potential for UK shale gas exploitation to undermine national and international efforts to tackle climate change; the water-intensive nature of the fracking process which could cause water shortages in many areas; the complete lack of evidence behind claims that shale gas exploitation will bring down UK energy bills; and concerns that it will impact negatively on UK energy security. Despite claims to the contrary, the report noted that evidence of local environmental contamination from shale gas exploitation is well reported in the scientific literature. It emphasizes that, "[t]here are widespread concerns over the lack of evidence on fracking-related health impacts," and that there is a lack of "substantive epidemiological study for populations exposed to shale gas extraction."[425]

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[422] Webb, E., Bushkin-Bedient, S., Cheng, A., Kassotis, C.D., Balise, V., and Nagel, S.C. (2014). Developmental and reproductive effects of chemicals associated with unconventional oil and natural gas operations. *Reviews on Environmental Health 29*(4), 307-318.

[423] Sample, I. (2014, December 5). Fracking chemicals could pose risks to reproductive health, say researchers. *The Guardian.* Retrieved from http://www.theguardian.com/environment/2014/dec/05/fracking-chemicals-could-pose-risks-to-reproductive-health-say-researchers

[424] Korfmacher, K.S., Gray, K.M., and Haynes, E. (2014, September 15). Health impacts of unconventional natural gas development: A comparative assessment of community information needs in New York, North Carolina, and Ohio. *Project Report, UR-UNC-UC Supplement 2012-13.* Retrieved from http://www.urmc.rochester.edu/MediaLibraries/URMCMedia/environmental-health-sciences-center/COEC/documents/UNGD-information-needs-asssessment-Final-project-report-091514.pdf

[425] Harrison, G., Parkinson, S., and McFarlane, G. (2014). Shale gas and fracking: examining the evidence. Published by Scientists for Global Responsibility (SGR) and the Chartered Institute of Environmental Health (CIEH). Retrieved from http://www.cieh.org/WorkArea/showcontent.aspx?id=53520

- July 18, 2014 – A working group of the Environmental Health Sciences Core Centers, supported by the National Institute of Environmental Health Sciences, reviewed the available literature on the potential health impacts of fracking for natural gas. They concluded that further research is urgently needed. Needs identified included: monitoring of air and water quality over the entire lifetime of wells; further epidemiologic research addressing health outcomes and water quality; and research addressing whether air pollution associated with fracking increases the risk of pulmonary and cardiovascular disease. The working group advocated for the participation of potentially affected communities in all areas of research.[426]

- July 12, 2014 – Eli Avila, Pennsylvania's former health secretary, said that health officials need to be proactive in protecting the public from the health effects of unconventional shale gas extraction. In 2011 funding was approved for a Pennsylvania public health registry to track drilling related complaints and address concerns, but was cut at the last minute. Speaking to the problem posed by the dearth of information, Avila asked, "How can you keep the public safe if you're not collecting data?"[427]

- June 30, 2014 – In a letter to the Pennsylvania Department of Environmental Protection, director of the Mid-Atlantic Center for Children's Health and the Environment, Jerome A. Paulson, MD, called for industry disclosure of all ingredients of fracking fluid; thorough study of all air contaminants released from drilling and fracking operations and their protected dispersal patterns; and study and disclosure of fracking-related water contamination and its mechanisms. Dr. Paulson said:

  > *In summary, neither the industry, nor government agencies, nor other researchers have ever documented that [unconventional gas extraction] can be performed in a manner that minimizes risks to human health. There is now some evidence that these risks that many have been concerned about for a number of years are real risks. There is also much data to indicate that there are a number of toxic chemicals used or derived from the process, known or plausible routes of exposure of those chemicals to humans; and therefore, reason to place extreme limits on [unconventional gas extraction].*[428]

- June 20, 2014 – Highlighting preliminary studies in the United States that suggest an increased risk of adverse health problems among individuals living within ten miles of shale gas operations, a commentary in the British medical journal *The Lancet* called for a precautionary approach to gas drilling in the United Kingdom. According the commentary, "It may be irresponsible to consider any further fracking in the UK

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[426] Penning, T. M., Breysse, P.N., Gray, K., Howarth, M., and Yan, B. (2014). Environmental health research recommendations from the Inter-Environmental Health Sciences Core Center Working Group on Unconventional Natural Gas Drilling Operations. *Environmental Health Perspectives, 122*(11). Advance publication retrieved July 18, 2014. doi: 10.1289/ehp.1408207

[427] *The Associated Press*. (2014, July 12). Expert: Pa. didn't address fracking health impacts. *York Dispatch.* Retrieved from http://www.yorkdispatch.com/ci_26135724/expert-pa-didnt-address-fracking-health-impacts

[428] Paulson, J.A. (2014, June 30). Retrieved from http://concernedhealthny.org/letter-from-dr-jerome-a-paulson-to-the-pennsylvania-department-of-environmental-protection/

(exploratory or otherwise) until these prospective studies have been completed and the health impacts of fracking have been determined."[429]

- June 20, 2014 – Led by an occupational and environmental medicine physician, a Pennsylvania-based medical and environmental science research team documented "… the substantial concern about adverse health effects of [unconventional natural gas development] among Pennsylvania Marcellus Shale residents, and that these concerns may not be adequately represented in medical records." The teams identified the continued need to pursue environmental, clinical and epidemiological studies to better understand associations between fracking, medical outcomes, and residents' ongoing concerns.[430]

- June 17, 2014 – A discussion paper by the Nova Scotia Deputy Chief Medical Officer and a panel of experts identified potential economic benefits as well as public health concerns from unconventional oil and gas development. On the health impacts, they wrote, "uncertainties around long term environmental effects, particularly those related to climate change and its impact on the health of both current and future generations, are considerable and should inform government decision making." The report noted potential dangers including contamination of groundwater, air pollution, surface spills, increased truck traffic, noise pollution, occupational health hazards and the generation of greenhouse gases. It also noted that proximity of potential fracking sites to human habitation should give regulators pause and called for a health impact assessment and study of long-term impacts.[431] Responding to the report, the Environmental Health Association of Nova Scotia applauded the go-slow approach and called for a 10-year moratorium on fracking.[432]

- May 29, 2014 – In New York State, more than 250 medical organizations and health professionals released a letter detailing emerging trends in the data on fracking that show significant risk to public health, air quality, water, as well as other impacts. With signatories including the American Academy of Pediatrics, District II, the American Lung Association in New York, Physicians for Social Responsibility, and many leading researchers examining the impacts of fracking, they wrote, "The totality of the science — which now encompasses hundreds of peer-reviewed studies and hundreds of additional

[429] Hill, M. (2014, June 20). Shale gas regulation in the UK and health implications of fracking. *The Lancet*. Early Online Publication, doi:10.1016/S0140-6736(14)60888-6

[430] Saberi, P., Propert, K.J., Powers, M. Emmett, E. and Green-McKenzie, J. (2014). Field survey of health perception and complaints of Pennsylvania residents in the Marcellus Shale region. *International Journal of Environmental Research and Public Health, 11*(6), 6517-6527.

[431] Atherton, F. (2014, June 17). Discussion paper: Hydraulic fracturing and public health in Nova Scotia . Nova Scotia Hydraulic Fracturing Independent Review and Public Engagement Process.

[432] Macdonald, M. (2014, June 17). Nova Scotia expert calls for go-slow approach for hydraulic fracturing. *The Canadian Press*. Retrieved June 20, 2014, from http://www.calgaryherald.com/health/Health+studies+needed+hydraulic+fracturing+approved+Nova+Scotia/9946368/story.html

reports and case examples—shows that permitting fracking in New York would pose significant threats to the air, water, health and safety of New Yorkers."[433] [434]

- May 9, 2014 – In a peer-reviewed analysis, leading toxicologists outlined some of the potential harm and uncertainty relating to the toxicity of the chemical and physical agents associated with fracking, individually and in combination. While acknowledging the need for more research and greater involvement of toxicologists, they noted the potential for surface and groundwater contamination from fracking, growing concerns about air pollution particularly in the aggregate, and occupational exposures that pose a series of potential hazards to worker health.[435] [436]

- May 1, 2014 – A 292-page report from a panel of top Canadian scientists urged caution on fracking, noting that it poses "the possibility of major adverse impacts on people and ecosystems" and that significantly more study is necessary to understand the full extent of the risks and impacts.[437] The *Financial Post* reported that the panel of experts "found significant uncertainty on the risks to the environment and human health, which include possible contamination of ground water as well as exposure to poorly understood combinations of chemicals."[438]

- April 30, 2014 – Medical professionals spoke out on the dearth of public health information collected and lack of long-term study five years into Pennsylvania's fracking boom. Walter Tsou, MD, MPH, of Physicians for Social Responsibility and former health commissioner of Philadelphia commented, "That kind of study from a rigorous scientific perspective has never been done." Other experts added, "There has been more health research involving fracking in recent years, but every study seems to consider a different aspect, and … there is no coordination."[439]

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[433] Concerned Health Professionals of NY. (2014, May 29). Letter to Governor Cuomo and acting Health Commissioner Zucker [Letter to Governor Andrew M. Cuomo & Acting Health Commissioner Howard A. Zucker]. New York City, New York.

[434] Hughes, K. (2014, May 29). NY fracking opponents call for moratorium of 3 to 5 years. *Daily Freeman*. Retrieved June 11, 2014, from http://www.dailyfreeman.com/general-news/20140529/ny-fracking-opponents-call-for-moratorium-of-3-to-5-years

[435] Society of Toxicology. (2014). Toxicologists outline key health and environmental concerns associated with hydraulic fracturing. *ScienceDaily*. Retrieved June 11, 2014, from http://www.sciencedaily.com/releases/2014/05/140509172545.htm

[436] Goldstein, B. D., Brooks, B. W., Cohen, S. D., Gates, A. E., Honeycutt, M. E., Morris, J. B., ... Snawder, J. (2014). The role of toxicological science in meeting the challenges and opportunities of hydraulic fracturing [Abstract]. *Toxicological Sciences, 139*(2). doi: 10.1093/toxsci/kfu061

[437] The Expert Panel on Harnessing Science and Technology to Understand the Environmental Impacts of Shale Gas Extraction. (2014). Environmental impacts of Hurricane Mitch. *Council of Canadian Academies*. Retrieved June 11, 2014, from http://www.scienceadvice.ca/uploads/eng/assessments%20and%20publications%20and%20news%20releases/shale%20gas/shalegas_fullreporten.pdf

[438] Canadian Press. (2014, May 1). Top Canadian scientists urge cautious approach to fracking until more known of impact. *Financial Post*. Retrieved June 11, 2014, from http://business.financialpost.com/2014/05/01/top-canadian-scientists-urge-cautious-approach-to-fracking-until-more-known-of-impact/?__lsa=3b44-76a1

[439] Khan, N. (2014, April 30). Health impact of gas fracking left in the dark. *Pocono Record*. Retrieved June 11, 2014, from http://www.poconorecord.com/apps/pbcs.dll/article?AID=/20140430/NEWS90/404300301/-1/NEWS01

- April 17, 2014 – In the preeminent *British Medical Journal*, authors of a commentary, including an endocrinologist and a professor of clinical public health, wrote, "Rigorous, quantitative epidemiological research is needed to assess the risks to public health, and data are just starting to emerge. As investigations of shale gas extraction in the US have continually suggested, assurances of safety are no proxy for adequate protection."[440]

- April 15, 2014 – The *Canadian Medical Association Journal* reported on the increasing legitimacy of concerns about fracking on health: "While scientists and area residents have been sounding the alarm about the health impacts of shale gas drilling for years, recent studies, a legal decision and public health advocates are bringing greater legitimacy to concerns."[441]

- March 3, 2014 – In the *Medical Journal of Australia*, researchers and a physician published a strongly worded statement, "Harms unknown: health uncertainties cast doubt on the role of unconventional gas in Australia's energy future." They cited knowledge to date on air, water, and soil pollution, and expressed concern about "environmental, social and psychological factors that have more indirect effects on health, and important social justice implications" yet to be understood. They wrote in summary:

  > *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. 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.*[442]

- March 1, 2014 – In the prestigious British medical journal *The Lancet*, researchers summarized workshops and research about the health impacts of fracking:

  > *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 [due to the large number of well pads being developed]; their close proximity to locations where people live, work, and play; and the need to transport and store large volumes of materials.*[443]

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[440] Law, A., Hays, J., Shonkoff, S. B., & Finkel, M. L. (2014). Public Health England's draft report on shale gas extraction [Abstract]. *BMJ, 1840*. doi: http://dx.doi.org/10.1136/bmj.g2728

[441] Glauser, W. (2014). New legitimacy to concerns about fracking and health. *Canadian Medical Association Journal, 186*(8), E245-E246. doi: 10.1503/cmaj.109-4725

[442] Coram, A., Moss, J., & Blashki, G. (2014). Harms unknown: Health uncertainties cast doubt on the role of unconventional gas in Australia's energy future. *The Medical Journal of Australia, 200*(4), 210-213. doi: 10.5694/mja13.11023

[443] Kovats, S., Depledge, M., Haines, A., Fleming, L. E., Wilkinson, P., Shonkoff, S. B., & Scovronick, N. (2014). The health implications of fracking. *The Lancet, 383*(9919), 757-758. doi: 10.1016/S0140-6736(13)62700-2

- February 24, 2014 – In a review of the health effects of unconventional natural gas extraction published in the journal *Environmental Science & Technology*, leading researchers identified a range of impacts and exposure pathways that can be detrimental to human health. Noting how fracking disrupts communities, the review states, "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." They concluded, "Overall, the current scientific literature suggests that there are both substantial public concerns and major uncertainties to address."[444]

- August 30, 2013 – A summary of a 2012 workshop by the Institute of Medicine Roundtable on Environmental Health Sciences, Research, and Medicine featured various experts who discussed health and environmental concerns about fracking and the need for more research. The report in summary of the workshop stated, "The governmental public health system, which retains primary responsibility for health, was not an early participant in discussions about shale gas extraction; thus public health is lacking critical information about environmental health impacts of these technologies and is limited in its ability to address concerns raised by regulators at the federal and state levels, communities, and workers employed in the shale gas extraction industry."[445]

- June, 2013 – A group of three nursing professors published a cautionary review questioning the rollout of "new energy practices" in shale development at a time when, though "[l]ongitudinal reports from long-term exposure to contaminated air and water from gas extraction don't exist … anecdotal reports make clear that the removal of fossil fuels from the earth directly affects human health." "Evidence of the negative human and ecologic health effects of fracking are emerging, and it should be noted that sufficient evidence has been presented to the [American Nurses Association], the American Public Health Association, and the American Medical Association's Resident and Fellow Section to result in a call for a moratorium on the issuance of new fracking permits nationally." They urge nurses to contribute to keeping health issues "front and center as we address national energy needs and policies."[446]

- April 22, 2013 – In one of the first peer-reviewed nursing articles summarizing the known health and community risks of fracking, Professor Margaret Rafferty, Chair of the Department of Nursing at New York City College of Technology wrote, "Any initiation

[444] Adgate, J. L., Goldstein, B. D., & McKenzie, L. M. (2014). Potential public health hazards, exposures and health effects from unconventional natural gas development [Abstract]. *Environmental Science & Technology*. doi: 10.1021/es404621d

[445] Coussens, C., & Martinez, R. (2013). *Health impact assessment of shale gas extraction: workshop summary*. Washington: THE NATIONAL ACADEMIES PRESS. Retrieved June 16, 2014, from http://www.iom.edu/Reports/2013/Health-Impact-Assessment-of-Shale-Gas-Extraction.aspx

[446] McDermott-Levy, R., Kaktins, N., and Sattler, B. (2013). Fracking, the environment, and health: New energy practices may threaten public health. *American Journal of Nursing, 113*(6), 45-51.

or further expansion of unconventional gas drilling must be preceded by a comprehensive Health Impact Assessment (HIA)."[447]

- May 10, 2011 – In the *American Journal of Public Health*, two medical experts cautioned that fracking "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." The authors urged that it would be prudent to invoke the precautionary principle in order to protect public health and the environment.[448]

Conclusion

All together, the findings from the scientific, medical, and journalistic investigations indicate that fracking poses significant threats to air, water, health, public safety, and long-term economic vitality. Concerned both by the rapidly expanding evidence of harm and by the fundamental data gaps still remaining, Concerned Health Professionals considers a moratorium on unconventional oil and natural gas extraction (fracking) the only appropriate and ethical course of action while scientific and medical knowledge on the impacts of fracking continues to emerge.

[447] Rafferty, M. A., & Limonik, E. (2013). Is shale gas drilling an energy solution or public health crisis? *Public Health Nursing, 30*(5), 454-462. doi: 10.1111/phn.12036

[448] Finkel, M.L. and Law, A. (2011). The rush to drill for natural gas: A public health cautionary tale. *American Journal of Public Health, 101*(5), 784-785. Retrieved from http://www.ncbi.nlm.nih.gov/pmc/articles/PMC3076392/