



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

2nd edition

December 11, 2014



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.

Sheila Bushkin-Bedient, MD, MPH
Larysa Dyrszka, MD
Yuri Gorby, PhD
Mary Menapace, RN

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

Kathleen Nolan, MD, MSL
Carmi Orenstein, MPH
Barton Schoenfeld, MD, FACC
Sandra Steingraber, PhD

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>

Table of Contents

Executive Summary	7
Air pollution.....	11
Water contamination.....	21
Inherent engineering problems that worsen with time.....	38
Radioactive releases.....	42
Occupational health and safety hazards.....	45
Public Health Effects, Measured Directly	51
Noise pollution, light pollution and stress	53
Earthquakes and seismic activity	56
Abandoned and active oil and natural gas wells (as pathways for gas and fluid migration).....	65
Flood risks.....	69
Threats to agriculture and soil quality	72
Threats to the climate system.....	76
Inaccurate jobs claims, increased crime rates, threats to property value and mortgages and local government burden	83

Inflated estimates of oil and gas reserves and profitability.....	91
Disclosure of serious risks to investors.....	94
Medical and scientific calls for more study and more transparency.....	96

*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 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/>.