palwv.org

The League of Women Voters of Pennsylvania

SHALE GAS EXTRACTION AND PUBLIC HEALTH

A Resource Guide

Marcellus Shale Natural Gas Extraction Study
2020 Update to Addendum

Shale and Public Health Committee
Lead Writer, Vera Bonnet

Acknowledgments

This Resource Guide on Shale Gas Extraction and Public Health is an Addendum to the original Marcellus Shale Study Guides developed in 2009-2010 by the League of Women Voters of Indiana County. The Shale Gas Extraction and Public Health Resource Guide was developed and researched over months in 2012-2013, written and edited in 2013 by Indiana County League member Vera Bonnet, who served as Lead Writer and Editor. Members of the Shale and Public Health Committee of the League of Women Voters of Pennsylvania, and additional members of the Indiana County League, contributed to the research and study, development, writing and review of the guide. We have updated the Resource Guide annually to include new research and reflect the evolving knowledge base.

Committee members include:

Vera Bonnet, League of Women Voters of Indiana County
Suzanne Fox, League of Women Voters of Greater Pittsburgh
Barbara Harley M.D., League of Women Voters of Greater Pittsburgh
Heather Harr, League of Women Voters of Greater Pittsburgh
Sherene Hess, Former President of League of Women Voters of Indiana County
Judy Hughes, Former President of League of Women Voters of Washington County
Ginny Kreitler, League of Women Voters of Radnor Township
Cecilia Larson, League of Women Voters of Greater Pittsburgh
Deborah Larson, League of Women Voters of Greater Pittsburgh
Shirley McIlvried RN MPH, League of Women Voters of Greater Pittsburgh
Don Naragon Ph.D., League of Women Voters of Gtr Pittsburgh & LWVPA Board
Clarice Reber, League of Women Voters of Indiana County
Donna Riggle, League of Women Voters of Washington County
Cindy Rogers, League of Women Voters of Indiana County
Mary Beth Sweeney, League of Women Voters of Greater Pittsburgh and Indiana County
Betty Tatham, League of Women Voters of Bucks County & former Vice President, LWVPA
Dreama Van Cise-Watta RN, League of Women Voters of Indiana County
Heather Wechter, League of Women Voters of Greater Pittsburgh
Dr. Roberta Winters, League of Women Voters of Radnor Township & former Vice President, LWVPA

There have been many studies and articles written and data collected relevant to the study of the public health impact of shale gas development. While the committee has reviewed many studies and articles in the course of writing this guide, their review – and what is covered in this resource guide - is by no means exhaustive. Furthermore, this is a rapidly developing field with change occurring constantly. The reader is advised to follow this issue to keep up with the changes.

League of Women Voters of Pennsylvania
226 Forster Street, Harrisburg PA 17102
717-234-1576
info@palwv.org
Shale study guides and information available at www.palvw.org
and https://shalepalwv.org

Printing and distribution of this guide made possible with funding from the Colcom Foundation and The Heinz Endowments to the League of Women Voters of PA Citizen Education Fund.

Table of Contents

SHALE GAS EXTRACTION and PUBLIC HEALTH

INTRODUCTION

In the United States, the practice of drilling before consultation with public health officials is standard procedure. Unconventional drilling for natural gas is no exception. The public is increasingly aware of the potential for degradation in the quality of water and air in the vicinity of unconventional gas extraction, and as a result, more people have raised serious questions about the risks of unconventional natural gas development to people's health. Yet there is still a great deal of confusion about the workings of the gas and oil industry and therefore about the risks of these new developments in shale gas extraction.

Drilling, extraction, processing, transmission, transportation, storage and distribution are all part of unconventional gas industry operations. The lay-person generally lumps these together as "fracking."

Industry tends to use a very narrow definition of fracking, preferring the apostrophized spelling (frac'ing) to distinguish this specialized usage. Fracking is thus reduced to a "little act . . . that helps enhance the production of a well" (quoted in Hood, 2014). In the same vein, a headline covering an article by AP Science Writer states, somewhat cryptically: "Research: Leaky wells, not fracking, tainted water," (Borenstein, 2014), effectively separating issues of well integrity from problems resulting from the actual fracturing process.

These esoteric lexical distinctions are lost on people whose health is impaired by a nearby industrial facility. The average person does not distinguish between each operation, even though each operation has potential consequences for human health -- and the health impact of each operation varies depending on numerous factors. While each operation may be carried out by specialized industry sectors, all these sectors, together and individually, are accountable for the safety of those who live, work and attend school in the affected areas.

In keeping with the public's perceptions of the industry, this guide uses the word "fracking" to cover all aspects of the production of gas using unconventional drilling techniques. We will also include petrochemical development in the Upper Ohio Valley. Taking a comprehensive approach to the problem, we will discuss not only direct impacts on the general public, but also worker health and safety issues, psychological impacts, community health, and potential short- and long-term impacts on the environment.

Exemptions from Federal Oversight and the Role of the States

Because of the known effects of chemical contamination, air and water are normally regulated by the federal Clean Air, Clean Water and Safe Drinking Water Acts. However the oil and gas industry has been exempted from meeting some of the standards set by these three acts. The so-called Halliburton Loophole, exempting the industry from the Safe Drinking Water Act of 1974 was embedded in the Energy Policy Act in 2005. Other at least partial exemptions for the industry are written into the following legislation (see more detail in LWVIC Study Guide V, 2009-2010):

- National Environmental Policy Act (requiring impact statements for major industrial projects. Because drilling is carried out in scattered sites, the individual sites are exempt.)
- Resource Conservation and Recovery Act (for "cradle to grave" tracking of industrial wastes)
- Comprehensive Environmental Response, Compensation, and Liability Act ("Superfund" tax)
- Toxic Release Inventory of the Emergency Planning and Community Right-to-Know Act

These exemptions from federal oversight do not prevent individual states from passing regulations. Under this system, the responsibility for monitoring and enforcement is primarily left to state governments (Phillips, 2011). This has resulted in a range of state responses to the industry. Most interesting are two contiguous states, New York and Pennsylvania, that sit atop the Marcellus Shale play and that have taken very different approaches towards regulating the shale gas industry.

The most significant exception to the practice of drilling before consultation is found in the state of New York. In 2008, New York state issued a moratorium on fracking, which delayed a long-awaited decision on whether to allow this technology for natural gas drilling in the state **(**Esch, 2012**).** A major development in 2015 was New York's banning fracking, a decision based in part on a 2014 New York State Department of Health report surveying the available research. The NY DOH report opens with a statement from the health Commissioner, stating that the "overall weight of the evidence from the cumulative body of information contained (in the report) demonstrates that there are significant uncertainties about the kinds of adverse health outcomes…the likelihood of occurrence ..and the effectiveness of mitigation measures….Until the science provides sufficient information to determine the level of risk to public health…DOH recommends that HVHF (High Volume Hydraulic Fracturing) should not proceed in New York State."

Rather than pursuing fracking, New York Governor Andrew Cuomo in June 2017 announced $1.5 billion in funding for renewable energy projects.

Another state contiguous to Pennsylvania, the state of Maryland, actually did conduct a prospective study outlining the likelihood of various types of potential risks prior to starting drilling in the state (Maryland Marcellus Shale Public Health Study, 2014). In 2015, Maryland put a moratorium on fracking until 2017. On April 4, 2017, Maryland Governor Larry Hogan, a Republican, signed a bill establishing a ban on fracking.

Unlike New York or Maryland, Pennsylvania has allowed unconventional gas extraction since 2005. Thus Pennsylvanians rely on federal and state regulations and the industry's best practices as the primary means of protecting public health. The state's willingness to accept the risks associated with drilling is in stark contrast with the caution of Pennsylvania's northern neighbor. Bamberger (2012) has described this choice as "an uncontrolled health experiment on an enormous scale."

In an historic move, the Pennsylvania Medical Society voted unanimously in October 2016 to call for a moratorium on new shale gas drilling and hydraulic fracturing, and for the state to set up an independent health registry and conduct studies of public health impacts of fracking.

2017 ushered in a new philosophy on environmental protection, particularly at the federal level, where new EPA head Scott Pruitt introduced a "Back to Basics" program that cut funding and narrowed the focus of the agency, while putting more emphasis on protecting jobs in the traditional energy sector (Guillen). In the same year, the Pennsylvania Senate, as part of its package to fund the budget, put forth the idea of speeding up DEP permit reviews by outsourcing them to outside contractors (Hurdle). Mr. Pruitt resigned in July 2018, but the pursuit of rollbacks of EPA regulations continues under his replacement, Andrew Wheeler.

Research on Health and Fracking -- a Brief History

Although hydraulic fracturing dates back to the 1940's, the combination of fracking technology and horizontal drilling has been in use only since 1998. Now, gas is the number one power source in the U.S., with 60% of gas produced in the U.S. and 48% of the oil coming from unconventional extraction (Compendium, 2018). At least 6% of the population – 17.6 million Americans – live within a mile of an active gas or oil well (Czolowski et al. 2017).

The development of horizontal drilling has affected depth of drilling, pressures, and the volume of chemicals and water used for extraction, among other things. Research on its impact on human health was negligible in the first 10 years of the use of these "unconventional" gas extraction technologies.

Recently however, the scope of health research has grown. Federal and state agencies are finding new strategies for examining the evolving questions. In the first publication of this Resource Guide, we stated that, "almost all peer-reviewed scientific publications on the environmental health and public health consequences of shale gas have been published since April 2011"(Howarth, 2012). However, as noted at the time, the pace and scope of public health research has been quickening. More than 90 % of all research on this topic has been published since the beginning of 2013 with 20% of the studies published in 2018 (PSE Healthy Energy

ROGER database). In 2020, the International Journal of Environmental Research and Public Health (ijerph) featured a special issue on Shale Gas and Fracking: Impacts on Health and the Environment. Also in 2020, the journal Toxicology and Applied Pharmacology did a special issue on the Biological effects of inhaled hydraulic fracturing sand dust.

There is now a large enough body of research that various organizations have taken on the task of compiling it. In July 2014, the Concerned Health Professionals of NY released a "Compendium" of research and articles on "risks and harms of fracking." The October 2015 updated "Compendium of Scientific, Medical and Media Findings Demonstrating Risks and Harms of Fracking" by the Concerned Health Professionals of NY and Physicians for Social Responsibility contains over 600 peer-reviewed documents. The March 2018 Compendium is based on more than 1300 available studies. The June 2019 Compendium is based on over 1700 peer-reviewed studies of the risk and harms of fracking in the PSE Healthy Energy "ROGER" database. As of October 2020, the ROGER database contained over 2000 studies (2051 entries).

In 2016, the authors of recently published methodologically "rigorous" research on fracking and health wrote that their studies on birth outcomes, asthma exacerbations, and other symptoms, "together with other studies, form a growing body of evidence that unconventional natural gas development is having detrimental effects on health…Over time, the evidence has gotten clearer, more consistent, and concerning" (Rasmussen, Schwartz & Casey, 2016). Gorski and Schwartz wrote a chapter on shale gas development and health concerns, published in 2019, for the Oxford Research Encyclopedia of Global Public Health. It features a chart of 14 original epidemiologic human health studies, including findings as well as limitations. The chapter describes pregnancy and birth outcomes, and asthma exacerbations, as being the health impacts with the most evidence of concern as of 2018. In a 2019 interview with *Environmental Health News,* Gorski said "What we found pushes back against the narratives we often hear that say we don't know enough about the health impacts yet," adding that "We have enough evidence at this point that these health impacts should be of serious concern to policymakers interested in protecting public health." Thus, it is more urgent than ever to understand the issues and the collective implications of the information put forward by researchers.

Much of the published research in the compilations is about air, water, chemicals and other aspects of fracking rather than research on the specific health impacts on people. Hays and Shonkoff in their 2016 published assessment of peer-reviewed scientific literature from 2009-2015 count only 31 peer-reviewed original research studies dealing specifically with how fracking affects people's health. Of these 31, "84% contain findings that indicate public health hazards, elevated risks, or adverse health outcomes" and "16% contain findings that indicate no significant public health hazards, elevated risks or adverse health outcomes associated with Unconventional Natural Gas Development (UNGD)." A follow-up analysis of 104 original peer-reviewed research published from 2016 – 2018 on health impacts of fracking found that 90.3% of the studies showed an association between UNGD and harmful health impacts (Ferrar, Jackson & Malone, 2019).

Deziel and colleagues (2020) conducted a scoping review of original epidemiological studies of exposure to unconventional oil and gas (UOG) development and verified human health outcomes. Of the 29 studies that met the researchers' inclusion criteria, 25 reported at least one statistically significant association between UOG exposure and adverse health outcomes. Health impacts included pregnancy outcomes, and birth outcomes (the most studied topic), cancer incidence, hospitalizations, asthma exacerbations, STD's, and traffic accidents. The review concluded that "current research points to a growing body of evidence of health problems in communities living near UOG sites" and that there is "a clear need for research on potential exposure pathways and mechanisms underlying observed relationships."

Much of the earlier research on shale and people's health used smaller sample sizes and relied more on self-selected samples or subjective survey responses, and "the vast majority of the papers on this topic indicated a need for additional study, particularly large-scale quantitative epidemiological research." As evidenced by the publication of some major large-scale studies each year since 2015, the trend is moving in this direction.

Many of the studies use proximity to shale gas wells or other shale gas operations as a stand-in for presumed exposure. Using these studies which show relationships between health impacts and proximity as inspiration, researchers have tried to quantify the potential scope of impact. The Fall 2018 "Oil and Gas Threat map" finds that there are 1.55 million Pennsylvanians living within a half-mile of the state's 108,000 oil and gas production and processing operations. The map, developed by environmental and mapping organizations Earthworks, Clean Air Task Force and FracTracker Alliance , also finds that nearly 311,000 children in Pennsylvania (including 73,000 in Allegheny County alone) go to daycare or schools that are within one-half mile of oil and gas wells or processing facilities (Hopey). The map counts over 30,000 childhood asthma attacks "due to oil and gas ozone smog." (Oil and Gas Threat Map 2.0)

The Colorado and Pennsylvania departments of health collaborated on an analysis, published in 2019 (Bamber et al.) of 20 epidemiologic studies of the potential for harmful health outcomes among those living near U.S. oil and natural gas (ONG) operations, adapting criteria from other medical and environmental health review frameworks (GRADE, the Navigation Guide, OHAT). This analysis found "modest scientific findings that support the outcome …of harmful health effects" (such as asthma), but with "significant limitations," such as not having enough different studies of a particular health outcome. The study notes that research quality has improved over the years, with the highest quality studies primarily found for birth outcomes (a category where more studies have been done). The health departments call for additional high quality studies "to confirm or dispute these correlations."

One of the criticisms of the health studies, including the larger epidemiological studies, is that proximity is an imprecise measure of dose or exposure. Stacy (2017) in a review of this literature, calls for better ways to measure exposure, including using blood samples of chemical markers, as well as the new generation of personal air and water emissions monitoring systems, such as Carnegie Mellon University researchers' Real-Time Affordable Multi-Pollutant (RAMP) sensor.

A study by Paulik and colleagues, published in 2018, had study participants wear wristbands that measured their personal exposures to PAH pollutants (polycyclic aromatic hydrocarbons). Air samplers were also placed at active well pad locations, and at proposed well pad locations. They found PAHs were significantly higher in air at active well sites, and significantly higher on the wristbands of those who had active wells on their properties. Air measures and personal exposures were also correlated. PAHs measured in air at active sites were more petroleum-derived than at proposed well sites.

A unique way of tracking shale gas activity is via satellite. Flaring can be seen from space with special equipment (Cushing et al. 2018). Johnston and colleagues (2020) used satellite observations from the Visible Infrared Imaging Radiometer Suite (VIIRS) to estimate ethnic disparities in exposure to flaring in South Texas. They found "census blocks with majority Hispanic population (>60%) were exposed to twice as many nightly flares" compared to areas less than 20% Hispanic. Disproportionate exposure defines "a pattern known as environmental injustice."

Public health is regulated under the umbrella of the Department of Health and Human Services, which includes numerous government entities. Among these are: National Center for Environmental Health (NCEH), the principal federal public health agency responsible for hazardous waste and public health; the National Institute for Occupational Safety and Health (NIOSH) dealing with worker safety; and the National Institute for Environmental Health Sciences (NIEHS) which is responsible for evaluation of water and air quality, among other mandates.

Other research has originated in the Department of Energy, and the Environmental Protection Agency (EPA), with additional input from the Science Advisory Board, the Government Accounting Office and the U.S. Geological Survey. Multi-agency projects include senior leadership from the U.S. Geological Survey, the Occupational Safety and Health Administration, and the Centers for Disease Control and Prevention (CDC).

There were some important government research reports that came out in 2015. Among these were a draft for external review of the EPA's long-awaited drinking water study; and the Pennsylvania Department of

Environmental Protection's study of the possible impacts of TENORMs – Technologically Enhanced Naturally Occurring Radioactive Materials – that come up from deep underground when shale is fracked. Both of these studies, while not finding "widespread" harm from fracking activities, did identify actual incidences of problems and risks to public health. In August 2016, the EPA's Scientific Advisory Board (SAB), after studying the EPA's June 2015 draft analysis for nearly a year, recommended that the EPA revise its original conclusions. The SAB said these conclusions minimized the potential water hazards of fracking, and were "inconsistent with the observations, data and levels of uncertainty" in the EPA study. The SAB made a number of recommendations, including quantifying the probability and risk of various failure scenarios, and looking more at local impacts. The SAB said the EPA final report should discuss why some research originally planned was not carried out. This would have included sampling water prior to, during and after fracking. The SAB also called for the final report to be understandable and accessible to the broad public.

Among the non-governmental agencies doing research on health and fracking is the National Science Foundation which has conducted several health-related studies. Also, major research universities have been examining the issue of safety and public health, sometimes with funding from the oil and gas industry. Several of these collaborations are discussed in the following pages.

Two major studies published in 2015 – one from two centers of the National Institute for Environmental and Health Sciences (NIEHS) based on hospitalization data, and another from the Geisinger Health System data - have the benefit of large population databases, and analysis of incidence data rather than potentially subjective survey responses. Large databases of patient electronic health records from the Geisinger Health System in Pennsylvania also constitute the sample for a study on fracking and asthma exacerbation published in the respected Journal of the American Medical Association (Rasmussen et al. *JAMA Internal Medicine)* in 2016.

Health Effects Institute, a non-profit independent research organization which is funded through public-private partnerships, has put together an extensive literature review and in 2015 proposed a strategic plan to guide future research. In 2019, Health Effects Institute (HEI) launched its new HEI-Energy affiliate "designed to provide high-quality and impartial science" that pursues answers to questions about health impacts of oil and natural gas from shale and other unconventional sources. HEI-Energy is supported with funding from the U.S. EPA, and from industry sponsors Chevron, ConocoPhillips, Equinox, Halliburton Energy Services, Noble Energy, Schlumberger, Shell Oil Company, and ExxonMobil. HEI-Energy simultaneously released two new companion reports by its Energy Research Committee. One is a review of the epidemiologic literature on potential human health effects associated with unconventional oil and gas development (UOGD). This report provides an extensive critique of individual studies, including highlighting their specific strengths and weaknesses. The report does describe evidence of possible harmful health impacts, but finds that it is difficult to conclusively link impacts to UOGD due to the use of surrogate measures of exposure (such as distance from a well-site). They call for actual measures of chemical or non-chemical agents originating from the UOGD. At the same time, HEI also released a draft for public comment of its "Human Exposure to Unconventional Oil & Gas Development: A Literature Survey for Research Planning," which identifies gaps in knowledge. Research workshops providing input into the planning process included a mix of industry, government and academic researchers, as well as experts from environmental organizations. These reports inform the HEI - Energy Research Committee's Research Solicitation in 2020 of multidisciplinary teams to conduct studies of health impacts of exposures in multiple oil and gas-producing regions in the U.S.

In April 2012, President Obama issued an executive order authorizing a multi-agency task force to "support safe and responsible development of unconventional domestic natural gas resources." The 13-agency working group was tasked with creating "sensible, cost-effective public health and environmental standards to implement federal laws and augment state safeguards." The agencies designated to take part in the monitoring and regulatory group include the departments of Defense, Interior, Agriculture, Commerce, Health and Human Services, Transportation, Energy, Homeland Security, the Environmental Protection Agency, the Council on Environmental Quality, the Office of Science and Technology Policy, the Office of Management and Budget, and the National Economic Council (ICIS, 2012).

As research evidence mounts of environmental and public health impacts of unconventional natural gas development, federal and state agencies in recent years began to pass more regulations and policies to address and prevent such impacts. However, in 2017 and 2018, the new federal approach to environmental protection includes calls for repealing Obama-era regulatory protections. Targets include the Clean Power Plan, methane rules, fuel economy standards, ozone standards, water, waste and science (Save EPA, 2018).

The EPA's proposed Strategic Plan for 2018-2022 says that "one of the EPA's highest priorities must be to create consistency and certainty for the regulated community." The strategic plan includes streamlining and speeding up permitting processes, prioritizing clean-ups of brownfields sites to make them "ready for anticipated use," "protecting underground sources of drinking water by providing for the safe injection of fluids underground for storage, disposal, enhanced recovery of oil and gas, or minerals recovery," and to "rebalance the power between Washington and the states" through "cooperative federalism."

TWO SCIENTIFIC PERSPECTIVES

Before discussing the results of research, an understanding of the fields of research and the methods used by researchers in each field is in order. The ultimate aim of both the environmental health researcher and the public health practitioner is to protect human health, but the emphasis of their respective work is different.

Environmental scientists approach health impacts using a variety of research techniques and disciplines. They aim for the highest standards of scientific accuracy which, among other things, depend on replication of results by other scientists. This practice requires future researchers to reproduce every aspect of the investigation in order to reliably compare results. However, this kind of rigorous scientific proof is not always possible when working on the highly complex system that is our environment.

The mandate of the public health practitioner is to act to alleviate illness in individuals who present symptoms. While health care workers do not conduct research per se, they collect daily evidence from their contacts with residents in the affected areas. In their role as humanitarians, doctors and nurses are concerned about the source of the problem and the extent to which it can be identified and eliminated. Their collective data about individual symptoms can provide invaluable evidence of impacts on humans from environmental causes.

The distinctions between environmental researchers and public health researchers are elaborated in the following discussion.

The Science of Environmental Health

Environmental health is a relatively new field, defined by the World Health Organization as the study of "all the physical, chemical, and biological factors external to a person . . . It encompasses the assessment and control of those environmental factors that can potentially affect health." Other observers have included psychosocial factors as well (Pope, 1995).

The following major methods of investigation are designed to explore different aspects of the problem. Each approach has its strong points and limitations, and each contributes information towards understanding the situation under investigation, with evidence that can answer different questions. The evidence is collected by various methods and is subjected to more or less rigorous testing. The most rigorous research includes old-fashioned lab work with individual chemicals. Epidemiological studies use statistical methods that have been greatly aided by the use of computers which can digest large data sets.

Whatever the methodology, all scientific papers must go through a process of "peer review," which involves scrutiny by other experts in the same field. If factual errors are found, or methods are not rigorously followed, or interpretations are not adequately documented, these must be addressed and corrected before the claims are accepted by the scientific community. Ultimately, science is a consensus-building process carried out by the scientific community (Oreskes and Conway, 2010).

The fields of study, from least to most rigorous, include:

- **Surveys and self-reports.** Research on health impacts includes surveys of residents in the affected areas who report on various changes in their health which have occurred after the installation of a gas well. These "self-reports" can also be found on the Internet and they are frequently cited as evidence of the danger of fracking. While the reliability of self-reports is compromised, these reports are useful as indicators of possible problems and open up areas for further research. As discussed below, public health officials and physicians have a responsibility to help those who report symptoms and to attempt to eliminate the cause(s) of the problem even if those symptoms do not meet the highest standards of scientific proof.

- **Exposure assessment and analysis**. These fields involve an examination of how contaminants in the environment affect a living being. The assessment is the final step of the process which begins with the contaminant's release. An assessment measures the amount of the contaminant which can be absorbed, and at what rate the organism will be affected. Because exposure assessments deal primarily with humans, they are good tools for public health practitioners**. Analysis** is used to identify and quantify exposures. While this research methodology does not directly study health impacts, it provides a link in the understanding of the overall problem by

  1) describing environmental exposures that may lead to a particular health outcome;

  2) providing information about exposures that can be further clarified in a toxicology study, or

  3) assessing risk if a substance appears to exceed recommended levels.

  NOTE: Exposure analysis requires baseline measures to be taken *before* the event, so that these measures can be compared to impacts *after* the event. This requirement has been difficult to meet in many rural areas where monitoring of water contamination and air pollution has not been a routine practice. As baseline measurements become more common as an industry practice, this research technique becomes more viable.

- **Toxicology** can be based on experiments with humans or with animals. The studies involve trials using exact dosages of a toxin to discover the health impact following the rule that *dose makes the poison*. While such a study incorporates the elements of experimental research (i.e., identical treatments, a control group for comparison, statistically significant results), there are obvious limits to applying the results of animal studies to human subjects. This is not a reason to ignore animal studies. Animals can provide critical epidemiological insights in their capacity as "sentinels" for human exposure. Like canaries in the coal mines, they indicate dangers ahead.

- **Environmental epidemiology** often deals with entire communities, including humans and animals. Because the toxins are in the environment, dosages are unclear, and the researcher has no control over the source. The epidemiologist cannot predict that a particular individual will suffer an adverse consequence due to a particular event. The best an epidemiologist can say is, "if a particular chemical . . . [was] not in the environment, some number out of every hundred people who got sick would have remained healthy, and some number of those who died might still be alive" (Davis, 2002). These results are not the "smoking gun" that can make or break a court case, but they are nonetheless based on sound statistical principles drawn from a wide array of available evidence and as such, the most rigorous conclusions can be drawn.

Despite the increasing pace of research and the resources applied to improving methods, NIEHS Senior Advisor John Balbus, M.D. stated that “the health system finds itself lacking critical information about environmental health impacts” (Loose, 2012).

Limitations of Research

Surveys and "self-reports" are the least reliable sources of information. Surveys can be done by mail, or face-to-face and each method has its pros and cons. Not only is the wording of the survey questions critical; so is the size of the sample. Generally speaking, the larger the sample size, the more accurate the results will be.

Results can be skewed, if only because people are suggestible. Simply by focusing attention on the problem, the researcher can prompt an answer. Even when the problem is verified by a physician or other health professional, the research does not meet a rigorous standard of proof because surveys cannot provide evidence of a direct cause-and-effect relationship between the health of the person and the drilling activity. Nevertheless, people's perceptions of their own health are a useful place to begin to understand the general nature of the problem and to design further research.

In the specific case of unconventional gas extraction studies, toxicology research is limited by the fact that the industry is exempt from disclosing the complete chemical composition of fracking fluids. The composition of these fluids is protected as “trade secret” information, although some companies are now disclosing this information voluntarily, primarily via FracFocus (See section on "State Agencies"). Although the FracFocus website, www.fracfocus.org , has recorded over 80,000 disclosures since 2011, disclosures may still not include *all* chemicals; “the listing of a chemical as proprietary on the fracturing record is based on the Trade Secret provisions” (2014). If the complete composition of the site-specific fracking fluid were made available to researchers, the accuracy of research would be considerably enhanced. In June 2015, the American Medical Association called for full disclosure.

In April 2016, the Partnership for Policy Integrity (PFPI) released a report, *Toxic Secrets*, looking at the EPA’s regulation of new chemicals used for drilling and fracking, under a program created by the Toxic Substances Control Act (TSCA). The PFPI found that between 2009 and 2014, the EPA reviewed 105 new chemicals proposed for use in shale gas extraction, and found health concerns about 88 of them (including skin irritation, lung effects, kidney toxicity and developmental toxicity). However, the PFPI report says that the EPA approved these chemicals for use without conducting health testing, assuming they wouldn’t leak and come into contact with the public. “The Toxic Substances Control Act doesn’t mandate health testing before a fracking chemical is put into wide use.” PFPI decries the confidentiality surrounding the identity, use and possible impact of these chemicals. In June 2016, Congress passed and President Obama signed the Frank Lautenberg Chemical Safety for the 21st Century Act (LCSA), modernizing the TSCA and strengthening its health provisions. However, PFPI is working with health professionals to petition for greater disclosure. In 2018, PFPI released a new report, “Keystone Secrets,” finding that in Pennsylvania, undisclosed chemicals were used 13, 632 times in 2,515 wells during 2013-2017. At least one chemical was undisclosed in 55% of wells drilled in PA between 2013 and 2017. The EPA allowed 62 chemicals-of-concern to be used in oil and gas wells. The identities of 41 of these chemicals were withheld (Horwitt, 2018). In 2019, PFPI focused on Ohio, finding that for more than 1,400 oil and gas wells drilled from 2013 -2018, public records reveal that “companies injected undisclosed fracking chemicals 10,992 times into 1,432 wells, utilizing a law that allows these chemical entities to be concealed as trade secrets.” FracTracker Alliance constructed a companion interactive map that can be used to pinpoint these locations.

Certain chemicals known to be used in fracking (such as methyl alcohol, hydrochloric acid, and boric acid, to name a few) have been proven to be hazardous to humans. But, as stated by former Pennsylvania State Representative Bud George, who chaired the Environmental Resources and Energy Committee, "without knowing the specific concentrations ... the level of harm ... cannot be predicted" (George, n.d.).

Even if the exact chemical breakdown of the horizontal hydraulic fracturing fluids were known, the complexity of environmental processes throws a wrench into even the best-designed studies. After all, what matters to our health is what comes OUT of the well -- which is somewhat different from what goes INTO the well. Pennsylvania requires chemical disclosure and has used the FracFocus website, “the national hydraulic fracturing chemical registry… to provide public access to reported chemicals used for hydraulic fracturing”

within a particular area. However, the FracFocus website has stated that "issues unrelated to chemical use in hydraulic fracturing such as Naturally Occurring Radioactive Material...(are) beyond the current scope of the site." Gas wells and water wells sit on geologic formations which differ from one site to the next. Depending on the composition of the strata through which the fluid must pass, as well as the chemicals that are injected, the results of an assessment may differ from well to well. A new tool, WellExplorer, enables researchers – and the public – to get information about hormonal, testosterone and estrogen modulators in wells in specific locations, determine proximity and exposure. WellExplorer utilizes FracFocus data on 134,900 wells. Frac Focus lists chemicals in wells but WellExplorer goes beyond this to provide information on biological action. Pennsylvania wells have disproportionately high numbers of ingredients targeting testosterone pathways (Wetherbee et al., 2020).

To further complicate matters, although certain health impacts seem to present themselves immediately, others, such as cancer, may not be evident for years. Even if evidence of illness is presented, the relationship between that finding and shale gas extraction may be inconclusive. For instance, epidemiologic measures of women's health have shown higher levels of breast cancer in Texas counties where fracking was first used fifteen years ago, relative to other counties in that state. Meanwhile, nationally, breast cancer rates have been dropping. Although the higher invasive breast cancer rates occurred in the same Texas counties which saw the most intensive gas drilling development and points of emissions in the Texas Commission on Environmental Quality's 2010 inventory (according to Heinkel-Wolfe, 2011), researchers have been reluctant to attribute the phenomenon to the gas industry. Correlation does not necessarily indicate causation, and the incidence of breast cancer in these counties could be attributable to other factors (Begos, 2012). Well-designed longitudinal studies, collecting data over a period of years or even decades, are needed. Continuing to study problems over time adds to our knowledge – in this case, the Texas Department of State Health Services released a report in 2014 finding that breast cancer cases were significantly higher than expected in Flower Mound.

In addition to these obstacles, environmental assessments for entire communities may face political hurdles. One major health impact assessment designed for Garfield County, CO by the University of Colorado School of Public Health was halted after the first year of a three-year study, when local officials decided to withdraw funding (Scofield, 2011; Shogren, 2012). The study was critiqued by the industry for measuring air samples close to Interstate 70 (Mickley and Blake, 2012). The EPA was also criticized for "abandoning" a study of Pavillion Wyoming, although a draft report was issued in 2011 that linked shale gas fracking to pollution of an aquifer.

Given the many variables that may influence a particular event, it is difficult "to draw good, solid conclusions about whether [unconventional drilling] is a public health risk as a whole." (Lustgarten, 2011). Uncertainty has a ripple effect, creating anxiety in lay people who live within the area of potential exposure. Ultimately, the question is, how much illness is required before "anecdotal evidence" adds up to "plausible evidence" that, in turn, mandates that humanitarian action be taken. This question is the purview of the public health professional.

THE USES OF RESEARCH

Christopher J. Portier, director of the National Center for Environmental Health (NCEH) and the Agency for Toxic Substances and Disease Registry (ATSDR) stressed the importance of research in an NPR interview, saying that a "well-conducted study ... could help us better understand if there's an impact, what its magnitude [is], how we should avoid having that impact if there is one" (Stein, 2012).

As investigators seek to refine their methods, public health concerns tend to be delegitimized. Confronted with a paucity of hard scientific evidence for establishing a clear path between fracking and various negative health impacts, scientists are playing catch-up with a well-funded and fast-moving industry. While studies proliferate and governments and individuals wait for conclusive findings which meet our culture's faith in the scientific process, there is continued tension between public health and industry objectives.

Corporate responsibility has increasingly become part of the business ethic, but it is undeniable that industry has a clear stake in downplaying risks and justifying current extraction methods. The corporate practice of exploiting uncertainty created by inconclusive experimental findings has been well-documented. (See for example, *Merchants of Doubt* by Oreskes and Conway, 2012).

Furthermore, research can be used to obfuscate as well as to clarify a problem. A University of Texas study purported to show that fracking had no effect on water quality; the lead researcher was found to have been paid several million dollars by gas industry sponsors (Wogan, 2012). Similar allegations in the same year forced the University of Buffalo to close a seven-month-old shale gas research institute when it was shown to be tied to industry (Thompson, 2012).

A study by the American Petroleum Institute (API) showing low levels of methane gas release was challenged by a group of researchers known as Physicians, Scientists and Engineers for Healthy Energy (PSE). The PSE accused the API of failing to use a systemic approach, using a biased survey instrument, suggesting the desired answers, and cherry-picking results, among other things (Howarth, 2012).

The industry has also critiqued some of the scientific research to date, accusing researchers of having insufficient data to support their conclusions, and using imperfect methodologies. (See for example, Steve Everley's and other blogs on the Independent Petroleum Association of America's Energy In Depth website.)

The industry also tracks and reports on incidences where studies have had to retract their findings. For example, a study that used a flawed methodology which led to overstated methane emissions, later adjusting its measurements and retracting its initial findings to show methane emissions within levels considered to have "climate benefits" (as compared to coal emissions) (Whitehead, 2018).

"No matter who backs which study, the studies with the most valid, replicable data will win out. That's how science works" (Nocera, 2013). In the meantime, as unconventional drilling continues, public acceptance can be wooed with well-funded PR campaigns, emphasizing issues of national security and job creation. To protect public health, Pennsylvanians can prompt public deliberation and responsible decision-making. This can be done by advocating for more research and better funding to improve monitoring, and by promoting preventative best practices during all phases of natural gas operations.

The Public Health Approach

Unlike clinical professionals (doctors and nurses) who treat individuals after they've become sick or injured, public health professionals are primarily concerned with prevention. They are tasked with implementing educational programs, developing policy, providing services, regulating health systems and conducting research**.** Public health practitioners are heavily involved with issues of social justice, such as health care equity, quality, and accessibility (Association of Schools of Public Health, n.d.).

For these professionals, the existence of a plausible relationship between observable health problems and the proximity of a likely source is sufficient cause for instituting preventative measures and policies to protect the public. Inaction is a form of action. On the other hand, industry is reluctant to support additional government intervention without conclusive evidence showing negative health impacts, even though taking precautionary measures is a common practice in this country. (As an example, the U.S. Food and Drug Administration (FDA) subjects all new drugs to testing before allowing them to be sold to consumers.)

In 1998, the Science and Environmental Health Network (SEHN) adopted a "precautionary principle," stating that health professionals must take "anticipatory action" even in the absence of scientific certainty. By shifting the burden of proof to those responsible for the potentially harmful activity, this standard parallels the FDA's operating procedures, requiring responsible parties to "vouch for its harmlessness and be held responsible if damage occurs" (SEHN, n.d.).

In the 21st century, the **precautionary principle** has slowly gained traction in the US. In 2003 the Board of Directors of the American Nurses Association adopted it, re-stating the principle in the following terms: "if it is within one's power, there is an ethical imperative to prevent rather than merely treat disease, even in the face of scientific uncertainty"(McDermott-Levy, 2012).

This is a significant endorsement since nurses are often the initial, and sometimes the only point of contact for people seeking medical care. Nurses are particularly important during the time of the COVID-19 pandemic. A workforce of 4.2 million trained professionals (Kaiser Family Foundation, March 2018), they are the largest group of health care providers in the United States, many of whom visit patients in their homes. With first-hand knowledge about potential problems in the community, including those related to possible environmental exposure, on-site visits provide opportunities to both detect problems and to initiate interventions (Institute of Medicine Report, 1995).

While the clinicians' primary job is to treat the sick, the accumulated knowledge of physicians does have a place in public health research. However, without an organized effort to gather and interpret the evidence collected from individual cases, this information can be lost. New research initiatives take on this task. For instance, the Geisinger Hospital System, located in the northern tier of Pennsylvania, has mined years' worth of data to determine if asthma rates among patients had changed after the gas industry began operating in the region. With their large store of electronic health records, Geisinger is in an ideal position to conduct research on asthma in Pennsylvania and other health topics. In February, 2013 Geisinger received a $1 million grant from the Degenstein Foundation to work on the planning and execution of the study in collaboration with two other health systems (Socha, 2013). In 2015, peer-reviewed studies from the Geisinger data began to be released. A study on radon (Casey et al.) was published in *Environmental Health Perspectives*. Reproductive impacts (Casey et al.) were investigated in a study published in *Epidemiology.* In 2016, initial plans to study asthma came to fruition when the Geisinger data yielded a study published in the Journal of the American Medical Association *(JAMA Internal Medicine).* The study found a relationship between unconventional natural gas development and asthma exacerbations (Rasmussen et al.) and was reported prominently in the mainstream press.

Since February 2012, the Southwest Pennsylvania Environmental Health Project (SWPA-EHP), a private non-profit environmental health organization, has been operating in Washington County for the specific purpose of providing advice and referrals to residents in this heavily drilled county as well as to serve as a resource center for physicians and researchers. Staff of the project performed a comprehensive literature review (available on request). They concluded that research (from animal models, human clinical observations, and epidemiological studies) converged to implicate the practice of unconventional hydraulic fracturing as a significant concern to public health, even if the evidence would not be sufficient to prove legal liability (Brown, 2012). In a 2017 published analysis of cases seen by a medical practitioner in their office, SWPA-EHP researchers found that the symptoms reported were consistent with what one would expect to find from exposure to toxics, and also with findings from health studies conducted by other researchers. Symptoms most commonly reported were: sleep disruption, headache, throat irritation, stress/anxiety, cough, shortness of breath, sinus problems, fatigue, nausea and wheezing. Analysis was restricted to adults living within one kilometer of a well, and cases which began prior to exposure or which could be explained by other pre-existing conditions were excluded. (Weinberger et al., 2017). EHP researchers Blinn, Brown, Greiner, and Utz (2020) have developed "a novel method of quantifying exposures and relating them to specific health symptoms."

HEALTH IMPACTS

A study of the materials known to be used in natural gas extraction resulted in a list of 353 chemicals (Colborn, 2011). By searching through existing literature on the lethality of these chemicals, the researchers came to the following conclusions:

75% of the chemicals have been known to affect the skin, eyes and other sensory organs, and the respiratory and gastrointestinal systems
40% could affect the brain/nervous system, immune and cardiovascular systems, and the kidneys
37% have been known to affect the endocrine system
25% could cause cancer and mutations

The following chart, compiled by the Medical Society of the State of New York (Bushkin-Bedient, n.d., used by permission), provides some specific effects of a dozen commonly used fracking chemicals.

Selected Toxins Associated with Hydraulic Fracturing

Chemicals	**Exposure Route**	**Effects in Humans**	**Effects in Animals**
Acetic Anhydride	Inhalation Ingestion Eye/skin contact Highly volatile	Severe irritation of eyes, upper respiratory mucous membranes and skin to very low concentrations - permanent corneal scarring - explosion related injuries	Highly corrosive to eyes, upper respiratory mucous membranes and skin Direct mortality
Arsenic	Oral – drinking contaminated water Inhalation	*IARC Group 1 Carcinogen*: -Adenocarcinoma of the lung -Cancers of skin, digestive tract, liver, urinary bladder, kidney, lymphatic and hematopoietic, meningioma *Noncancer chronic effects*: -Severe peripheral vascular disease, -"blackfoot disease" - arsenicosis: arsenic poisoning	Carcinogen: -Adenocarcinoma of lung -Lymphocytic leukemia -Lymphoma
Benzene	Inhalation Oral –drinking contaminated water	*IARC Group 1 Carcinogen*: -Leukemia (acute myelogenous) *Noncancer acute effects*: Neurological: - drowsiness - headaches - unconsciousness - convulsions - skin - eyes and upper respiratory tract irritation GI: Nausea, vomiting *Noncancer chronic effects*: -blood dyscrasias - aplastic anemia -excessive bleeding -leukopenia -immunosuppression	Carcinogen in experimental animals In rodents: -Oral cavity -Malignant lymphoma -Lung Cancer -Mammary gland *Noncancer acute effects:* -Neurologic, immunologic, hematologic -Low toxicity from inhalation -Moderate toxicity from ingestion *Noncancer chronic effects:* Similar to human findings

Chemicals	Exposure Route	Effects in Humans	Effects in Animals
		Developmental: -low birth weight, -delayed bone formation	
Chlorine dioxide	Inhalation	Severe respiratory and eye irritant, Congestion of lungs, chronic bronchitis Mortality at 19 ppm	Severe respiratory and eye irritant Purulent bronchitis Mortality at 150-200 ppm
Ethylene glycol (commonly known as antifreeze)	Ingestion of contaminated water	Acute: -Neurotoxicity -Cardiopulmonary effects -Renal Low dose effects: eyes, nose and throat	Hepatic and renal damage Fetotoxicity in rodents
Formaldehyde	Inhalation Ingestion in contaminated water or food	*IARC Group 1 Carcinogen*: -nasopharyngeal and sinonasal cancer -lymphohematopoietic cancer *Noncancer acute effects:* Respiratory -Eye, nose and throat irritation *Noncancer chronic effects:* -Respiratory -Eye, nose, throat -Skin irritation; contact dermatitis -Menstrual disorders	Carcinogenic in experimental animals: In rodents: - Nasal squamous cell carcinoma - Leiomyosarcoma of stomach, intestines -Lung cancer *Noncancer acute and chronic effects:* - Lesions on nasal epithelium and lower respiratory system - Weight loss
Lead	Inhalation Ingestion Dermal contact	*IARC Group 2B Carcinogen:* Associated with cancer of: - Lung - Stomach - Urinary bladder *Noncancer effects:* - Neurotoxicity (especially fetal and childhood development) - Kidney damage - Anemia - Immune system - Cardiovascular system - Male infertility (decreased sperm count)	Carcinogenic to experimental animals: Adenocarcinoma of the kidney Tumors of brain Hematopoietic system Lung Noncancer effects: Birth defects
Phenol	Inhalation Ingestion Eye/skin contact Absorption through skin	*IARC Group 3 Carcinogen*: (not classifiable in humans) *Non cancer acute effects*: Severe irritation to eyes, skin, mucous membranes -CNS impairment -Damage to liver and kidneys -Mortality following high dose exposure (1 gram oral ingestion is lethal; death associated with	Carcinogenic to experimental animals: Leukemia and lymphoma Non cancer acute effects: Severe irritant of eyes (immediate corneal opacification in rabbits) Irritant of upper respiratory mucous membranes; Neurotoxic to motor centers in

Chemicals	Exposure Route	Effects in Humans	Effects in Animals
		respiratory failure) *Noncancer chronic effects*: Systemic disorders including Gastrointestinal, neurological, dermatological	CNS (twitching, convulsions) Tachy/bradycardia, hypotension Dyspnea Noncancer chronic effects: Damage to lung, liver, kidneys,
Toluene	Inhalation Ingestion	*IARC Group 3 Carcinogen* *Noncancer acute effects*: Neurotoxic; fatigue, drowsiness, headaches, nausea, unconsciousness Cardiac arrhythmia Oral ingestion, high dose=lethal (associated with severe CNS depression, pulmonary hemorrhage, myocardial necrosis, and acute tubular renal necrosis) *Noncancer chronic effects*: CNS depression, ataxia, tremors, cerebral atrophy, impaired speech, hearing and vision, Inflammation and degeneration of nasal epithelium, pulmonary lesions Maternal Reproductive : - increased spontaneous abortions Developmental: - neurotoxicant, - attention deficit - cranial-facial and limb anomalies	Acute: Central nervous system depression Immunosuppressed (increased risk of pulmonary infection) Chronic: Hepatic Renal Pulmonary Impaired hearing Developmental toxicant
Uranium-238	Ingestion (food, water) Inhalation	No information on acute effects. *Chronic effects*: Renal toxicity	No information on acute effects. Chronic effects: -Inflammation of nasal mucosa -Renal toxicity
Radium-226	Ingestion (drinking water)	*IARC Group 1 Carcinogen* No information on acute effects. *Noncancer chronic effects*: - anemia - necrosis of the jaw - brain abscess - bronchopneumonia and death (from oral ingestion) - acute leukopenia (from inhalation)	
Radon-222	Inhalation	*IARC Group 1 Carcinogen* No information on acute effects. *Non-cancer chronic effects*: - chronic lung disease - pneumonia - pulmonary fibrosis	Weight loss, hematologic disorders

IARC : International Agency for Research on Cancer: **Group 1=** known to cause cancer in humans and animals; **Group 2A=** probably carcinogenic to humans; **Group 2B=** possibly carcinogenic to humans; **Group 3=** not classifiable as to its carcinogenicity in humans; ppm = parts per million

Using completely different methods, a community survey conducted in 14 Pennsylvania counties investigated the extent and types of symptoms most frequently reported by residents in areas of gas extraction (Steinzor, 2013). The 108 respondents lived in 55 households, which were no further than five miles away from a gas production facility. The top 25 symptoms reported were:

1. increased fatigue (62%),
2. nasal irritation (61%),
3. throat irritation (60%)
4. sinus problems (58%),
5. eyes burning (53%),
6. shortness of breath (52%),
7. joint pain (52%),
8. feeling weak and tired (52%),
9. severe headaches (51%),
10. sleep disturbance (51%),
11. lumbar pain (49%),
12. forgetfulness (48%),
13. muscle aches and pains (44%),
14. difficulty breathing (41%),
15. sleep disorders (41%)
16. frequent irritation (39%),
17. weakness (39%),
18. frequent nausea (39%),
19. skin irritation (38%),
20. skin rashes (37%),
21. depression (37%),
22. memory problems (36%),
23. severe anxiety (35%),
24. tension (35%)
25. dizziness (34%).

The Steinzor study does not attempt to measure levels of exposure, nor to assess long-term health effects. Nevertheless, the correspondence between the symptoms described in the Steinzor study and the known health impacts of various chemicals makes a *prima facie* case for caution in the development of unconventional drilling.

While the above-mentioned "health woes" may appear to be fairly innocuous to those who are not affected by them, a Texas jury awarded $2.9 million to a family for property damage and personal injury in a suit against Aruba Petroleum, an oil company whose wells virtually surrounded the family home. Symptoms included headaches, nausea, rashes, dizziness and vomiting (Morris, 2014). The company appealed the decision and in early 2017 the 5th District Court of Appeals reversed the decision, saying that Aruba didn't actually intend to or know that they would "create an interference on the Parrs' land" (Mosier).

A 2016 study by researchers from Johns Hopkins and the Geisinger Center for Health Research found different specific symptoms – sinus/nasal, migraines and fatigue – were significantly associated with exposure to greater levels of unconventional natural gas activity (Tustin et al.).

In June 2015, a major study was published linking hydraulic fracturing to increased hospitalizations. It was conducted by researchers from the University of Pennsylvania and Columbia centers of the National Institute of Environmental Health Sciences (NIEHS). This was based on the analysis of large databases containing over 198,000 hospitalizations. The study examined the link between drilling well density and 25 categories of hospitalizations by zip code between 2007 and 2011 in three northeastern Pennsylvania counties. The researchers found significantly higher inpatient prevalence rates (hospitalizations per 100 residents per year) for cardiology and neurological conditions in areas closer to active wells. Hospitalizations for skin conditions, cancer, and urological problems were also associated with the proximity of residences to active wells. Although the researchers admit that this study does not conclusively prove that shale gas drilling causes these conditions and hospitalizations, and they call for further research, the study still represents "one of the most comprehensive to date to link health effects with hydraulic fracturing."

In 2019, a published study by Denham et al. found hospitalizations for genitourinary conditions (particularly for urinary tract infections, kidney infections, and stones in the ureter) were associated with greater cumulative fracking well density in Pennsylvania counties. More hospitalizations for skin conditions were also observed with higher cumulative well count and well density.

A pilot study by McKenzie et al. published in 2019 was described in the 2019 Compendium as "the first study to evaluate, with direct measurements, indicators of cardiovascular disease, and the intensity of oil and gas activity." In this pilot study, 97 adults living in Colorado were examined for early signs of cardiovascular disease. High blood pressure, changes in stiffness of blood vessels, and markers of inflammation were seen more often where people lived near greater oil and gas activity.

Considerations Relating To Exposures To Toxic Substances

We know that certain chemicals that are either used in horizontal hydraulic fracturing or are by-products of fracking are hazardous to human health. The extent to which these chemicals are involved in air and water pollution as a result of fracking is still to be determined. Before discussing the specifics of different forms of pollution in air and water, there are some general precepts to keep in mind when assessing the current state of knowledge.

1) The potential for health disorders resulting from gas extraction is not limited to the immediate vicinity of the well. Polluted air can be carried up to 200 miles from its source by prevailing winds (TEDX). Furthermore, although any one small engine or even a single drilling site may not emit significant amounts of pollutants, the cumulative effects of air pollutants from many gas wells located in the same general vicinity can be significant enough to meet and exceed regulatory limits.

Nonetheless, natural gas pollutant sources are currently regulated as individual point sources in Pennsylvania (Reber, 2012). More obvious, but equally important, contaminated waters could affect large watersheds. In the past there have been limited baseline measurements for air and water quality prior to drilling. While many companies and property owners now routinely test well water prior to drilling and at intervals thereafter, it is often difficult to trace pollution sources over time. This is especially true in areas far from the drilling site or source of accidental release, making it very challenging to know to what extent downstream health impacts can be attributed to shale gas production.

However, studies are being conducted that do attempt to assess the possible impact of shale gas operations by measuring differences in the prevalence or absence of health conditions and symptoms in relationship to proximity to wells (and other shale gas operations). A Yale university-led random survey of 492 people in 180 southwestern Pennsylvania households found 39% of those living less than two-thirds of a mile from a well reported upper respiratory symptoms, compared with 18% of those living more than 2 km. away. Thirteen percent of those living closer to a well reported rashes or other skin irritation, compared to 3% of those who lived further away. The authors of this peer-reviewed study are unclear if these symptoms could be attributed to tainted water, air contaminants, or to stress or some other factors, noting that this study doesn't prove that the self-reported symptoms were caused by shale wells, and that more research needs to be undertaken (Rabinowitz, 2014).

2) We know that health effects may be different for different populations, and vary by duration of the exposure. Acute effects are usually an immediate result of exposure and are generally reversible when exposure ends. Chronic effects tend to appear later, sometimes years later, and are not reversible. People with chronic diseases may experience aggravation of the disease when exposed to certain pollutants. Young children and the elderly are at greater risk, as are pregnant women (EPA, 2010).

Peng and colleagues investigated the health impacts of Marcellus shale from 2001-2013 by merging PA DEP well permit data with a database of all inpatient hospital admissions. They were particularly interested in diseases sensitive to air pollution. Looking at changes over time in hospitalization rates in well versus non-well counties, they found a "significant association between shale gas development and hospitalizations for pneumonia among the elderly." They found this consistent with higher levels of air pollution resulting from unconventional natural gas development (2018).

More research is emerging that examines possible impacts of gas operations on maternal, fetal and child health. In early 2014, McKenzie and her colleagues' retrospective cohort study of birth outcomes and proximity to gas operations in rural Colorado examined records of 124,842 births between 1996 and 2009 and found greater incidences of congenital heart defects (CHDs) and neural tube defects (NTDs). More recently, McKenzie, Allshouse and Daniels addressed "limitations of previous studies in a new and more robust evaluation," published in July 2019, which "provides further evidence" of an "association between maternal proximity to oil and gas well site activities and several types of CHD's (congenital heart defects)." A University of Oklahoma study also found significantly higher incidence of neural tube defects among children whose residence at birth was within two miles of a drilling and fracking site (compared to those with no wells). For this study, records of all births and all congenital anomalies between 1997 and 2009 were examined, along with historical data on well production and location (Janitz et al., 2018). Another Oklahoma study (Apergis et al. 2019) found a relationship between fracking activities and three indexes of infant health, including mortality. Studying 590,780 births across all 76 Oklahoma counties between 2006-2017, the researchers concluded that "the closer the mother's residence at birth to fracking wells, the more negative the effects on infants' birth healths."

Anecdotal reports from a midwife of stillbirths and from parents of birth defects were reported (in *Bloomberg News* and *TruthOut*) in 2014 in Utah's Uintah Basin. A 2014 study confirmed high levels of volatile organic compounds (VOCs) which the study's authors associate with high levels of oil and gas production (11,000+ wells) in the Uintah Basin (Helmig 2014) . Another detailed study of well location data and infant health outcomes by economists from Princeton, Columbia and MIT was presented at the January 2014 annual meeting of the American Economic Association, according to *Bloomberg News*.

A retrospective cohort published study (2015) of over 15,000 live births in Southwestern Pennsylvania between 2007 and 2010 by S.L. Stacy and colleagues from the University of Pittsburgh Graduate School of Public Health and the Magee-Womens Research Institute found relationships between lower birth weight, a higher incidence of small for gestational age (SGA) newborns and fracking well density. Also, a study (Casey et al., 2015) published in *Epidemiology*, reports greater incidence of high-risk pregnancies and pre-term births in areas with more active shale gas operations. These results are based on another retrospective cohort analysis of electronic health record data from 2009 to 2013 for 9,384 mothers and 10,946 newborns in the Geisinger Health System (which covers north and central PA). Casey et al. (2019) conducted research to see if mental health issues in pregnancy serve as an intermediary factor leading to birth impacts. Although greater exposure in pregnancy to oil and gas activity was found to be associated with a higher incidence of maternal anxiety and depression in pregnancy, and also associated with birth impacts, the analysis did not find a relationship between maternal mental health issues and pregnancy and birth outcomes.

In a study published in 2017, Whitworth and colleagues conducted a retrospective birth cohort analysis of a diverse urban population of 158,894 women in North Texas and found relationships between maternal residential proximity to unconventional natural gas activity and incidence of pre-term birth or fetal death, but little indication of an association with birthweight. Another study published in 2017 compared early infant mortality in the 10 most heavily fracked counties with all of Pennsylvania, in 2007-2010 versus the pre-fracking control period of 2003-2006. Authors Busby and Mangano found that while early infant mortality decreased by 2.4% in Pennsylvania as a whole, there was a significant increase in mortality among the 82,558 births in the 10 heavily fracked counties, seen particularly in the north eastern counties. The authors posit a possible relationship with naturally occurring radioactive materials in produced water which may contaminate water in private wells.

A study conducted by economists from Princeton (Currie) and University of Chicago (Greenstone) and Meckel of UCLA received major attention when published in late 2017. They looked at birth certificates for all 1.1 million infants born in Pennsylvania between 2004 and 2013, combining this data with maps showing where and when wells were drilled. They found reduced health among infants born to mothers living within 1.9 miles of a well-site during pregnancy. There was a 25% higher probability of low birth

weight within .6 miles. One of the unique aspects of this study was comparing siblings with and without prenatal exposure to shale gas activity; the exposed siblings faired worse at birth. Lead author Janet Currie stated, "we have pretty good evidence of a causal effect of health outcomes and fracking – not just a correlation."

In the first published epidemiological study of California oil and gas development and birth outcomes, Tran (2020) and colleagues found that exposure to active oil and gas development was associated with adverse birth outcomes in rural areas. Impacts (including low birth weight, small for gestational age) were greater among those exposed to higher production volumes. In rural areas, oil and gas development may contribute a larger portion of exposure to emissions and toxic chemicals than in urban areas where there are more sources of pollution.

Cushing (2020) and colleagues studied flaring in South Texas as a pathway to exposure to harmful emissions and its relationship with adverse birth impacts. Exposure to a high number of nightly flare events was associated with 50% higher odds of pre-term birth, and shorter gestation, vs. those with no exposure.

Children and pregnant women are particularly susceptible to "endocrine disruptors," a class of chemicals that mimic hormones and thus derail normal developmental functions. Very small amounts of these chemicals can have an effect on pregnant women, their children and their unborn babies, depending on developmental stage (Colborn, 1993). A study (Kassotis) published in December 2013 tested 12 suspected endocrine-disrupting chemicals associated with hydraulic fracturing and found that 11 blocked estrogen hormones and 10 blocked androgen hormones. Water samples were analyzed and samples from drilling sites had moderate-to-high endocrine-disrupting activity compared with low levels of endocrine-disrupting activity in samples from areas with little or no drilling. Dr. Susan Nagel, one of the authors, says such activity could "raise the risk of reproductive, metabolic, neurological and other diseases, especially in children who are exposed to endocrine-disrupting chemicals."

Two studies in mice reported impacts from pre-natal exposure to fracking chemicals. In one study, prenatally exposed mice later as young adult females developed abnormal mammary glands. Their mammary glands exhibited changes that would be predictive of cancer and also of problematic lactation (Sapouckey et al, 2018). In another study, mice exposed prenatally to a mix of 23 fracking chemicals exhibited immune system dysfunction later in life (Boule et al., 2018).

In *Molecular and Cellular Endocrinology*'s special issue on endocrine disruption, researchers (Nagel et al., 2020) review the impact in adulthood of perinatal exposure to a mixture of 23 chemicals at levels commonly found in oil and gas wastewater, surface and groundwater on mice, tadpoles, and human tissue cells. The chemical mixture disrupted hormone receptors and led to other changes such as morphology of mammary glands, and induced pre-cancerous lesions, and reduced sperm counts.

For a pilot study published in 2019, Caron-Beaudoin and colleagues measured urinary and hair concentrations of trace metals (many of which are known developmental toxins) among pregnant women in an area of Northeastern British Columbia where there is a lot of fracking. They found higher concentrations of manganese in hair and urine, and higher median values for barium, aluminum and strontium in hair (particularly among indigenous women).

Furthermore, although many times chemicals are found to be well below federal limits, these standards are usually designed for healthy adult males who are exposed intermittently during work hours. Risks will be different -- and often higher -- for people who are exposed 24 hours per day, even though the exposure may be at lower levels (Colborn, 2010).

Researchers have also advocated in favor of "low-dose testing," finding that the traditional linear relationship of dose-related response does not always hold true, and that non-monotonic responses should be examined, especially among babies and children (Birnbaum, 2012; Vandenburg, 2012).

3) Air and water monitors are only effective if they are placed in affected areas for long enough periods to be able to detect the full impact of the pollutant, the fluctuation of the pollutants, and any relationship of weather to pollution concentrations (Colborn, 2010). Several recent studies have been critical of current methods of collecting and analyzing emissions data. In Pennsylvania, the SWPA Environmental Health Project demonstrated that measurement methods underestimate the intensity, frequency and duration of chemical releases (Brown, Weinberger, et. al., 2014). Further exploring this in a 2015 published study, Brown, Lewis and Weinberger modeled a hypothetical case study based on actual observations in Washington County. High (peak) levels of small PM 2.5 particles and of volatile organic compounds happened 83 times over a 14 month period. Compressor station emissions produced 118 peak exposures over a year, and a gas processing plant 99 peak exposures in a year. The variability and fluctuations in exposures would be consistent with the episodic nature of some of the types of health complaints reported. They found that the drilling, flaring, finishing and production phases were more problematic than the actual "fracking" stage (when the shale seams are first penetrated to make possible the release of gas). Weather conditions were also an important variable determining exposure to six air pollutants currently regulated by the EPA that were found at the unconventional natural gas development sites. In Texas, researchers were similarly concerned that communities were receiving "potentially false assurances" regarding health problems because of "dramatic shortcomings" in monitoring of air pollution (Rawlins, 2013). The states' monitoring efforts also came under fire by groups which claimed that Texas was doing a very poor job of monitoring, describing the chemicals released into the air as a "toxic soup" (Morris, Song & Hasemeyer, 2014).

The same holds true for radioactive releases. A study found that the testing protocols used both by state regulators in Pennsylvania and EPA regulators can result in dramatic underestimates. Pennsylvania wastewater produced in the Marcellus Shale tends to have a high saline content. These contaminants are known to skew results when testing for radioactive elements. While more accurate tests exist, the procedures used by the EPA have not been updated (Kelly, 2014).

4) Gases (like methane) can travel through water, and under the appropriate conditions, may become airborne. Whether traveling through water or air, many chemicals are eventually deposited in the soil where they can accumulate over time and potentially contaminate our foodsheds, especially in areas like Pennsylvania which is primarily agricultural (see section on "Hydraulic Fracturing And Our Food Supply").

What We Know about Environmental Hazards

"Legacy Problems"

Numerous studies have been conducted in the past four years on the subject of air and water pollution resulting from shale gas extraction. As is true for much of this research, it often originates in either Texas, Pennsylvania or Colorado where drilling has been ongoing for a period of years. Prior to the recent innovations in extracting shale gas, these states had been heavily drilled using traditional vertical wells. Many of these wells were in use and then abandoned before the industry was regulated as it is today, and many of these wells were not capped. These wells have left a "legacy" with which today's operators must contend.

As far back as 1985, the Texas Department of Agriculture reported that pollution from drilling operations migrated into abandoned wells that had been improperly plugged. An example cited in this report described disposal fluid entering an abandoned well which was located a half mile away. In Pennsylvania, where the number of abandoned wells has been estimated to number approximately 200,000, problems of this nature have been reported in Greene County (Legere, 2014).

Stolz' (2013) research on the Woodlands development in Butler County Pennsylvania documented problems with well water after fracking, using surveys and PA Department of Environmental Protection

(DEP) data. The researcher attributes these problems to the pressure of fluids and proppant changing the hydrology of the system and aggravating legacy issues.

Another complication arises from the fact that wells from earlier days of conventional drilling were often unmapped. Consultants to the oil industry have documented these problems, stating that "we remain incapable of fully describing the complexity of the fracture, reservoir, and fluid flow regimes" (Vincent, 2009). With little information about their location, it is not uncommon for new bores to intersect nearby wells, releasing gas through old, deteriorated casings and providing a pathway for methane and fluids to migrate to the surface and into surrounding aquifers. The problem is compounded by the fact that depending on the geology of the area, fractures can extend "unexpectedly" over "very large distances" (Fisher et al., 2005). New wells with many lines can exacerbate the problems.

The PA DEP, in its revision of the oil and gas rules for unconventional wells, is requiring operators to identify old wells by surveying within 1000 feet of a proposed unconventional well site. This should be done so that new wells don't intersect or connect with old wells. To expedite the process, the Department put old wells on a map, using historical data and aerial photography. The goal is to merge the information into a digitized file that can be posted online for the use of drilling companies (Legere, 2014). The information is now available to the public as part of the DEP's Oil and Gas Mapping of conventional and unconventional oil and gas wells, including producing and non-producing wells, at www.depgis.state.pa.us/PaOilAndGasMapping/

Air Hazards

An analysis of published, peer-reviewed literature on the subject of air pollution found a number of studies showing that chemicals "known to be associated with increased risk of morbidity and mortality" are found in areas where gas extraction occurs. These areas tend to have high levels of ozone, declines in air quality, and in some cases higher rates of health problems that are known to be linked to air pollution (Shonkoff, Hays & Finkel, 2014). Furthermore, based on exposures to air pollutants, the estimated potential for health risks was found to be greater for people living closest (within one half mile) to the site (McKenzie, 2012). In 2020, air pollution research predicts connections between COVID-19 impacts and particulate pollution (Setti et al.)

The aforementioned Rabinowitz (2014) study did find residents living within a half mile of a heavily drilled area in Washington County, Pennsylvania were more than twice as likely to report problems of the upper respiratory tract than people who lived at a greater distance from the wells .

Two 2012 studies in Colorado set the groundwork for studying the health impacts of airborne chemicals. One of these linked a single well to more than 50 airborne chemicals, most of them known to have an effect on health (Song, 2012). In the same year, researchers at the University of Colorado published a paper which reported results of three years of air sampling. They concluded that the greatest potential for health impacts from airborne chemicals occurs during the well completion period, when condensate tanks are vented during filling, and methane is flared off. However, a report from Texas found that emissions were not limited to the well completion period, but were also "strongly associated" with compressor stations (Rich, Grover & Satler, 2014). Methane also leaks from pipelines.

Methane is 84 times more potent than carbon dioxide at trapping heat in the atmosphere in the first 20 years after being emitted (Litvak, 2015). In 2016, the EPA admitted that the formula they had used for years to estimate emissions had flaws. The EPA raised their estimates for oil and gas emissions by 34%, naming the oil and gas industry the **"single leading source" of methane emissions** in the atmosphere. Methane emissions previously were primarily attributed to cows and other livestock. Further evidence shows increased methane emissions in the atmosphere directly over heavily fracked areas of the U.S. (Compendium, 2016).

A review released on May 13, 2020 by the Environmental Defense Fund finds that methane leaks are more prevalent in Pennsylvania than reported. Fugitive emissions from unconventional gas wells in 2017 totaled 543,000 tons, far more than the 70,150 tons reported to the state. The EDF report says that natural gas drillers in PA leaked more than 1.1 million tons of methane over the course of 2017, 16 times as much as what was reported to the state. Methane emissions from older conventional wells totaled 599,200 tons. The Pennsylvania Department of Environmental Protection (PA DEP) doesn't collect fugitive emissions data on conventional shale operations.

The practice of flaring methane has been limited by the EPA beginning in 2015. Companies have begun to upgrade their facilities to comply (Hopey, 2012). In August 2015, the EPA announced a package of rules to further curb emissions of methane and volatile organic compounds (VOC's), particularly from shale gas operations. The rules extend to pneumatic pumps at well sites, equipment at compressor stations, transmission facilities and processing plants. However, the EPA rules are for new operations and do not cover methane emissions at existing sites. The Trump administration seeks to roll back the methane pollution rules regulating flaring, leaks and venting on federal lands. The EPA also made recommendations on reducing VOC's from oil and gas operations in states with high ozone pollution, including Pennsylvania (Litvak, 2015). In 2020, the PA DEP solicited comments on a new rule, first proposed in April 2019, which would require cutting emissions of VOC's and methane.

In early 2016, PA Governor Tom Wolf announced a four-point strategy to reduce methane emissions covering both new and existing sources. The plan includes introducing a general permit that requires the use of Best Available Technology (BAT), better record-keeping and quarterly inspections for leaks. It calls for more stringent Leak Detection and Repair (LDAR) at compressors and processing facilities, and LDAR best practice programs along transmission and gathering lines. The DEP was also working on developing leak-reducing policies for existing sources.

Non-methane hydrocarbons, which include several polycyclic aromatic hydrocarbons (PAHs), are known to impact the human endocrine system. These chemicals can be dangerous even at very low concentrations and have been known to be correlated to lower developmental and IQ scores in prenatally exposed children in urban areas (Colborn, 2012). At this time, in certain rural areas where fracking is prevalent, air quality has been shown to be worse than in urban centers (Grossman, 2013).

Nitrogen Oxide and Ozone Precursors - Despite the many exemptions made to federal laws for the gas industry, diesel exhaust, the source of nitrogen oxides, is still on the federal watch list for the oil and gas industry. Diesel fumes have long been known for their lethal impact in urban areas. In the gas extraction process, these fumes are emitted by banks of machinery on the well pad and by vehicles transporting water, chemicals, sand and equipment (Kaktins, n.d.). Respiratory problems and lung disease caused by ozone have been extensively documented by the American Lung Association long before the gas boom, and are a routine part of the EPA Air Pollution Control Orientation Course (EPA, 2010).

McCawley (2017) speculates that the increase in diesel truck traffic associated with a fracking operation represents the greatest source of respiratory health impacts, accounting for increased risks to those living by roads not immediately near the well.

According to John Hanger, former Secretary of the Pennsylvania DEP, "gas drilling is the second largest source of nitrogen oxide pollution in the state (second to coal-fired power plants)" (Phillips, 2011). These oxides are particularly dangerous when they combine with toxic Volatile Organic Compounds (VOCs) and hydrocarbons to form ozone. Ground level ozone produces harmful smog which causes irreversible damage to the lungs. Chronic exposure can lead to asthma and chronic lung disease. Depending on the duration of the exposure and the concentration of the chemicals, chronic effects can include decreased lung capacity and less commonly, lung cancer, damage to the immune system and neurological, reproductive and developmental problems (TEDX). In addition to causing respiratory tract

infections and asthma, airborne chemicals can also affect the skin, and can cause eye irritation, sore throats and headaches.

Other substances of concern are sulfur dioxide (SO_2), particulate matter, and hydrogen sulfide (H_2S) that are also found in the vicinity of wells (See LWVPA Study Guide #2).

Air pollution exposure is also known to inflame the brain, which can lead to neurological diseases such dementia and autism. Some scientists estimate that 20% of dementia cases stem from air pollution (Pelley, 2020). The immune system over-responds to chronic exposure to particulate matter, and this leads to tissue damage. Particulate matter can travel up the nose into the olfactory nerves that lead to the brain. Particulate matter can also enter the bloodstream through the lungs and then travel through the bloodstream to the brain.

Air contamination from fracking has been found to affect infants and children. The *New York Times*' Drilling Down series described a hospital system in Texas which reported a high incidence of asthma among young children in counties with some of the heaviest drilling (Urbina, 2011). Geisinger Health System data analysis of 35,508 patients ages 5-90 showed that asthma patients in homes near wells with the most production activity were more likely to experience attacks than those in homes near the least amount of activity (Rasmussen et al. 2016). An analysis of the scientific literature published in 2016 (Webb et al.) documents the effects of air pollution on the respiratory health of infants and children. It suggests health impacts of unconventional natural gas development, such as asthma and school absences, from exposure to ozone, benzene, silica dust and other pollutants associated with UNGD.

A study published in 2018 examined the relationship between hospitalizations for pediatric asthma and unconventional natural gas development. They looked at zipcodes with and without exposure to UNGD between 2003 and 2014, stages of drilling activity, and reported air emissions. During the same quarter that a well was drilled, the study found a 25% increase of being hospitalized for asthma. Odds were also increased among young children and adolescents for "ever" establishment of shale gas activity within a zipcode, and for sites where there were increases in specific air emissions. Associations remained for up to eight years after drilling started in a community (Willis et al.).

Water Hazards

In the process of drilling and fracking a well for unconventional natural gas extraction, wastewater of varying composition returns to the surface at different rates. Brine is the result of drilling a deep well and boring horizontally into the shale. It is highly salty and can contain rock cuttings. Even when greatly diluted, salt levels in brine remain above drinking water levels (*Science Daily,*2012). Salts found in the brine as well as other chemicals such as barium, strontium, arsenic and naturally occurring radioactive material (NORMS) would normally remain trapped in the deep underground rocks. However, they can become dissolved or mixed with the fluids used during drilling and extraction processes and return to the surface. Once a well is fracked, about a third of injected fluids return as "flowback" after a few days or weeks. Over the life of the well, the remaining wastewater that emerges from the well can be termed "produced" water. It gradually diminishes in quantity over time.

Analysis of produced water from three shale plays (Barnett, Eagle Ford and Marcellus) showed big differences in content in the different areas (Barron, 2014). The analysis found inorganic chemicals such as arsenic and barium at levels unsafe for drinking water. It also identified organic chemicals such as toluene, which can cause cancer. Benzene was not detected in this analysis, which surprises some researchers, but potentially toxic halocarbons resulting from chlorine treatment were found (Hirji, 2014).

Disposal of wastewater from natural gas extraction is a complex issue that has not yet been fully resolved. In recent years, technological advances have allowed some of the wastewater to be treated and reused in future fracking. In the past, the handling of wastewater has created difficulties for municipal treatment

plants that were generally not equipped to remove radioactive or other materials (Hopey, 2011). As a result the water discharged into the rivers was only partially treated.

A study published in the *Journal of Fish and Wildlife Management* examined the effects of high salinity wastewater (brine) from oil and natural gas drilling on freshwater mussels downstream of a brine treatment facility in the Warren, PA area of the Allegheny River. The study measured high conductance in the water and found that "junior northern riffleshell mussel survival was severely impaired" within the conductance zone, concluding that the results "clearly demonstrate toxicity" to this federally endangered species (Patnode et al., 2015). A study of the same area published in 2018 found chemicals from wastewater in Warren were still bio-accumulating in the bodies of the mussels, which Penn State co-author Nathaniel Warner says is an indication that the chemicals are entering the food chain (Geeza et al.).

Compounding other problems that can occur at water treatment plants are bromides. This non-toxic salt compound is converted to brominated trihalomethanes (THMs) when exposed to chlorine used by municipal water treatment plants. THMs are linked with birth defects, bladder cancer and other cancers (Hopey, 2011). According to TEDX, the Superfund Act classifies many of the chemicals found in fracturing fluids and degradation products as hazardous waste. However, **federal law exempts oil and gas development waste from the definition of "hazardous".**

Samples of drilling wastewater effluents discharged to surface water after treatment at two municipal and one commercially operated wastewater treatment plants were analyzed by researchers from University of Pittsburgh Graduate School of Public Health (2013) and found to contain barium, strontium , bromides and benzene at levels above "human health criteria." A study in Colorado analyzed flowback and produced water over 220 days, finding toxicity in various stages of the fracturing process (Hull et al., 2018).

Certain chemicals found in wastewater are known to disrupt the endocrine system with potential health consequences such as spontaneous abortions, fetal death and irregular fertility cycles. These chemicals can interfere with both human and animal reproduction and may have long-term consequences for agriculture and food production (see section on the food supply). Researchers found significantly more endocrine-disrupting activity downstream of a West Virginia wastewater injection well site, compared to reference waters upstream of the site. The endocrine disrupting "activity downstream was above levels known to result in adverse health effects" (Kassotis et al., 2016).

In an exploratory study of 66 Ohio households, Elliott and her co-researchers found relationships between proximity to oil and gas wells, drinking water contaminants such as benzene, and health symptoms such as stress and fatigue (2018).

Released contaminants may be absorbed through the skin, inhaled during daily activities like bathing or showering, or simply by breathing vapors from wastewater stored in pits or tanks. While efforts are made to keep the fracking fluids from entering homes and watersheds, toxic events occur. Casings fail, storage pond liners tear, wastewater trucks overturn -- just to name a few of the problems (Legere, 2010). And these events can have consequences for both humans and animals. The Pennsylvania Department of Environmental Protection (DEP) on August 28, 2014 posted for the first time their official tally of and details about 240 private water wells damaged by oil and gas operations since 2007. In only one case did the DEP explicitly state that industrial chemicals in drinking water were due to drilling operations. In response to a Susquehanna resident's complaint about foamy, foul-smelling water, in May 2014 the DEP found chemicals including methylene chloride and tetracholorethene that "were consistent" with the surfactant used to drill a natural gas well 1,500 feet away (Legere, 2014).

Researchers investigated a cluster of foals with dysphagia, born between 2014 and 2016 in an area in Pennsylvania active with unconventional natural gas development, and compared them with foals born at a farm in New York state owned by the same farmer that did not have difficulty swallowing. Of 65 foals

at the Pennsylvania farm, 17 were born dysphagic. The odds of being born dysphagic went up with each additional month of gestation at the farm in PA. Prior to installation of a water filtration system, the water at the Pennsylvania farm was higher in polycyclic aromatic hydrocarbons (PAH). After the water filtration system was installed, the level of PAHs was not higher at the PA farm than the NY farm, and the incidence of the dysphagic neurodevelopmental impact was eliminated in the following years (Mullen et al., 2020).

The EPA Study on the Potential Impacts of Hydraulic Fracturing on Drinking Water Resources was authorized and funded by Congress in 2010. The study included 18 research projects and addressed large volume water withdrawals; fracturing fluid spills and drinking water sources; well injection; flowback and produced water; and wastewater treatment and waste disposal. A draft report of the results came out in June 2015. The report found there were not "widespread" impacts on drinking water resources in the United States, but the EPA report established that "there are above and below ground mechanisms by which hydraulic fracturing activities have the potential to impact drinking water resources." These mechanisms include water withdrawals in places and times when water is lacking, spills, fracturing into underground drinking water resources, below ground migrations of gases and liquids, and "inadequate treatment and discharge of wastewater." The EPA did find incidences where these mechanisms led to compromised water supplies. The report notes that the EPA's investigation, although detailed and time-consuming, was hampered by a lack of data, including a paucity of long-term and pre-post studies, and "inaccessibility of some information on hydraulic fracturing and potential impacts" (EPA, 2015). As noted earlier the Science Advisory Board for the EPA study recommended revising the conclusions of the report to reflect the problems with gathering data and the EPA's final report reflected these recommendations.

Methane migration - One question that has provoked a lot of interest and has yet to be answered satisfactorily is when, and to what extent does methane gas migrate into ground water. The gas is not considered harmful if ingested. However, this colorless, odorless, tasteless gas that is released during drilling, can cause asphyxiation when it enters confined living spaces. In high enough concentrations, it creates a risk of explosion.

A 2011 study of 60 private wells in northeastern Pennsylvania and New York found methane in 85% of the wells, nine of which were above levels where action is recommended. The researchers matched the chemistry of the methane found in the water wells to the methane from the fracked well. This study also indicated that methane levels in private water wells were, on average, 17 times higher when they were within 1,000 yards of a natural gas well (Bauers, 2011).

Gas migration has been a problem for decades in Pennsylvania, and the documentary *Gasland* has made the world aware of the phenomenon. Antics aside, the explosion of a water well in 2009 in Dimock, PA has had ongoing repercussions for residents. On New Year's Day, 2009 a water well blew up with such force that it tossed a slab of concrete weighing several thousand pounds into the yard of the homeowner. Though no one was hurt in the explosion, subsequently 15 families filed a federal law suit against the drilling company claiming that that the water was undrinkable. The gas company was told by DEP to shut down three wells for contaminating 18 water wells. A moratorium was placed on further drilling and the company agreed to pay for water for the residents, without however accepting responsibility. Since that time both the DEP and the EPA were involved in testing the water until the EPA study in Dimock was halted and drinking water deliveries ceased. However, in the course of its investigation the EPA found elevated levels of barium, arsenic or manganese in the water supply of several households (State Impact Topics, n.d.). Hazardous levels of methane were also found in some water wells, which had to be vented as a precautionary measure to prevent explosion. In 2016, a federal jury awarded $4.2 million to two Dimock families whose wells were contaminated (Legere, 2016). The Agency for Toxic Substances and Disease Registry released a report in 2016 saying that the levels of contaminants found in Dimock residents' wells made the water "unsuitable for drinking", created health hazards and also the threat of explosion from methane.

A 2014 study devised a way to distinguish between naturally occurring methane and methane from shale gas operations by analyzing noble gases and hydrocarbon tracers. Using this technique, the study identified seven cases in Pennsylvania and one in Texas where the shale gas operations were the source of the methane. The researchers said the methane came from cracks in the steel cases or flaws in the cement of the wells, rather than from the fracturing deep underground (Darrah, 2014).

Most drillers test private water wells within 1,000 feet of a drill site to protect themselves against the presumption that the operator is responsible for problems within that zone. Homeowners have a right to ask what water quality tests will be conducted and to receive copies of the test results. These tests may not take all relevant measures, leaving it up to the property owners to order more expensive tests. Residents who suspect that methane has entered their home through the water lines or other entry pathways, are advised to use fans and ventilation when showering or washing clothes.

Shale Waste Disposal and Radioactive Waste

Oil and gas extraction generate waste, and unconventional shale gas extraction has added more. These include liquid wastes – such as the large quantities of wastewater generated as flowback in the initial fracking of a Marcellus well and then as produced water that comes up with the gas once the well starts producing; solid wastes such as drill cuttings and drilling muds and sludges; and also air emissions at wellheads, compressor stations and elsewhere along the journey of fracked gases. Due to the large quantities of waste generated, the presence of harmful and radioactive chemicals within the waste, and the lack of safe ways of disposing of the waste, waste disposal has been referred to as the "Achilles' heel" of the industry.

In the spring of 2015, Earthworks issued a major report, *Wasting Away,* on oil and gas waste in the Marcellus/Utica region, focusing particularly on the procedures and regulations for handling such waste in New York, Ohio, Pennsylvania and West Virginia. The report shows that liquid waste production from oil and gas wells in the Marcellus region of Pennsylvania increased 104% between 2011 and 2014, to 41.3 million barrels. During the same period, solid wastes increased 516% to 1.6 million tons. Both liquid and solid wastes may contain radioactive materials. Earthworks issued an update to this report in September 2019, including an interactive map produced in conjunction with FracTracker Alliance. The report shows that the oil and gas industry produced 69.3 million barrels of liquid waste in 2018 in Pennsylvania, up 20% from the previous year, and 1.4 million tons of solid wastes (up 36% over 2017).

Also in 2019, a study of Pennsylvania waste disposal trends between 1991 and 2017 from PSE Healthy Energy (Hill et al.) was published. The study includes waste from both conventional and unconventional oil and gas operations. Although Pennsylvania does require drillers to report information about their waste to a centralized public reporting system, the report found that one-third of the liquid waste over the years lacked a reported final destination.

2018 studies led by Dartmouth researcher Josh Landis find that the interaction between slick water and black shale during the process of fracking causes the shale to release radioactive material. The radium in the wastewater comes out of the shale rock, not from the pre-existing underground briny waters, as was previously thought.

Naturally occurring radioactive material (NORM), like radium and radon are known to cause cancer. Radium tricks the body by mimicking beneficial elements like calcium. As a result it is deposited in bones where it causes cancerous mutations. It can also interfere with the bone marrow's ability to create blood cells, causing a condition named "aplastic" anemia.

Another source of concern is radon and its decay products. This radioactive substance, when airborne, can enter a person's system through the lungs and tends to be most detrimental to smokers who are already at risk for lung cancer. A team of doctors in the New York area detailed these problems in a letter to the

Governor, with particular reference to the relatively short distance between gas origination in Pennsylvania's Marcellus Shale and the homes and offices in New York City. The doctors raised the possibility that by traveling through distribution pipelines along with the natural gas, the radon, which has a half life of 3.5 days, can reach the City before decaying into other substances (Campbell, 2014).

Harvard scientists determined that the radioactivity of airborne particles increases significantly downwind of fracking sites, using data collected from radiation-monitoring stations. These stations were built during the cold war as a response to the threat of nuclear war. Data was collected from 157 stations across the US between 2001 and 2017. Researchers (Li et al., 2020) compared the radioactivity data with the position and production information for 152,904 fracking wells. Some locations were downwind of nearly 600 wells. The researchers also found that unconventional wells generated much greater radioactivity than conventional operations. The initial source of the radioactivity is a uranium isotope in the rock. Conventional wells won't disturb the uranium in the rocks compared to the deep fracturing and blasting associated with unconventional operations. Unconventional wells also generate larger quantities of radioactive liquids. The uranium isotope decays into radon gas, which then decays to ultrafine particles containing polonium-210 and lead-210. These are presumed to attach to particles already in the air and then carried downwind. Polonium isotopes are very toxic. The downwind radioactivity was more pronounced in the Marcellus and Utica shale in Pennsylvania, West Virginia and Ohio, where the rocks contain more uranium than in Texas or North and South Dakota. Study leader Petros Koutrakis said that determining from where in the operations and which stage of production the emissions come from could help to stop the radioactive leaks.

A peer-reviewed study published in *Environmental Health Perspectives* in 2015, which was conducted with the Geisinger Health System, analyzed more than 860,000 indoor radon measurements in a Pennsylvania DEP database from 1989 to 2013. The researchers found that radon levels in Pennsylvania have been on the rise since 2004, around when the "fracking industry" began drilling natural gas wells in the state, with nearly 7500 unconventional wells drilled between 2005 and 2013. Counties with more than 100 drilled wells had higher levels of radon than those with no wells. Buildings using well water measured higher on radon than those without. Unconventional gas drilling was thus a predictive factor for higher radon concentration, along with factors such as weather and the geology of the ground underneath buildings. This conclusion drew the ire of Pennsylvania's Marcellus Shale Coalition, which put a rebuttal on its website stating that radon is a historical fact in Pennsylvania, that radiation is everywhere, and citing the PA DEP TENORM study as evidence. The TENORM study synopsis says "there is little potential for additional radon exposure to the public due to the use of natural gas extracted from geologic formations located in Pennsylvania." The complete TENORM study does detail concerns. However, a re-analysis of Pennsylvania fracking and radon data, conducted by Black, McCoy and Weber, did not find a causal relationship between fracking and indoor radon levels, likening the relationship to one between "ice cream sales and murder rates" (2018).

Residual solids include drill cuttings, debris, and materials that settle out from wastewater or remain following evaporation of fluids in open pits. Because these residual solids can contain heavy metals, naturally occurring radioactive material (NORM), and other contaminants, their disposal can be problematic. Using landfills for disposal allows these substances to accumulate indefinitely (Urbina, 2011) and also risks contamination of water and soil. According to a local newspaper in Greene County, Pennsylvania a truckload of waste triggered a radioactivity alarm at a disposal site. Testing revealed it contained nine times the state standard for radium 226 (Kinsell, 2013). In January 2015, the Pennsylvania DEP, concerned over radon, instituted monthly caps on fracking sludges to ensure that such waste was being mixed with non-radioactive waste at a ratio of 1:50 (Litvak, 2015).

This incident confirms reports that levels of radioactivity in wastewater produced from the Marcellus Shale is extremely high, a fact which has been reported by numerous studies. An article in the *New York Times* cited research showing that radioactive levels have been measured at rates that are "hundreds or even thousands of times the maximum allowed by the federal standard for drinking water" (Urbina,

2011). Federal and state officials reacted quickly and public water suppliers said they would cooperate with the Federal EPA on monitoring requirements and effluent limits for water processing plants. Another published study by scientists from Duke University, documented high levels of radium in stream sediments of Blacklick Creek, a tributary to the Allegheny River (Warner, 2013).

Wastewater is sometimes disposed of by injecting the wastewater at high pressure into injection wells. A 2016 US Geological Survey study by Denise Akob and her colleagues found increased radioactive compounds and other evidence of water contamination downstream of a West Virginia wastewater disposal injection well site.

In the spring of 2016, the EPA prohibited discharges of unconventional oil and gas extraction wastewater to publicly-owned treatment works (POTW's).

The use of impoundments or reserve pits to store contaminated water was the subject of a study in which a soil analysis was conducted on two sites. One of the sites had been drained and the other still in use. Findings showed varying levels of radioactive contamination in the soil, including alpha, beta, and gamma radiation. The presence of certain radioactive elements was found to exceed regulatory standards by more than 800% (Rich, 2013).

Radioactivity has also entered the environment when the brine itself or salts retrieved from the brine through aeration are used for de-icing roads. This run-off can endanger pets, animals living in the wild, or livestock drinking from a ditch near the side of a treated road. Eventually, the salts and radioactive elements are apt to enter surface waters. With this comes the risk that radioactive matter will eventually accumulate on surrounding lands and be absorbed into the food chain (White, 2012).

There are 13 states in the U.S. that permit oil and gas wastewater to be spread on roads to de-ice or reduce dust. Lab experiments have shown that nearly all of the metals from these wastewaters leach from the roads after the rain, "likely reaching ground and surface water." A study by Penn State researchers and their colleagues, published in 2018 (Tasker et al.), found that in the state of Pennsylvania between 2008 and 2014, the spreading of oil and gas wastewater released over four times more radium into the environment, compared to oil and gas wastewater treatment facilities, and 200 times more radium compared to spill events. The oil and gas wastewater was from conventional, not unconventional wells (which presumably would have even higher concentrations of radioactive materials). The authors point out that current state regulations do not require radium analysis of wastewater before spreading on the roads.

The Pennsylvania Department of Environmental Protection did release in early 2015 its in-depth study of TENORMS (Naturally Occurring Radioactive Materials that are Technologically Enhanced, i.e. brought out through gas extraction). The study's sample included dry gas and wet gas operations, and also conventional gas operations. The study synopsis says there is "little or limited potential for harmful radiation exposure to workers and the public from the development, completion, production, transmission, processing, storage and end use of natural gas." But the study found "potential radiological environmental impacts" from spilled fluids and at "all facilities in Pennsylvania that treat O&G wastes." At centralized wastewater treatment plants and zero liquid discharge plants that treat oil and gas wastewater, the study identified "potential for internal radiation exposure to workers and members of the public," particularly if "disturbed during routine maintenance." Also, the study describes a "potential for exceeding public dose limits from external gamma radiation for workers at the natural gas processing plant." Detailed in the actual body of the study are other concerning results. For example, levels of Radium 226 were significantly higher in horizontal drill cuttings than vertical drill cuttings.

In 2016, seven environmental organizations sued the EPA in order to get new and better standards for the disposal of liquid and solid wastes from shale gas development which the groups say now poses a threat to environmental and human health. The groups claim that the EPA has shirked its duties under the federal law that governs waste disposal, the Resource Conservation and Recovery Act (RCRA). The

agency failed to update and tighten regulations for the handling of oil and gas waste after the agency concluded back in 1988 that federal regulations were inadequate (Hopey, 2015). In December 2016, EPA entered into a Consent Decree and agreed to review the treatment of oil and gas wastes. Under the terms of the Decree, the EPA had until March 2019 to determine if the rules need revision (Jaeger, 2017). In April 2019, the EPA decided not to revise the regulations.

Pennsylvania classifies oil and gas waste as "residual waste." Earthworks' *Wasting Away* report (2015) posits that the federal lack of designating oil and gas wastes as "hazardous waste", even though such wastes contain toxic and radioactive materials, leads to inadequate methods of disposal and disorganized "piecemeal" efforts to regulate oil and gas waste in Pennsylvania and elsewhere. The report says that comprehensive, coordinated oversight, "cradle-to-grave" tracking and reporting, and better waste disposal procedures are needed. At the federal level, Congressman Matt Cartwright from Pennsylvania introduced in 2015 the CLEANER bill so that oil and gas operations would not be exempt from treating their waste as hazardous under the Resource Conservation and Recovery Act. In 2016, the Pennsylvania DEP in its Chapter 78a revisions of the oil and gas regulations limits the most problematic aspects of waste disposal such as open pits and centralized impoundments. In 2020, PA State Representative Sara Innamorato put together a table of experts to study waste disposal over a nine month period. She and her colleagues are working on crafting legislation that closes the hazardous waste loophole.

SEISMIC ACTIVITY

One method of disposing of frack water involves the use of injection wells. The practice has been used for many waste materials over time. This is especially the case in Ohio, where deep sandstone formations are deemed suitable for injection. There has been a spate of relatively weak earthquakes in areas where injection wells are being used. This has lead to scientific interest in the potential linkage between the injection of large amounts of frack water and the tremors.

In the past six years, government geologists and seismologists have been increasingly involved in studying earthquakes in the central US, an area where earthquakes are not a common phenomenon. In May of 2014, the US Geological Survey issued an official earthquake warning for Oklahoma, citing a "dramatic increase in the frequency of small earthquakes," and in fact the numbers have continued to rise. A 5.7 magnitude earthquake in 2011 produced a series of aftershocks felt in 17 states. It destroyed 14 nearby homes and was felt as far away as Milwaukee (*Oil & Gas Journal*, 2014). In September 2016, Oklahoma experienced its strongest earthquake since 2011, a 5.6 quake that was felt as far away as Chicago (NBC News).

A study by a Cornell geologist is one of many to link the earthquakes to drilling related activity (Keranen, 2014). In 2015, the US Geological Survey (USGS) had more certitude in attributing the earthquakes to underground wastewater disposal. One such study (McNamara et al. 2015) concluded that a "fundamental change in the earthquake-triggering process has occurred" in central Oklahoma. The Oklahoma Supreme Court began to allow people to sue the oil and gas industry for damages caused by earthquakes they believe to be industry-induced. Researchers found Google searches for anxiety in Oklahoma increased with additional earthquakes (Casey et al., 2018).

Although earthquakes have usually been attributed to injection of wastewater, rather than to the fracking of well sites, in 2015 there was more evidence of fracking itself triggering earthquakes (CHPNY Compendium). On April 25, 2016, Pennsylvania saw its first "induced" earthquakes linked to shale gas operations. These five small (1.7 - 1.9) earthquakes in Lawrence County were attributed to hydraulic fracturing rather than to injection wells.

An outbreak of nearly 800 minor earthquakes over a six-month period occurred in the Greenbriar area of Arkansas, leading to a magnitude 4.7 earthquake on February 27, 2011 (Arkansas Online, 2011). Subsequently, the Arkansas State Oil and Gas Commission placed a six-month moratorium on this type of

wastewater disposal. A decline in the number and strength of earthquakes during that period has been recorded. However, researchers said that it was too early to attribute the decline to the shutdown of the wells (Eddington, 2011). Later, an EPA draft report stated “Do not operate well” for wastewater injection wells known to cause induced seismicity if the shaking cannot be stopped by other means, such as reducing the amount injected (Soraghan, 2013).

A published study by Shirzaei (2016) used satellite-based radar imagery to document how fracking wastewater migrating into faults led to an increase in pressure that triggered a 4.8 magnitude earthquake in 2012 in Texas. Choy (2016) found a rapid increase in fracking wastewater preceded the rupture of a fault plane in 2014 in Kansas, and a 4.9 magnitude quake. These and other studies provide additional evidence of a causal relationship between fracking waste disposal and other operations and earthquakes.

All these earthquakes and links to shale gas-related activities led the USGS to include for the first time “human-caused earthquakes” in its forecast of earthquakes for 2016.

A study of earthquakes occurring in the Barnett Shale in Texas showed that injection-triggered earthquakes are "more common than is generally recognized" (Frohlich, 2012). According to the study, the amount of water injected is not likely to be the sole cause of the seismic activity. The earthquakes seem to be linked to existing weaknesses in the earth's crust, such as a fault line which is already in a stressed state. A knowledge of the subsurface geology might help determine when and whether to use deep-well injection for disposal purposes.

The Pennsylvania DEP has permitted 12 injection wells, including in Plum Borough, a suburb of Pittsburgh. In March 2019, the EPA issued a permit but as of the fall of 2019, the PA DEP permit for the Plum injection well was still pending, and the DEP had issued deficiency letters. The DEP approved a permit for the Plum injection well on April 24, 2020 – during the first spike of the COVID-19 pandemic. The DEP permit requires the company to monitor groundwater and seismic activity. The borough still opposes the injection well. The company, Penneco, said that due to the uncertainties of the marketplace during the pandemic, they have put the project on hold.

In 2014, wells were permitted in Elk County and Clearfield Counties. However, in Clearfield, the EPA later remanded the permit, citing "factual mistakes" in the agency's response to public comments (Colaneri, May, 2014). Residents of a sparsely-populated township in Indiana County passed an ordinance to prevent the re-use of an old well for the purpose of waste disposal, after their objections and appeals were denied. The company which received the approval filed suit. In the spring of 2017, the PA DEP filed suit against Highland Township in Elk County and Grant Township in Indiana County at the same time that it approved injection well permits in those townships. In October 2019 at a Commonwealth Court hearing in Pittsburgh, Grant Township sought to preserve its challenge to the PA DEP permit. The DEP called for dismissal of the challenge. Victory came for the Grant Township environmentalists in 2020 when the DEP revoked the industry’s permit for the Grant Township injection well.

Although Pennsylvania is not a state that is known for earthquakes, the PA DEP in 2017 confirmed the first shale gas drilling-related earthquakes in the state. For the Clearfield County, Elk and Indiana county injection wells permitted in 2017, the DEP now requires operators to install seismic detection equipment, and report data promptly (Hurdle, 2017). The PA DEP has considered creating regulations to determine if there are "seismic hazard areas" where injection wells should be avoided (Legere, 2014). Pennsylvania in 2016 expanded its network of seismic monitors, so that it can detect minor earthquakes and shut down gas operations in early response.

HYDRAULIC FRACTURING AND OUR FOOD SUPPLY

The primary stakeholders in our foodsheds are farmers, who must cope with changes in water levels, soil contamination, farmland fragmentation, impacts on crop yields, livestock poisoning and falling

reproductive rates. On the other end of the food chain is the public which must rely on food safety inspectors who are not trained to look for microscopic changes in animal organs (Royte, 2012).

Several studies of agricultural impacts have been done. Adams & Kelsey (2012) at Penn State analyzed data on herd size, on milk production, and also on the number of shale wells by county between 2007 and 2010, a period where unconventional drilling started to take hold in Pennsylvania. They found that counties with 150 or more wells drilled into the Marcellus shale on average experienced an 18.7% decrease in dairy cows, compared with a 1.2% decrease in counties with no Marcellus wells. Milk production increased .6% in Pennsylvania between 2007 and 2010, and .9% in counties with no wells, but decreased 18.5% in counties with more than 150 wells. The authors are unclear whether this pattern is a result of a negative impact on land, water or animal health, or due to farmers leasing their land for shale drilling and then reducing their dairy operations (although some farmers used the money to increase their herd).

A peer-reviewed study, reported in *The Nation* (Royte, 2012), also suggested a link between fracking and illness in food animals. The research was conducted by Michelle Bamberger, a veterinarian, and Robert Oswald (2012), a professor of molecular medicine at Cornell University. Based on case studies of twenty-four farms in six shale gas states, they found that accidental or incidental exposure to fracking chemicals resulted in the death of 17 cows (Louisiana), 70 cows (Pennsylvania), and smaller numbers in other states. Other animals experienced neurological, reproductive and serious gastrointestinal problems.

Bamberger and Oswald's study of exposures in farm animals includes a case in which a herd of 40 cows was exposed to contaminated water, resulting in the death of half the herd, and an unusually high number of stillborn and stunted calves. This case is of special interest, because the same farmer pastured another 60 head separately, with no access to the contaminated water. This "control group" showed no adverse effects during the same time period (Bamberger, 2012). The authors state a concern that meat products from animals that survive chemical exposures will end up in the food supply.

A study conducted by the U.S. Geological Survey in collaboration with the U.S. Fish and Wildlife Service tied a fish die-off (including a threatened species) in a Kentucky creek to a fracking wastewater spill that changed the water's pH to more acidic and also increased stream conductivity. The analysis of water samples and fish samples collected immediately after the spill "clearly showed that the hydraulic fracturing fluids degraded water quality" in the creek, "to the point that the fish developed gill lesions and suffered liver and spleen damage" (Papoulias, 2013).

The Concerned Health Professionals of NY's 2016 *Compendium* describes the practice of California farmers using recycled oil and gas wastewater to irrigate crops. Tests conducted on one such operation confirmed the presence of volatile organic compounds including acetone, which is linked in lab studies to kidney, liver and nerve damage.

The *Denver Post* reported 578 spills in Colorado in 2013, about 200 gallons' per day worth, putting soil and farms at risk (Finley, 2014). The Pennsylvania DEP's TENORM study (2015) investigated the risks from conventional gas waste brines being used on roads- which can run off into farm fields - and recommended that this use be further studied to assess the threat of radiological impacts. In 2016, seven environmental organizations suing the EPA asked that the agency ban putting wastewater on fields and roads (Dennis, 2016).

In simulations of how spills of hydraulic fracturing chemicals could affect agricultural topsoil, Colorado State University researchers found that biodegradation of the commonly used surfactant polyethylene glycol was slowed down or stopped in the presence of the fracking biocide glutaraldehyde or salt concentrations typical of fracking brine wastewater (McLaughlin, 2016).

The U.S. Forest Service reported that hydrofracturing fluid applied to the soil of West Virginia's Monongahela National Forest killed more than half the trees in the area exposed and drastically changed

the soil chemistry. The study showed that the fracking fluid also caused severe damage and death to ground vegetation. Surface soil concentration of sodium and chloride increased 50-fold but declined over time (Adams, 2011). These results illustrate what could potentially happen to fruit trees and vegetables in the foodsheds (Cernansky, 2011). More research needs to be done on the impact of shale gas development on crops.

NOISE LEVELS AND NATURAL GAS DRILLING/PRODUCTION

For the duration of the drilling phase, noise emitted from drilling Marcellus Shale natural gas wells is very intense (80-94 dBA). Construction noise can be intermittent or fairly constant and typically lasts for several weeks, 24 hours per day (Sutter County, nd). On or near these sites, Occupational Health and Safety Administration (OSHA) requires workers to wear hearing protection devices to prevent permanent hearing loss, as it is well established that noise levels at and above 80 dBspl can harm human hearing.

Noise attenuates with distance, barriers, weather conditions, and surfaces that reflect sound. However, with noise levels on drilling pads reaching 50 dBA within 900 yards of the drilling pads, people who live, learn or work in the vicinity may find that the noise interferes with speech, understanding, learning, health, sleep and sense of well-being. Typical ambient noise levels in rural, non-commercial areas are reported at 35-45 dBA. Suburban areas measure like rural areas. In urban areas, noise levels vary with the type of neighborhood, with busy commercial areas measuring at 60 dBA or higher. Colorado researchers found noise levels in a residential area exceeded recommended levels during construction and drilling (Blair et al., 2018).
The World Health Organization (1999) states that with continuous noise, sleep starts to be affected at 30 dBA. Other health effects of noise are increased blood pressure, increased cholesterol levels, and cardiovascular disease. People seem to vary in what types of noises are most annoying. Some research suggests that very low frequencies can lead to restlessness and irritability. Generally, during the day, most people do not have a problem with the sound of 50 dBA, although constant noise is worse than intermittent noise. For shale drilling, intermittent sources of noise include trucks and fracking rigs.

Noise from compressor stations, which is present 24 hours per day, 7 days per week, is very intense (90 dBA). Great annoyance from compressor noise is the topic of numerous anecdotal reports. Boyle's (2017) pilot study of noise near natural gas compressor stations in West Virginia found higher levels of noise in homes within 750 meters of a compressor station than in control homes more than 1000 meters away. This was true of noise outdoors and inside the 11 homes in the study, indoors during the day and at night. Indeed, a specialist in environmental law at Pittsburgh's Duquesne University law school predicts that noise created by pipelines and compression stations is likely to become the most litigated energy issue in the coming decades (Bombatch, 2013).

An interesting distinction should be made between noise level, i.e., **intensity** (in dB), and the individual's perception of noise, or **loudness**. In a person with normal hearing, an increase of 10 dB in noise level generally *doubles* the individual's perception of loudness. Therefore, a resident of a quiet residential neighborhood or rural area, would experience the noise as being significantly louder when the level increases by only 10 dB (Earthworks, n.d.; Sutter County, n.d.).

Effect on Understanding of Speech

We also know that noise affects the ability to understand speech, with greater decreases among people with hearing loss, those who use hearing aids, or in aging populations. The World Health Organization states that sound levels of 35 dBA or less are required for clear speech perception. We know that children learn less efficiently in noisy classrooms especially if they have pre-existing conditions (Center for Hearing and Communication, 2013). Thus, if drilling or compressor noise increases ambient noise levels above 35 dBA, a person's ability to understand speech and to learn efficiently may be affected.

Thus, noise produced by Marcellus Shale natural gas production could interfere with daily living activities of our citizens living or attending school in close proximity, particularly to compressor stations. It is an issue worthy of more study and thought. Paulson (2010) has recommended greater oversight by specific agencies of children's environmental health at school to address noise and other major environmental problems. Ziemkiewicz, Quaranta and McCawley (2014) have made specific recommendations to reduce noise pollution (which they observed at peaks above 95 dBA at one West Virgina well site). They recommend routing traffic away from residences where possible, and depressing the roadway slightly to break the sound line. They also recommend installing sound meters at sites which pick up measurements 24 hours a day, and which are connected to a central monitoring location. When safe levels are exceeded, "engineers should investigate to seek the source and report not only the cause but also the steps taken to prevent a recurrence."

BEST PRACTICES FOR PHYSICIANS

As knowledge increases about shale gas development and public health, professionals are developing best practice recommendations for physicians, community health centers and patients. One of the main recommendations for health professionals working in shale country is to incorporate questions about shale into patient intake forms and into doctor-patient discussions. Questions about exposure to shale gas operations have not previously been included as part of patient intake questionnaires, but doing so can provide clues to explaining symptoms whose possible etiology might otherwise be missed by the doctor or patient. Collecting such information can also help provide research data on the prevalence -- or absence -- of shale gas-related health symptoms among those living or working in areas of shale gas operations.

The Southwestern Pennsylvania Environmental Health Project (SWPA – EHP) has developed a patient intake questionnaire, a question prompt for health providers to use in discussion with their patients, and an occupational history question protocol for patients who work in the shale gas industry. These may be found on the SWPA-EHP website.

The questions focus on surveying proximity to shale gas operations, determining dates of beginning of operations in relation to symptom onset, and identifying potential pathways of exposure to toxic by-products of shale gas operations (e.g. through air or water). The patient intake form lists a variety of symptoms that have been reported in conjunction with exposure to shale gas, including burning throat, skin rashes, nosebleeds, nausea, abdominal pain, breathing difficulties, and other symptoms. Such symptoms may appear in isolation, or as a constellation of symptoms.

Public health experts such as Dr. David Brown recommend taking precautionary and preventative measures to limit one's exposure to air and water if one lives in close proximity to shale gas operations. These measures include removing one's shoes upon entering the house, using bottled water for drinking, and keeping a health diary to share with one's doctor. A list of recommendations developed by SWPA-EHP and entitled "Good Things To Do If You Live Near Gas Drilling" may be found on the SWPA-EHP website.

THE PSYCHO-SOCIAL TOLL OF THE BOOM AND BUST CYCLE

The boom and bust cycle is typical of extractive industries, from Gold Rush days until the present. Because of its long history, the phenomenon has been well-documented. The Marcellus Shale boom has followed the same general pattern that previous cycles have demonstrated, most recently in the American west which first experienced a gas boom during the 1970's and 80's (Jacquet, 2009).

The "boomtown model" describes how the rapid development of the natural gas industry uncovers and exacerbates existing social pressures, especially in thinly populated rural areas where services are limited. These problems are compounded by lack of planning for the numerous changes that occur as a result of

the industrial intervention. The current gas boom, though somewhat attenuated due to market forces, has replicated the historic pattern.

While the average person might expect the "boom" to be mostly prosperous and upbeat, and the "bust" to be a period of decline, the facts paint a much more complicated picture.

The boom is a period of higher employment, with some landowners clearly benefitting from leasing arrangements with the industry. Also, businesses benefit from the new or expanded opportunities such as sub-contracting industry-related services like trucking, water purification, drilling, etc. Secondary impacts on hotels, restaurants, clothiers, and other businesses are also felt and a multiplier effect further spreads the benefits across the area.

However, there is a downside to all this. When the demand for workers, particularly for qualified workers, outstrips the local supply, a large influx of transient workers gathers in the community. These new arrivals have their own needs and lifestyle preferences, which may be out of sync with the family-oriented permanent community. Medical facilities must adapt to a higher number of emergency room visits, higher rates of STDs and patients who may be uninsured. While many of the new arrivals are single men, some bring their wives and children, who add to the local school population. All of these changes can create a financial strain on the facilities which are forced to assume a greater debt burden (Eligon, 2013).

A study of shale gas activity and rates of sexually transmitted infections (STI's) examined records from the Ohio Department of Health from 2000-2016 and shale activity records from Ohio Department of Natural Resources. The researchers found that counties with high shale gas activity had 21% increased rates of chlamydia compared to counties with no shale gas activity, and 19% higher rates of gonorrhea (Deziel et al., 2018).

The boom period is also often characterized by an increase in rentals and a decrease in available housing. Law enforcement also must adjust to the new realities which may include a spike in the crime rate. Infra-structure maintenance becomes a major issue as large trucks and vehicles tear up roads that are designed for infrequent traffic. Back roads become congested with trucks, and noise levels go up. A published study from the Geisinger Health System researchers found that northern Pennsylvania counties with drilling had higher crash rates than those with no drilling. Modeling of their data suggested a significant 5% increase in fatal crash rates per each 10 additional wells drilled in the northern counties. The relationships were less clear-cut in southwestern Pennsylvania, although the authors calculated a 10% rise in heavy truck crash rates per each additional 10 wells (Graham et al., 2015). Colorado researchers found higher rates of truck and multivehicle truck accidents with injuries in counties with more oil and gas wells (Blair et al., 2018). Xu and Xu (2020) found that an additional post-fracking well within 6 miles of a road segment led to 8% more fatal crashes, which they attributed to heavier truck traffic.

Furthermore, as is evident from the list of symptoms earlier in this resource guide, some of the symptoms reported by residents in gas-producing areas are psychological. Severe anxiety, tension, irritability and depression are all on the list. These may have any number of sources, but a pilot study shows that concern over health problems believed to be caused by natural gas operations is not insignificant and worthy of further study (Penn Medicine, 2013).

In another study, University of Pittsburgh researchers found that some of the leading causes of stress were 'feelings of being taken advantage of, having their concerns and complaints ignored, and being denied information or misled" (Science Daily, 2013). One respondent summed it up this way, "We are not in control of our lives . . . I feel like I'm stuck in a bad dream" (Resick & Knestrick, 2013).

Fisher and colleagues conducted interviews with 34 residents of Guernsey and Noble counties in Eastern Ohio about their quality of life, and found psychological stress. "Residents living near UNGD found themselves anxious about the uncertainties of fracking; frustrated by interactions with oil and gas industry

officials; stressed about noise or light pollution; and, in some instances, facing the possibility of moving from the region" (2018). Malin (2020) describes stressors affecting people living near unconventional natural gas operations, particularly "uncertainty" due to inaccessible information, and feelings of "powerlessness" to decide "how, when and where" production takes place.

Leiter (2017) discusses how people who presume they will be safe and happy in their homes can suffer when industrial development occurs on or near their property, referencing the concept of "solastalgia" – psychic distress caused by environmental changes to the land at one's home which alters a person's sense of belonging. A survey study in the West Texas Permian basin (Elser et al., 2020) found evidence of increases (some statistically significant) in the perceived threat of environmental issues, the "felt impact" of environmental change, and loss of solace (solastalgia), particularly among women, and among subgroups that had experienced at least one earthquake of magnitude 3+ , and among those with exposure to oil and gas injection wells.

Humans don't adapt to change easily, at least in the short term, especially when a long-established, slow-paced rural life is disrupted and replaced by a barrage of unfamiliar inputs: the 24-hour cycle of modern industry, environmental degradation, medical uncertainties, and potential tensions between neighbors who have chosen different strategies for dealing with the changes. The toll may sometimes appear greater than the benefits to some of those affected.

Johnston and Cushing's review (2020) of chemical exposures and health in fenceline communities describes how polluting industries locate in low-income "environmental justice" communities of color where the social stressors people have experienced increase their vulnerability to health impacts.

The above paragraphs describe the boom. A period of decline may follow, when some of the extra income for local businesses, and some local jobs also disappear. We have learned from previous cycles of the necessity of mitigating the effects of a "boom" industry on our landscapes and our lives. Precautionary measures include diversifying the economy so as to not become over-reliant on one industry, and planning to address future impacts (Stares, 2013). Today's largest gas companies have a stake in being socially responsible, and increasingly, they are aware of this. As the industry expands and impacts more individual landowners and more communities, companies face the challenge of responding appropriately and responsibly to the psycho-social impacts of shale gas development.

OCCUPATIONAL HAZARDS

According to occupational safety scientists, fatality rates in the oil and gas industry have risen dramatically with the growth of the industry. A December 2018 report by the *Texas Tribune* using data from the Bureau of Labor Statistics says that 1,566 oil and gas workers died from on-the-job injuries between 2008-2017. According to the AFL-CIO's 2016 report, *Death on the Job: The Toll of Neglect*, the current number of fatalities for oil and gas workers stands at five times the national average. Fatalities are most likely to occur in operations run by small subcontractors (those with less than 19 employees), whether they are engaged in drilling or well servicing (Urbina, 2012). The National Institute of Occupational Safety and Health (NIOSH) publishes an annual fatality report, detailing the circumstances of oil and gas worker deaths. One of the NIOSH epidemiologists commented on a new hazard alert for produced water tanks/wastewater tanker trucks which have killed workers welding those tanks when they caught fire or exploded, "People sometimes think that's water, because they call it those names: produced water, salt water, brine. It's not just water. It can blow up." (Legere, 2015).

NIOSH also published a strategic plan to guide its research through 2025. In 2016, NIOSH started a three-year study surveying 500 oil and gas workers out in the field about past injuries, safety concerns, and factors contributing to vehicle crashes.

Interestingly, the largest cause of fatalities in the industry is highway accidents, with almost a third of the total fatalities occurring among truck drivers. Accidents are in part due to the condition of the trucks, and also to clauses in regulations that exempt the drivers in the oil and gas industry from certain protocols. According to Urbina, in 2009 the PA State Police reported that 40% of the trucks inspected had to be taken off the road because they did not meet vehicle safety standards. Furthermore, in a pattern that is typical for this industry, drivers are exempt from occupational safety regulations. Working longer hours, the drivers make more money, but with some shifts lasting up to 20 hours, they are also risking their lives. Exemptions for the oil and gas industry have been in place for almost 50 years (Urbina, 2012). In 2018, NIOSH issued a fact sheet for "Oil and Gas Workers: How to Prevent Fatigued Driving at Work."

For those who are injured on the rig site, complications also arise due to the rural locations of the wells, posing challenges to EMTs who are unfamiliar with new roads hacked out of forests and fields. Also in rural areas, where doctors generally specialize in family medicine, physicians were at a further disadvantage in treating workers due to policies in Act 13, § 3222.1, regulating access to and sharing information about the complete list of chemical components of fracking fluids, in order to protect trade secrets (University of Pittsburgh, 2013). This policy was criticized as a "physician gag rule."

The Pennsylvania Supreme Court in 2016 ruled certain parts of the Oil & Gas Act unconstitutional, including the "gag rule" restrictions on physicians, saying that it was a "special law" and thus violated the state constitutions prohibitions on laws that benefit specific groups or industries. The decision was praised by State Representative Dan Frankel, who had previously included a provision to eliminate the "gag rule" in House Bill 1105, the Patient Trust Act.

Aside from the hazards of working with heavy equipment, one serious side effect of the job is exposure to radioactivity. Like the people who live in the vicinity of unconventional gas wells, workers are also exposed to radioactivity. However, workers are more likely to actually come into direct contact with the radioactive material during normal operations, such as cleaning equipment containing residual materials. Workers who handle solvents or are exposed to ionized radiation can be at a higher risk for brain cancer (Food & Water Watch, 2017).

In a Center For Disease Control National Institute of Occupational Safety and Health [NIOSH] blog (5/23/12), it was stated that most of the attention, to date, on safety and health implications of hydraulic fracturing has been related to the environment, particularly ground water. There is very little data regarding occupational health hazards during fracturing operations. NIOSH initiated "The Field Effort to Assess Chemical Exposures in Oil and Gas Extraction Workers." In August 2014, NIOSH published online results of a small study showing benzene in the urine of Colorado and Wyoming workers who monitor flowback fluid, in some cases at high levels that could potentially lead to leukemia (Esswein). NIOSH also reported on "at least four…recent worker fatalities related to or located at flowback operations…from what appears to be acute chemical exposures"(Snawder, 2014).

Silicosis

The initial hazard assessment identified exposure to crystalline silica during hydraulic fracturing as the most significant known health hazard to workers. The first peer-reviewed study documenting exposures at harmful levels was published in 2013 (Esswein et al, NIOSH).

NIOSH explains that crystalline silica, in the form of sand (frack sand) plays a major role in the fracturing process. Each stage involves hundreds of thousands of pounds of frack sand. Moving, transporting and refilling this much sand generates considerable dust, including respirable crystalline silica, to which workers can be exposed.

Inhalation of this fine dust can cause silicosis, an incurable but preventable lung disease. The disease typically develops after a long period of exposure and progresses gradually. However, rapidly fatal cases

resulting from very intense exposures over a few months or a few years are documented, according to NIOSH. Crystalline silica has been determined to be a lung carcinogen and there is evidence that it causes chronic obstructive pulmonary disease and some autoimmune diseases. Individuals with silicosis are known to be at higher risk of tuberculosis and other respiratory infections.

NIOSH reports that respiratory protection is not sufficient to adequately protect against exposure. A combination of product substitution, engineering, administrative and personal protective controls, along with worker training, is needed to control workplace exposure to silica during fracturing. NIOSH worked with their researchers and industry partners to come up with controls, simple and complex, that can be implemented.

Workers at the sites where the sand mining takes place are also at risk for silicosis and the other health conditions mentioned above. According to a News Brief of American Planning Association the Cambrian quartz sandstone underlying Minnesota, Northern Illinois and Wisconsin is ideal for the fracturing process. Sand mines in these areas are the primary source of the sand. Skyrocketing demand has exposed more workers to the tiny airborne silica particles that can cause silicosis, cancer and autoimmune diseases (conditions which may not become obvious for 10 or 15 years after exposure), as well as the noise, light of round the clock operations, truck traffic, ground water pollution and diesel pollution.

Rando and co-researchers created a job exposure matrix, using archival particle count data, to retrospectively estimate exposures to respirable quartz, some going back years. They looked at 67 workers with silicosis and 167 matched control workers from 21 different industrial sand plants. They found that the workers with silicosis had significantly greater exposures – with the median cumulative exposure more than twice that of their matched controls who did not have silicosis.

A special series in *Toxicology and Applied Pharmacology* features studies of the health impacts of inhaled fracturing sand dust. Anderson et al (2020) investigated impacts at 1 day, 7 days and 27 days post-exposure and found "impairment of immune function." Krajnak et al. (2020) found that male rats' exposure to frack sand dust (FSD8) "results in adrenoreceptor-induced increases in heart rate and blood pressure."

The *Engineering News-Record* (2012) reported that new OSHA research, in which 116 air samples were taken at 11 fracturing sites in 5 states, found that sites consistently exceeded current OSHA standards in addition to far tighter voluntary industry standards. The article also reports that the silica hazards on one-third of the sites were at least 10 times higher than current NIOSH exposure recommendations as well.

The Occupational Safety and Health Administration (OSHA) issued a final rule which took effect on June 23, 2016 to protect workers from exposure to respirable crystalline silica. It gives the hydraulic fracturing industry two years to comply with most of the requirements (and five years for engineering controls). The rule reduces the permissible amount of exposure, requires engineering controls such as water or ventilation to prevent worker exposure, mandates the training of workers to reduce exposure, and provides medical exams for highly exposed workers. In August 2019, OSHA put out a request for information on the effectiveness of alternative engineering and control methods in order to ascertain whether revisions to the rule would be appropriate (Federal Register, August 15, 2019)

Although the potential of the threat of silicosis to workers is being evaluated, the risk to residents who may live in close proximity to well pad operations where sand is being used, or to sand storage areas, is yet to be determined.

ETHANE CRACKERS AND PETROCHEMICAL DEVELOPMENT

Chemical "cracking" is a process whereby molecules of hydrocarbons are broken down into smaller molecules. A "cracker" is the industry term for a plant that handles this operation. An ethane cracker

takes ethane, a gas product, and at very high temperatures creates ethylene, a petrochemical compound used in the manufacturing of plastics and other materials such as ethylene glycol (anti-freeze). In the U.S., ethane crackers are found mostly on the Gulf Coast. There are also ethane crackers in other parts of the world. With the development of the Marcellus Shale and Utica formations which are more plentiful sources of ethane, the Pittsburgh region has become a target for ethane cracker plant construction.

Southwestern Pennsylvania has the "wettest Marcellus shale" gas in the Marcellus formation. Natural gas is methane. But, in southwestern Pennsylvania the gas wells typically produce 80% methane, 10 - 15% ethane, ~5% propane, ~2% butanes and ~2% higher hydrocarbons (pentane, hexane etc.) (Deal, 2011). Facilities have been built by Momentum Midway at Scio, and by Mark West at Cadiz, Ohio and Houston, PA (near Washington, PA) to separate the wet well gas into the commercially useful components. In 2018 Pennsylvania produced 29.7% of U.S. ethane – and Texas produced 29.5%. Ohio produced 8.1% of U.S. ethane, West Virginia 7.5%, Louisiana 6.5% and Oklahoma 6.4%.

Shell Chemical Appalachia LLC on June 7, 2016 announced its “final investment decision” to construct a facility on the brownfields site formerly occupied by the Horsehead Corp. zinc smelter in Potter and Center Township in Beaver County. In 2015, Shell obtained authorization from the Pennsylvania Department of Environmental Protection for the construction and temporary operation of the Beaver County ethane cracker complex. In 2017, Potter Township granted Shell a conditional use permit for the site. Site preparation is essentially complete: sewers, building foundations and piping. In November 2017 Shell announced that construction of the plant itself had started. Driving past the site, you will see extensive construction – buildings, reactors, pipe-bridges, distillation columns, cooling towers. In October 2018 a 288-foot quench tower was lifted into place. Shell reported that the project is “ahead of projected timeline” with the plant opening (production start-up) in the early 2020’s. In mid-March 2020, in response to the COVID-19 pandemic and after complaints of unsanitary conditions, crowding and lack of hand sanitizer, construction was “temporarily suspended.” The 800 contractors, including 200 Shell employees, were sent home. After taking corrective action to improve social distancing on the job and commute, plus improved hand-washing stations, in April about 5,000 workers had resumed construction of the facility (Ellwood City Ledger, August 2020). In September 2020 Shell announced that construction is about 70% complete with most of the production units in place.

In anticipation of starting up, Shell awarded the contract for mechanical and maintenance of the facility to AECOM Energy and Construction Inc. AECOM’s workers will supplement/complement the Shell maintenance workers already on site (April 18, 2019, *Pittsburgh Business Times*). The Beaver County Corporation for Economic Development has purchased a 54-acre property that sits between the Shell site and the BASF and NOVA Chemicals properties and will serve as a buffer for Shell Chemical’s ethane plant. Under a unique arrangement, Shell has agreed to underwrite the cost of the acquisition. The land was previously owned by the Lyondell Environmental Custodial Trust.

With guidance from Shell, local educational facilities, such as Community College of Beaver County, are providing classes and training for the job skills necessary to work at a cracker plant in particular and other modern, highly computerized manufacturing facilities. The Williamsport *Sun-Gazette* reported that Shell donated $250,000 to the Pennsylvania College of Technology to enhance and upgrade the college’s Plastics Innovation & Resource Center. In December 2017, Shell launched a website for applicants for career opportunities at the future ethane cracker plant. However, on December 8, 2019, the front page headline in the *Pittsburgh Post-Gazette* reported the Carnegie Mellon University “Study: Shale gas job gains don’t offset the damage done” due to health impacts that cause premature deaths, and environmental and climate impacts.

The “Falcon” pipeline will supply ethane to the Shell facility. Shell Pipeline, not Shell Chemical, is in charge of building the pipeline. The Falcon pipeline runs north from Cadiz, OH to Scio, OH; then east to the Shell plant. A second branch of the Falcon pipeline runs north from Houston, PA to the Shell facility. Shell has completed negotiations with property owners to obtain right-of-way (easements) for the

pipelines. Since the pipeline is a "private" project, *eminent domain* cannot be used to obtain the right-of-way. Route changes are caused by failure to obtain easements, unacceptable geology, water issues, and reducing impact on existing sensitive uses, and other issues. In 2018, the PA Department of Environmental Protection and the Ohio EPA opened comment on Shell's Falcon pipeline. In Pennsylvania, this was for water obstruction/encroachment and earth disturbance permits for the Falcon pipeline. In response to requests, the comment period was extended and hearings were held (in both states). The PA DEP held three hearings, in each of the counties where the Falcon is planned to pass. Of particular concern are the proposed pipeline crossings of the waters feeding into the Ambridge Reservoir, which serves about 70,000 people in Beaver and Allegheny counties. Following the hearings, the PA DEP later issued three technical deficiency letters (for Allegheny, Beaver and Washington Counties), to which Shell responded in the summer of 2018 (Jackson, 2018).

In spite of vocal local opposition, in February 2019 Shell reported on their website that the right-of-way easements had been obtained, permits had been granted, and the planning, engineering, design and construction were progressing. The Federal Energy Regulatory Commission (FERC) had, on September 7, 2018, announced that Shell's petition for a declaratory order pertaining to a new interstate pipeline had been granted. As reported in a December 20, 2018 press release, the PA DEP approved the Pennsylvania portion of the Falcon pipeline (Allegheny, Beaver, and Washington counties). On March 26, 2019, the imported steel pipe for the Falcon pipeline arrived at the Port of Philadelphia. The pipe was unloaded onto trucks for shipment to the pipeline sites (K. Randolph, *Pennsylvania Business Report*). On August 23, 2019, the *Pittsburgh Business Times* reported that construction of the challenging section of the Falcon pipeline under the Ohio River had been completed. The *Beaver County Times* reported on June 25, 2019 that the Falcon pipeline will be buried 4 feet underground (more than the required 3 feet) with a blue marker ribbon 2 feet above the pipeline to warn of its proximity. Emergency shut-off valves are being placed every 7.5 miles rather than the required 15 miles. The pipeline will be buried 56 feet under the water intake line of the Ambridge Reservoir, more than the 31 feet required by the PA DEP. The actual construction of the Falcon pipeline has been sub-contracted to Minnesota Limited LLC.

The Falcon pipeline has been beleaguered by geographical and COVID-19 challenges. Horizontal drilling is used to install the pipeline under rivers, wetlands, roads and railroads. Karsts and abandoned orphan coal mines causes losses of the fluids used to horizontally drill into the mines and karsts. The losses are reported as spills. Pipeline construction was not halted during the initial COVID-19 restrictions. In Pennsylvania, the Department of Community and Economic Development (DCED) told Shell to "go ahead" with the project. All the pipe has been installed in the Falcon pipeline with only valving and other safety systems to be completed. Restorative environmental work on the pipeline right-of-way is 85% complete (October 2, 2020 *Pittsburgh Business Times*).

In August 2019, the PA DEP revoked the Beaver County Conservation District's ability to issue permits for erosion and sediment control and aspects of construction permits such as for pipelines. This came after a state evaluation report characterized the BCCD's permitting performance as unsatisfactory and missing documentation and said the BCCD does not possess the expertise to issue the permits.

Adding to local concerns over the pipelines was a large explosion that destroyed a home on September 10, 2018 in Center Township, Beaver County. The gathering line, part of Energy Transfer Partners' Revolution pipeline, was in a trial run. ETP's ME2 (Mariner East 2) pipeline project in Pennsylvania has experienced environmental violations, spills, and stops ordered by regulators (Mamula, 2018). Natural gas (methane) and nitrogen will also be supplied by pipelines built by non-Shell companies to the Shell facility. No information is available concerning the location/route of the natural gas and nitrogen pipelines because these gases will be supplied by other (non-Shell) companies.

The Shell facility would convert ethane to ethene (ethylene) and then, in separate facilities on the site convert the ethylene to many grades of polyethylene which would be shipped from the site as pellets. The pellets would be shipped by river barge, rail car and in minor amounts by truck. Other manufacturers –

possibly to be built near the Beaver County cracker - would convert the pellets to consumer products such as films, extruded pipe, coatings for paper, insulation for cables and wires, bottles, and other molded plastic consumer goods. Note that ethylene is a flammable gas with a boiling point of -104 deg. C (-155 deg. F), significantly below room temperature. Polyethylenes are solids with melting points above room temperature; about 125 deg. C (about 257 deg. F). Solid polyethylene pellets are easier, safer to ship than flammable, compressed ethylene gas.

According to Shell's plans as reflected in the DEP permits, the actual Beaver County manufacturing facility will consist of seven high temperature (1500 deg. F = 800 deg. C) ethane cracking furnaces, an ethylene purification system and three polyethylene production lines (two gas phase lines and one slurry technology line) which will be able to produce several grades of polyethylene (linear low density, low density and high density polyethylenes). To support these production lines will be raw material/product shipping and receiving facilities, warehouses, wastewater treatment facilities, cooling water towers, administration/laboratory buildings, site security facilities, emergency flare and a natural gas-fired cogeneration power plant.

Shell has begun construction of an Innovation Center and Center of Expertise on the site of the cracker plant. The facility will include analytical labs and testing labs allowing Shell to work with customers to improve the plant's products to meet customer requirements (Stonesifer, 2019).

Ethane crackers have the potential to emit harmful pollutants subject to Clean Air Act regulations, such as nitrogen oxides, sulfur dioxide, and particulate matter. Volatile organic compounds (VOC's) emitted by ethane crackers can combine with nitrogen oxides to create ground level ozone (smog). Exposure to VOC's and ozone has been associated with increases in lung conditions such as asthma and cardiovascular effects. The Pittsburgh region is already an area of nonattainment for some of these pollutants. On August 28, 2017 Shell reached a settlement agreement with two environmental groups, Clean Air Council and Environmental Integrity Project, to install and operate a fence-line monitoring equipment/program to ensure that any gasses or contaminants at the cracker plant's boundaries remain at acceptable levels. Shell will also increase the frequency of monitoring the plant's flares and ensure the flares meet or exceed the requirements of the Clean Air Act by destroying 98 percent of pollutants. The data from the monitors are to be publicly available on a website (Litvak, 2017). Citizens will be trained to understand the data.

Carnegie Mellon University has deployed about 50 real-time, affordable, multi-pollutant (RAMP) air quality monitors to measure CO, CO2, O3, NO, NO2 and SO2) and particulate pollutants (PM2.5). One of the monitors is across the Ohio river from Shell's plant and four are west or southwest (down wind) from the plant. The other monitors are close to other sources of pollution and might not be very sensitive to air pollution contributions from the Shell plant. For a map showing the locations of the monitors and links to real-time data for each monitor please see: http://pghaqmap.com/map/index.html#

Shell has obtained a temporary permit from PA DEP for the proposed/calculated/expected emissions into the air from the facility. This permit covers the period from design, construction and initial production. After startup, Shell must apply for a Title V (final) air permit to operate the facility. Shell may continue to operate using the temporary permit while the Title V permit is being evaluated by PA DEP. A Title V permit is valid for five years and then must be renewed. [For an in-depth discussion of the Title V permitting process, please see the "Title V, A Citizens' Guide to Stationary Source Permitting Process" published by the CleanAirCouncil, Philadelphia].

Since the Beaver County ethane cracker complex would be built in an air quality "nonattainment region", Shell is required to purchase emission reduction credits from other companies that have lowered their emissions below the regulated levels for their area/facility. These can include credits from coal plants or other companies that have already closed. Every ton of regulated pollutant that Shell is expected to emit in excess of the permitted level requires the purchase of an offsetting credit of 1.1 - 1.15 tons of each

regulated pollutant. Specifically, Shell is required to purchase for 115 tons/100 tons credits for volatile organic compounds (VOCs) and credits for 115 tons/100 tons of nitrogen oxides (NOx) and for 110 tons per 100 tons of particulate matter <2.5 micrometers in diameter(PM2.5). In 2017, Shell obtained permission from the DEP to substitute additional NOx credits when it was unable to secure enough of the less plentiful VOC credits. In addition the PA DEP, in the background information for the proposed air quality plan, states that Shell will also emit carbon monoxide (CO), particulate matter <10 microns in diameter (PM10), sulfur oxides (SOx), ammonia (NH3), hazardous air pollutants (HAPs) and carbon dioxide (CO2). Included in the emissions are the estimates for the four flares that are to be on-site. Flares are used to control operating pressures within the plant processes, to control quality and during plant upsets. The amount/level and composition of a flare emission is difficult to predict because the primary use is during an upset when the plant processes are not operating as intended/desired, making it very difficult to discuss the toxicological nature of the flare emission plume at any given time. A toxicology summary for the listed pollutants is found on page 33 of the Clean Air Council's "Health Impact Assessment of the Shell Chemical Appalachia Petrochemical Complex" (2014). Please note that the emissions values published by PA DEP in a May, 2015 Fact Sheet for the Proposed Air Quality Approval are different from the values on page 33 of the Clean Air Council report (which were taken from a 2014 US EPA Air Quality Plan application by Shell). The toxicological information is not dependent on the values.

University of Pittsburgh environmental and occupational health professor James Fabisiak is concerned that the Beaver County ethane cracker could erase the improvements in air quality that the Pittsburgh region has seen. Fabisiak likens the impact to that of adding an additional 36,000 cars here (2016). The plant would be the largest source of volatile organic compound (VOC) emissions in western Pennsylvania, at a projected 522 tons of VOC emissions per year, larger than Clairton Coke Works' 336 tons.

The Beaver County ethane cracker will also be a major source of greenhouse gasses that impact climate change. The DEP permit shows the Shell cracker is proposed to release 2,248,293 tons of CO2e yearly, estimated to be equivalent to putting 430,000 additional cars on the road annually (Mehalik, 2017).

In addition to needing to address possible air impacts, potential water impacts must also be considered. The Beaver County ethane cracker facility will use process water withdrawn from the Ohio River (33 - 50% of the zinc smelter use rate) and potable (drinking) water purchased for Center Township Water Authority. Most of the process water will be used to cool processes at the facility. Shell predicts about 80% of the process water will be lost to the atmosphere as steam. Sanitary wastewater would be treated by Center Township Sanitary Authority which operates under NPDES permit PA0037940. Less waste water will be generated after plant construction is complete so that Potter Township customers could use Center Township Sanitary Authority if Potter Township wishes to enter into an agreement with the Authority. The facility site plan has a wastewater treatment plant which requires a NPDES permit for operation. A permanent storm water management system will be installed. In 2017, the DEP approved the granting of an NPDES wastewater permit to Shell, allowing construction of the plant to go forward. There were questions raised in prior testimony to the DEP about letting Shell apply as an amended extension of the now-demolished Horsehead zinc smelter's permit, which pre-dated the more stringent environmental limits put into place in 2010, rather than applying as a new facility.

Questions have also been raised by citizen groups about the nearby Ambridge Reservoir and surrounding watershed, and the various pipelines feeding the cracker plant and other unconventional natural gas-related infrastructure. The Ambridge Water Authority has developed a Source Water Protection Plan for the reservoir and its watershed.

To provide enough flat land at the plant site, Shell has built culverts to contain Rag Run and Poorhouse Run. To offset the impact of these actions Shell is required to restore and enhance about 58 acres tract of the South Fork of Cross Creek by 1) removing invasive species and restore native species, 2)

improve/increase wildlife and fish habitat, 3) restore degraded streams/reduce bank erosion/improve aquatic habitat and 4) reestablish floodplain wetlands.

To mitigate the effects of spilled polyethylene pellets Shell plans to implement the guidelines from Operation Clean Sweep® to reduce loss of pellets from the facility into the environment (www.opcleansweep.org). Shell also will use dust control measures on the roadways and during the construction phase to "keep the dust down". No other mention of solid waste disposal methods is provided.

To improve traffic flow near the plant site, Shell has relocated and widened PA Rt. 18 and improved the Rt. 18 – I-376 interchange. The old interchange had turns that were so tight that trucks had a tendency to tip over. Since the Shell facility is on both sides of Rt. 18, Shell has built a bridge over Rt. 18 so that intra-plant traffic will not need to cross Rt. 18 with a “grade level” intersection.

The Beaver County ethane cracker complex will produce noise and light beyond the levels of the empty, shutdown zinc smelter plant. The levels will depend on point of observation, proximity, how high above the plant, in the daytime or at night. Shell will use "noise suppression" technologies and equipment. Lighting is required for nighttime safety, security and operations.

Interestingly, Reuters in September 2020 reported that Shell has embarked on a cost-cutting review, dubbed internally as Project ReShape, to cut 40% off the cost of producing gas and oil in order to focus more on renewable energy and power. Deep cuts are also planned for Shell’s LNG operations.

In addition to the ethane cracker in Beaver County north of Pittsburgh, two additional ethane crackers (total of three) are in some stage of proposal/development in the Ohio River basin. Each and all of these crackers could create petrochemical complexes in the Ohio River Basin region, and with these complexes additional, new cumulative risks and health impacts.

The First Energy’s old, idle R.E. Burger coal-fired power plant in Dilles Bottom, Mead Township, Belmont County, Ohio has been demolished by First Energy and the site completely cleared. On June 8, 2017 PTT Global Chemical America (PTTGCA) purchased this site from First Energy. The PTTGCA plant is expected to crack ethane to ethylene which would be polymerized to produce both high density polyethylene and linear low density polyethylene for shipment to their customers. There may be about 6000 jobs for the construction phase and 500 permanent jobs at the plant. PTTGCA now owns more than 500 acres in Belmont County which includes a former coal mine, a former sand and gravel quarry, and a closed asphalt plant. PTTGCA is clearing commercially valuable trees with diameters 3” or greater, from the site. PTTGCA is reported to be buying homes “close to the site.” Site preparation and transfer to PTTGCA work was facilitated by grants totaling about $50 million from JobsOhio. In March 2018, PTTGCA introduced Daelim, a major Korean engineering, procurement and construction company, as a partner in the project for the facility design/evaluation and securing funding for the project. On June 25, 2019, Bechtel, along with its partner Samsung, announced that they had been awarded the engineering, procurement and construction (EPC) contract for the PTTGCA plant. Bechtel is also the EPC company for the Shell plant in Beaver County. Therefore, as work is completed on the Shell plant, Bechtel could move its assets and labor force to the PTTGCA site. PTTGCA has signed a Memorandum of Understanding with JobsOhio to “jointly establish a community infrastructure development plan to enhance the well-being and quality of life for the communities in the area surrounding PTTGC America’s planned petrochemical complex in Belmont County, Ohio, after the Final Investment Decision” (Funk, 2017). In May 2018, PTTGCA/Daelim published statements committing to the protection of land, natural resources and local history, water quality and air quality. The Ohio Environmental Protection Agency has issued two key permits for the proposed petrochemical complex in Belmont County: on December 21, 2018 the air permit http://pttgcbelmontcountyoh.com/wp-content/uploads/2018/12/PTT-Air-Issued.pdf and on December 27, 2018, the modified water permit http://pttgcbelmontcountyoh.com/wp-content/uploads/2018/12/PTT-NPDES-mod-issued.pdf. In 2020, PTTGCA declared that the first phase of

site preparation, engineering and design work was complete. Therefore, activity at the potential cracker site would be reduced for the next two-three months, which coincided with the beginning of the COVID-19 shutdown. In June 2020, PTTGCA postponed "the final decision to invest" for 6-9 months, possibly into 2021. Citing low "gas and plastic prices" plus the uncertainties of the COVID-19 pandemic, Daelim withdrew from the project (WTOV9 July 14 2020). But PTTGCA signed an agreement with the Mountaineer NGL gas storage facility to store ethane in this salt dome which is about 8 miles south of the plant site. PTTGCA also signed a "long term" ethane supply agreement with Range Resources for 15,000 barrels a day (*Times Leader* September 24, 2020). For additional/current detail on the PTTGCA status please see the company's web site for this project: http://pttgcbelmontcountyoh.com/.

Municipalities near the PTTGCA site want to upgrade underground water and sewer facilities so the right infrastructure will be in place for the plant and the people it would bring in. Colleges in the area, such as Belmont College and West Virginia Northern Community College, are starting programs to help local residents find jobs at the site.

The Ohio Department of Development proposed an Ohio Enterprise Zone program for the PTTGCA site which would provide a 15-year property tax exemption. The Shadyside school district, Mead Township and Belmont County accepted and approved this enterprise zone. Over the 15 year life of the zone, the school district would receive $38 million, the township 9.5 million, and the county $20-24 million (*Design and Development Today*, Mark Gillespie, AP, March 26, 2020).

PTTGCA demonstrated a willingness to work with local public interest groups and environmental organizations by signing onto two agreements. One dealt with plant operations – enhanced stack monitoring, leak detection and routine maintenance work, plus, transparency in PTTGCA's reports to the Ohio environmental protection department. In the other agreement, PTTGCA presented strategies more commonly used in Thailand that would be implemented in Dilles Bottom that go beyond the legal requirements. For example, "upcycling plastic waste" into products of greater value, increasing the use of recyclable and renewable materials, reducing greenhouse gasses by capturing carbon dioxide to produce sodium carbonate, and establishing community waste banks to serve as a model of waste management. (*Times Leader* February 4, 2020).

Braskem, a Brazilian company, announced plans to build ethane crackers in Wood County (Parkersburg), West Virginia. In July 2019, Braskem no longer had an interest in building cracker plants in West Virginia. Braskem would like to sell the recently purchased former SABIC plant south of Parkersburg, WV. In 1988 Braskem began production of polypropylene at its Neal production facility in Kenova WV. Current production level at this plant is reported to be 500 million lbs/year. In La Port, Texas, in March 2017, Braskem began production of "ultra high molecular weight" polyethylene and in June 2018 began production of the "largest polypropylene plant" in the U.S. Note that in Brazil, Braskem produces polyethylene from ethylene that is derived from sugarcane-based ethanol (see http://www.braskem.com.br/usa and http://plasticoverde.braskem.com/br/site.aspx/plastic-green).

In 2014, Appalachian Resins leased about 50 acres of land near Clarington in Salem Township, Monroe County, Ohio, which is on the Ohio River. It is the next county south of the PTTGCA proposed plant. The facility would crack ethane to ethylene which would be converted to polyethylene for shipment to customers. This plant might employ as many as 1,800 construction workers and a maximum of 300 employees, a smaller plant than others proposed for the Upper Ohio Valley. In 2015, Appalachian Resins put the project on hold, reportedly because at the time it was perceived as too difficult to find enough qualified people to build and staff the facility, in addition to two other ethane crackers in the region (Veazey, 2015).

Aither Chemicals had announced plans/interest to use Marcellus/Utica shale gas. In 2015 Aither Chemicals was reported to be "out of business" by *Pitchbook Platform*, but Aither Chemicals is still listed by Dunn & Bradstreet with a "poor" rating.

In October 2019 ExxonMobil was rumored to be interested, scouting for locations to build a cracker plant either in the Pittsburgh or Philadelphia regions. But in September 2020 "Exxon said unequivocally they have no active plans for such a facility in the Keystone state" (*Marcellus Drilling News*). Note: this does not rule out inactive plans on the shelf for future reconsideration.

Eduardo (Jay) Olaguer and HARC research colleagues have studied the emissions of benzene and other toxics exposures (BEE-TEX) in Houston's Ship Channel. Olaguer and his colleagues (2016) have developed new approaches to addressing the health risks of ethane cracker and other petrochemical emissions by working with citizens in fence-line communities to better measure and monitor the pollution.

Some regional planners and civic leaders look forward to these complexes creating economic opportunity. Speaking at the Marcellus Shale Coalition's 2015 conference, Pennsylvania House Speaker Mike Turzai announced the GOP's plans to create "Keystone Energy Zones" offering tax breaks to provide incentives to manufacturers that use natural gas as an energy source or "to put in manufacturing facilities that would utilize natural gas as a feedstock for other products." In 2019, Pennsylvania HB1100, incentivizing the use of natural gas, passed and was sent to the PA Senate. It has been reported (Stephan 2016) that "local administrations have granted Shell strong support and financial incentives, including a massive tax credit of 5 cents/gallon (corresponding to $2.10/barrel) of ethane used to produce ethylene until 2042. Local experts estimate that Shell could save up to 20% in taxes in Pennsylvania through this credit." Tax breaks for four manufacturing facilities were included in a fiscal code bill, HB 732, which was signed in the Pennsylvania House July 14, 2020 and in the PA Senate July 15, 2020, and was approved by Governor Wolf on July 23.

TEAM PA, a public-private partnership that works closely with the PA Department of Economic Development, commissioned IHS Markit to conduct research, and released in March 2017 a glowing report on the economic potential for petrochemical development.

Ethane storage capacity would need to be developed to secure the future of petrochemical development in the region. Brian Anderson, Director of the National Energy Technology Laboratory, and researchers at the WVU Energy Institute have identified several geological formations in the region that are favorable for the storage of ethane (Junkins, 2017). Senator Shelley Moore Capito of West Virginia introduced a bill in 2017 to study the proposed Appalachian Storage Hub.

The governors of Pennsylvania, Ohio and West Virginia have met to plan collaboration on what the petrochemical industry has dubbed the "Shale Crescent." In September 2017 it was reported that about 460,000 barrels of ethane per day are currently being produced in the Pennsylvania-Ohio-West Virginia region. This is almost three times the amount of total/combined ethane expected to be used per day at the Royal Dutch Shell ethane cracker set for Beaver County, Pa., plus the amount to be used by the potential PTT Global Chemical America cracker at Dilles Bottom (Junkins, 2017). The amount of ethane being produced from southwest PA wells may also be enough to support additional ethane cracker and petrochemical plants in Philadelphia.

These studies and business-boosting efforts focus on geologic and economic potential, not health impacts. All of this comes at a time when plastics, especially single use plastics such as bags and straws, are under increasing scrutiny, in the U.S. and especially internationally. The Center for International Environmental Law's (CIEL) white paper (2018) explores human health impacts across the entire life-cycle of plastics, from extraction of fossil fuels at the gas wellhead, transport of those fuels to industrial plants to be transformed into plastic polymers, to the manufacturing and use of plastic products, to their disposal and persistence in the environment. According to report author, Giulia Carlini, the report details how polymers themselves and the hazardous additives to the virgin plastic can disrupt important physiological functions, particularly as endocrine disruptors. Later on, in disposal, plastics fragment into tiny particles, entering our water, air, and the food chain, and ending up in our bodies. A 2019 report released by CIEL, "Plastic and Climate," explores the climate change impacts of extracting materials for, producing, using, and disposing of plastics.

Methanol Production

Methane is the most abundant component of shale gas. Manufacturing processes based on methane as a starting raw material would be expected to be developed in the Upper Ohio Valley region.

Methanol (CH3OH) can be manufactured from methane (CH4) or natural gas. Usually, the process involves four steps. Methane from natural gas/shale gas is heated to remove sulfur compounds. Next, the heated gas is mixed with steam at high temperature and high-pressure and passed through tubular reactors containing nickel catalyst to produce synthetic gas (syngas) which is a mixture of hydrogen, carbon monoxide and carbon dioxide. In the third step the syngas is passed over another catalytic bed, usually copper-based, to produce crude methanol. This step requires cooling as the reaction produces heat. In the fourth step the crude methanol is repeatedly distilled until the methanol meets the customer's quality specifications. The volatile material that distills off before the methanol, is used as some of the fuel in the syngas step. Water that distills off is used to produce the steam in the syngas step. The heavier materials (still bottoms) may be further purified to produce commercially valuable materials or may be used as fuel in the syngas step or may be disposed of in an on-site chemical waste facility. During start-up and in case of process over-pressure, emergency flares will be utilized. Methanol is shipped by barge, by rail car, by truck/tank wagon, by drum and in bottles for laboratory use.

Methanol is a liquid at room temperature (boiling point 148.3F/freezing point -143.7F). Methanol is flammable with an open cup flash point of 60.1F. Acute exposure of humans to methanol by inhalation or ingestion may result in vision disturbances, such as blurred or dimness of vision, leading to blindness. Neurological damage, specifically permanent motor dysfunction, may also result. Contact of skin with methanol can produce mild dermatitis in humans. Ingestion of "home brewed" ethanol/alcohol that is "tainted" with methanol has been reported to cause death.

Methanol is used as both a fuel, as a component of fuels and as a component of de-icers and antifreeze products. Methanol is also used to manufacture fuel additives (methyl *t*-butyl ether, methyl *t*-amyl ether). Methanol is used to manufacture pharmaceuticals, to make monomers in the plastics industry and as a "common" industrial solvent. Methanol is added to waste water at treatment facilities to de-toxify nitrates in the waste water flowing into the treatment facility.

US Methanol LLC was formed in 2016 to produce methanol from methane. The 220,000 tons/yr. "Liberty One" production plant is located on the Dow (formerly Union Carbide Corp.) site in Institute, WV. The plant is scheduled to start production during the fourth quarter of 2019. US Methanol is in the early developmental stages of a second methanol plant, the "Liberty Two", which is to be located in Belle, WV on an existing DuPont site and would produce 165,000 tons/yr. Both Institute and Belle are near Charleston, WV.

From US Methanol's submission to the West Virginia Dept. of Environmental Protection (WVDEP), the maximum quantities of pollutants "Liberty One" facility can emit:

CO	37.140 tons/yr.
Methanol	7.130 tons/yr.
PM10	3.830 tons/yr.
SO2	0.360 tons/yr.
VOC	14.050 tons/yr.
PM2.5	3.830 tons/yr.
Total particulate	3.830 tons/yr.
VHAP	7.990 tons/yr. (volatile hazardous air pollutants)
NOx	72.620 tons/yr.
CO2	63,636. tons/yr.

About one ton/yr. hexane and 1.4 tons/yr. pentane may be emitted. Most other organic hydrocarbons may be emitted at less than 0.001 ton/yr.

The final methanol product is shipped from "Liberty One" with a purity of 99.959% methanol, with 0.028% water and 0.013% ethanol.

If US Methanol has submitted permit requests for the construction and operation of "Liberty Two", the WVDEP has not published them in the dep.wv.gov/daq/Documents database as of Sept. 2019. Based on production volume, "Liberty Two" could be expected to emit about 75% of the materials from the "Liberty one" unit.

Primus Green Energy announced plans for a modular 64,250 tons/yr. methanol plant in Proctor, WV (near New Martinsville) on a Covestro (formerly Bayer) plant site. Primus plans to partner with Jereh Oil and Gas Engineering Corporation to implement the project. Production from the plant is to start in 2020. Primus Green Energy could add three additional methane to methanol modules at this site producing a total of about 257,000 tons/yr. of methanol. Primus Green Energy's mission/concept is to produce "small" manufacturing units that can be assembled in gas and oil fields to convert the natural gas that is currently flared off into methanol and to use similar technology in a second, different unit to produce gasoline. Even though both methanol and gasoline are flammable liquids, these liquids are easier to transport than natural gas and, depending on market conditions/pricing, may have higher market value.

From Primus Green Energy's submission to the WVDEP, the maximum quantities of pollutants the first modular unit of the facility can emit:

CO	33.16 tons/yr.
Methanol	2.42 tons/yr.
SO2	1.21 tons/yr.
VOC	12.20 tons/yr.
PM2.5	3.23 tons/yr.
PM10	3.23 tons/yr.
VHAP	6.96 tons/yr. (volatile hazardous air pollutants)
NOx	70.30 tons/yr.
CO2	130,854. tons/yr.

Each of the additional units could be expected to emit similar levels of materials or four times these levels for the entire methanol production site at Proctor, WV.

In comparison to a cracker plant each methanol unit does not produce large quantities of pollutants. But, the sum of all the methanol units does add to the already overburdened levels of air pollutants in a currently non-attainment air quality region.

During the debate in 2020 on HB 1100 (Energize Pennsylvania Initiative), it was rumored that Elis Energy is interested in building a methane-to-methanol plant in Northeastern Pennsylvania, perhaps Luzerne County (February 6, 2020 Consumer Energy Alliance).

Any "good" source of methane can be a site for a plant to convert methane to methanol. For example, in Oregon, Ohio, an industrial suburb of Toledo, Interstate Chemical Company subsidiary Alpont LLC is building a methanol plant next to a high-pressure gas pipeline. Alpont's customers are in the greater Toledo area.

Liquefied Natural Gas (LNG)

No chemical reactions occur during the conversion of "raw" well-head natural gas from to LNG. The function of the liquification process is to purify the well-head gas to commercially desired products. In northeast Pennsylvania methane is usually the only material from the purification process. In southwestern Pennsylvania, depending on the composition of the well-head gas; methane, ethane, propane, butane and other hydrocarbons are the usual materials separated from the well-head gas during the purification process. The process used depends on the composition of the well-head gas. In general, the separation/purification processes involve:

1) Mercury removal - the well-head gas may contain 0.05 ppb by volume mercury which is removed by a catalytic process, molecular sieves or activated carbon.
2) Carbon dioxide and hydrogen sulfide removal – absorption either by amine solution or membrane separation. The amine solutions are recovered/regenerated by steam distillation. If the sulfide content is high enough, the sulfide is recovered either as elemental sulfur or as sulfuric acid solutions.
3) Dehydration – water vapor is removed by passing the gas stream through molecular sieves designed for this specific purpose. The "wet" sieves are regenerated by passing hot dry waste gas through the sieve and cooling the gas to condense the water. The waste gas is burned to provide heat sources for all the processes.
4) The dry gas stream is chilled to condense/remove the "higher" boiling materials such as butane, benzene, pentane, hexane, toluene
5) The chilled gas stream is cryogenically cooled to below -260F to liquify the gas. The liquefied gas is cryogenically distilled to separate the commercially viable material in the liquid. Boiling points in deg. F are:

   Methane -263/264
   Ethane -128/129
   Propane -43/44
   Butane +30

6) Each product, methane, ethane, propane etc. is stored in insulated tanks capable of withstanding the pressure of the product at liquified temperature.
7) Each liquified product may be shipped by pipeline, truck/tank wagon, railcar or barge/ship.

Each facility has/uses safety pressure relief flares.

Based on the December 2018 application, the Bradford County Real Estate Partners LLC natural gas processing plant in Wyalusing Township, Bradford County, Pennsylvania may emit ("potential emissions") the following maximum emissions from the entire site:

Pollutant	**Tons Per Year**
Nitrogen oxides (NOx)	100
Carbon monoxide	88
VOC	49
PM10/PM2.5	100
Sulfur Oxides (SOx)	84
Green House Gases (CO2)	1,108,111
Ammonia	91
Hazardous Air Pollutants	16
Sulfuric acid	26

The major components of the hazardous air pollutants are:

formaldehyde 4.6 tons/year
hexane 1.1 tons/year

(Page 38 from New Fortress Energy LNG Plant Plan Approval Application (December 2018))

Compressor Station

No chemical reactions occur as the gas passes through a compressor station. Compressor stations are required to provide pressure to the gas as the gas leaves the well-head and to maintain pressure along the length of a pipeline. As natural gas moves through a pipeline, distance, friction of the gas flow, and elevation differences reduce line pressure which may reduce or slow the flow of the gas through the line. A "typical" compressor station may have filter/separator/scrubber to remove liquids from the gas stream, especially if the compressor is the first station after the gas leaves the well. The gas then goes to/though a compressor. Compressing the gas heats the gas about 7 – 8 degrees for each pressure increase of 100 psi. The heated, compressed gas goes through an air-cooled cooling unit. Most compressor stations have an air-cooled lubrication system to lubricate the "moving parts" of the station. Most stations are computer monitored remotely. Power is supplied by burning natural gas. For example:

Adelphia Pipeline Company
Quakertown Compressor Station (Bucks Co.)

Pollutant	**Tones Per Year**
PM10	1.92
PM2.5	1.92
SO2	0.11
CO	11.15
NOx	17.15
VOC	19.93
CO2e	33,905.

US EPA Definition: Carbon dioxide equivalent or CO2e means the number of tons of CO2 emissions with the same global warming potential as one ton of another greenhouse gas, and is calculated using Equation A-1 in 40 CFR Part 98. (CFR = Code of Federal Regulations)

Laurel Mountain Midstream LLC
Shamrock Compressor Station (German Township, Fayette Co.)

Pollutant	**Tones Per Year**
NOx	85.0
CO	77.0
VOC	33.0
Hazardous Air Pollutants	10.0
PM10	16.0
Formaldehyde	6.4

For additional general information on compressor stations see the Penn State ref:
https://extension.psu.edu/understanding-natural-gas-compressor-stations

Quakertown compressor station see: **the proposed quakertown compressor station**

Shamrock compressor station see: Laurel Mountain Midstream, LLC – Shamrock Compressor Station

Final Air Quality Plan Approval (PDF)

Compressor stations' health impacts have been studied less that the health outcomes of fracking wells. Hendryx and Luo (2020) did a county-level ecological study using volatile organic compound (VOC) emissions data from the 2017 National Emissions Inventory, looking at age-adjusted mortality data from the CDC, and covariates such as race, education, poverty, urbanicity, obesity, smoking, from the County Health Rankings data. Results show that total age-adjusted mortality was significantly higher in association with larger non-methane VOCs emissions from compressor stations. Twelve individual VOCs were also related to significantly higher mortality. The "results provide preliminary evidence that compressor stations along natural gas pipelines are sources of pollutant exposure that may contribute to adverse human health outcomes."

RESPONSE AT THE STATE LEVEL

Marcellus Shale Advisory Commission

The Constitution of the Commonwealth of Pennsylvania states: "The people have a right to clean air, pure water, and to the preservation of the natural, scenic, historic and esthetic values of the environment. Pennsylvania's public natural resources are the common property of all the people, including generations yet to come. As trustee of these resources, the Commonwealth shall conserve and maintain them for the benefit of all the people" (Article I, Section 27).

With the advent of large-scale unconventional gas extraction, the rights guaranteed in the Constitution are relevant to new legislation governing shale gas extraction in Pennsylvania. In 2012, Governor Corbett signed Act 13, a bill which imposed an impact fee and set forth safety standards. In addition, the bill also contained language that impacts the role of municipalities to regulate natural gas operations through local zoning and ordinances. Because public health decisions depend on local monitoring and often require local action, these limitations could, if enacted, restrict the ability of local public officials, including public health professionals, to respond to community concerns. However, in December 2013 the Pennsylvania Supreme Court ruled that Act 13 put municipalities in conflict with their constitutional responsibility under the Pennsylvania Constitution's "Environmental Rights Amendment" (Article 1 Section 27). The Pennsylvania Supreme Court agreed that Section 3303 of Act 13 (excluding municipal regulation of oil and gas ordinances) and Section 3304 (requiring uniformity of local zoning ordinances) were unconstitutional. In this *Robinson Township* decision, the significance of the "Environmental Rights Amendment" for promoting "environmental constitutionalism," has been described by Derndach (2014) as having the potential to affect cases in "other states and countries.".

In 2011, the Governor established a 31-member Marcellus Shale Advisory Commission by Executive Order. The document states: "The Commonwealth takes seriously its responsibility to ensure the development of gas in a manner that protects the environment and safeguards the health and welfare of its citizens." Within the commission, one of the four groups was specifically tasked with "the enhancement of public health and safety." Yet, according to a published document, none of the 42 members of the Advisory Commission had recognized expertise in environmental public health. Indeed, the researcher concluded that "despite recognition of the environmental public health concerns related to drilling in the Marcellus Shale, neither state nor national advisory committees selected to respond to these concerns contained a recognizable environmental public health expert" (Goldstein, 2012).

Nevertheless, the Governor's Advisory Commission called on the Pennsylvania Department of Health to make recommendations regarding its projected role in protecting public health in affected areas. Its recommendations include: 1) routine evaluations of environmental data collected from a variety of government, industry and academic partners; 2) the establishment of a population-based health registry; 3) a system for "timely and thorough investigation of complaints;" and 4) educational programs about potential impacts on health.

Adding to these responsibilities, in October 2012, Senator Joe Scarnati (R-Jefferson) introduced Senate Bill 1616 establishing a permanent Marcellus Shale Health Advisory Panel as recommended by the Governor's Advisory Commission. As chair of the 9-member panel, the Secretary of Health would be responsible for overseeing a variety of activities, including investigating advancements in science, technology and public health data and providing information, analysis and recommendations to Pennsylvania elected officials, regulators and the general public. Although SB1616 did not pass, Senator Scarnati introduced a bill proposing a similar nine-member panel, SB375, in February 2015. No funding was included in the budgets under the previous governor to establish a health registry. The new Governor Tom Wolf did include funding for the health registry in his budget and $100,000 has gone to the PA Department of Health. At $100,000 it does not begin to cover the estimated expenses of fully implementing such a registry, but it provides seed money to plan the establishment of a health registry.

A white paper from the Southwest Pennsylvania Environmental Health Project (2015) defines a health registry as an organized "dataset of information about individuals collected in a systematic and comprehensive way" that can "shed light on an incompletely understood …constellation of health conditions" to better define "associations between environmental exposures and adverse health events." Over time, the registry can monitor incidence and prevalence of symptoms, detect patterns, serve as a warning system, inform patient treatment and help guide policy and regulations. The paper describes various types of health registries that have been set up in the past (e.g. of Gulf War veterans), and presents a set of questions to consider in devising Pennsylvania's health registry. In 2017, the SWPA Environmental Health Project went ahead and launched its own health registry, which is enrolling participants not only from Pennsylvania but from across the U.S. who register online at http://www.environmentalhealthproject.org/health-effect-registry Healthy people may also register and have their health tracked over time.

In March 2017, the Pennsylvania Department of Health launched a new electronic unconventional oil and natural gas health complaint registry, which may be the only registry in the country to track health complaints related specifically to unconventional operations (Colorado's health complaint registry database deals with oil and gas generally).

State Agencies Responsible for Public Health

Because oversight of the gas industry has been left to the states in so many instances, it is particularly important for citizens to be informed about these agencies. Evidence shows that the role of Pennsylvania's Department of Health as an effective citizen advocate in regard to the Marcellus Shale industry is seriously undermined due to structural impediments and lack of funding, Thus the first line of defense is left to other agencies, primarily the PA Department of Environmental Protection (DEP).

Pennsylvania's **Department of Health** would be the obvious key player in safeguarding the public, but even before fracking became a hot issue, the department received low grades, characterized as under-funded and understaffed. The University of Pittsburgh's Associate Dean of Public Health Practice found that while public health entities exist at every level of government, "respective sources of authority are distributed among various departments without coordinated oversight and accountability among numerous agencies" (Potter, 2008). Furthermore, Pennsylvania has ranked 50th in the number of public health workers per citizen, with 37 workers per 100,000 citizens, compared to a national average of 158/100,000 (Goldstein, 2011).

Public health officials had expected to get a share of the revenue being generated by the state's new Marcellus Shale impact fee to undertake the new responsibilities. But representatives from Governor Tom Corbett's office and the state Senate cut the health appropriation to zero during final negotiations. As a result, the Department of Health was left with a new workload but no funding for it. SB790, introduced in 2013, would have directed $3 million from the natural gas impact fee to the health department to create a public health registry and study air quality and health impacts (O'Connell, 2014). Health clinics, a

resource for many uninsured people in areas where shale gas drilling is occurring, have also been subject to financial cuts. However, the Pennsylvania Supreme Court placed a temporarily injunction on further health center closings in 2013 (Giammarise, 2013). All 26 nurses whose positions had been furloughed dating back to 2013 were re-instated in 2015.

The neighboring state of Maryland has taken a different approach. Through an executive order from the Governor of Maryland, the Maryland Department of Health commissioned the University of Maryland School of Public Health to conduct an extensive health impact assessment of potential health impacts if drilling were to take place in the state. The report researched a wide variety of factors, did a "scoping" of community concerns, took baseline measurements, and issued "hazard ranks" for the different factors, with air quality, public safety, and occupational health ranking "high." The state of Maryland posted links to the report on its website (2014). Maryland banned fracking in 2017.

Despite staff cuts, the DOH does log complaints related to natural gas development, as does the state Department of Environmental Protection. (According to a State Impact report, only two other states -- Colorado and N. Dakota -- maintain a database of complaints.) A 2014 report indicated that the Pennsylvania Department of Health logged 57 complaints since 2011 (Colaneri, 2014). The DOH came under scrutiny in 2014 when two retired employees claimed that they were expected to follow special procedures when a caller brought up certain subjects, including fracking (Colaneri, 2014). An August 2014 letter, signed by over 400 health professionals in Pennsylvania, called for investigations into past operations. The letter also asks for implementation of new guidelines and reforms such as establishing a registry of all calls and health concerns, and making this information accessible to the public (Garber, 2014). The Health Department is currently implementing changes in procedures. While budgetary constraints limit the ability of the PA DOH to track over time the health of residents who live near unconventional gas operations through a population-based registry, as of 2017 the agency is tracking health complaints through its newly launched electronic unconventional oil and natural gas development health complaint registry.

The Pennsylvania Department of Health has come under criticism in 2019 from residents of Washington County, for determining that local cases of the rare childhood bone cancer Ewing sarcoma do not constitute a cancer cluster. In the Canon-McMillan school district *Pittsburgh Post-Gazette* reporters David Templeton and Don Hopey, in an in-depth investigation, identified six cases. Note that only 250 cases are reported annually in the U.S. Residents suspect pollution from shale gas development may be causing these and other rare cancers affecting youth in the area. The PA DOH also confirmed 12 cases since 2011 in nearby Westmoreland County, which has also experienced shale gas development, but did not classify that as a cluster either. In November 2019, following appeals by visiting cancer patients and their families confronting the Governor, Governor Wolf announced a $3 million pair of studies to research the health impacts of shale gas development. Each study will take three years. One of the studies will try to reproduce some of the Geisinger epidemiological research findings, particularly regarding childhood asthma. The other study will look specifically at the relationship between fracking and childhood cancer.

Most citizen complaints appear to be handled by the **Department of Environmental Protection** (PA DEP), the state's primary enforcement agency regarding regulation of water and air quality which is responsible for enforcing the state's Oil and Gas Act. Impacts on water quality are also monitored by the **Pennsylvania Fish and Boat Commission, the Susquehanna River Basin Commission [SRBC], the Delaware River Basin Commission (DRBC), and the U.S. Fish and Wildlife Service (**LWV Study Guide V).

The Delaware River Basin Commission is made up of commissioners representing the governors of Pennsylvania, New York, Delaware and New Jersey, plus representation from the Army Corps of Engineers at the federal level. On September 13, 2017, the Commission voted 3-1-1 to approve a resolution starting a process of a permanent ban on fracking in the watershed. The resolution, which is supported by Governor Wolf, would apply to Wayne and Pike counties in Pennsylvania. A proposal

which must be delivered by November 30, 2017, was open to a public comment process, with a vote thought to be likely in 2018. After a period of public comment, as of fall 2019 the DRBC was still reviewing comments and no time frame for a vote had been set up yet, despite support for the ban by the governors of Pennsylvania, New York and Delaware. In May 2020, The Natural Resources Defense Council (NRDC) filed a brief to support the de facto fracking ban and oppose Wayne Land and Mineral Group suing the DRBC. In September, the DRBC voted to delay the decision on the New Fortress Gibbstown liquefied gas export terminal (Food & Water Watch, September 10, 2020).

In 2013, the Pennsylvania DEP was funded at $135 million dollars, supplemented by $215 million in federal dollars. These funds were used to operate its 24 regional and district offices and eighty well inspectors employed by the DEP's Bureau of Oil and Gas Management. Funding steadily decreased during the Corbett administration. (State Impact Topics, n.d.) According to former DEP Secretary John Quigley, the DEP's staff has been reduced by 14 % over the past decade (compared to a 6% loss on average for other departments), and 671 staff positions were cut, including 411 permit reviewers and field inspectors. In 2014, DEP did quadruple the size of its enforcement staff to 130 employees, 65 of whom are inspectors. New threats to funding for DEP staffing emerged in 2017 – anticipated budget cuts at the federal level, and, as part of a struggle to fund Pennsylvania's budget, a plan to privatize some of the DEP's functions, which would be likely to make it easier for industry to obtain permits. In early 2018, under the Wolf administration, the PA DEP budget was about $149 million, with the total across all funds including federal funds, $722 million. In 2005, the DEP had a total of 3,132 full-time employees. In early 2018, that number was 2,461 (McKelvey, 2018).

Discrepancies in reporting of drilling waste have also been uncovered (Litvak & Radwin, 2014). For example, one Pittsburgh-based company told the DEP that it sent 21 tons of drill cuttings from its shale wells to area landfills in 2013; but landfill records reported receiving 95,000 tons of drill cuttings and fracking fluid in the same year. The DEP is now investigating cases of alleged under-reporting.

The state of Pennsylvania codified an inspections policy for oil and gas wells in 1989. Among other things, it states that a well must be inspected seven times before gas can be produced and at least once a year after the well has begun producing. An Earthworks analysis of state enforcement data claims that thousands of wells are not being inspected. The state claims these are mainly older wells (Begos, 2012). Pennsylvania now has an accessible on-line database of interactive reports showing production information, permits issued, drilling commence dates, operator specific data, and inspections, violations and enforcement actions.

The citizens' role in enforcement would be considerably enhanced if the public had access to more information. Operators must disclose information on chemical usage in "well completion reports" that are filed with the state Department of Environmental Protection. Operators have also been required to release this information to FracFocus.org, an on-line database which is maintained by the Ground Water Protection Council and the Interstate Oil and Gas Compact Commission. FracFocus has become a national clearinghouse for chemical information related to fracking, despite certain technical limitations which limit its usefulness (Colaneri, August 2013). However, both the state and FracFocus make exemptions for chemicals deemed proprietary, or "trade secrets."

Another government function is to follow up on citizen complaints and to issue stays and/or fines for violations by the oil and gas operators. According to the Earthworks report, citizen complaints were responsible for 2,890 oil and gas inspections between 2007 and 2011, and violations were found in over 700 cases. Earthworks found however, that these violations were not necessarily followed by enforcement action (Baizel, 2012). An investigation by the office of the PA Auditor General, confirmed the findings of the Earthworks report and made recommendations for change.

In 2013, the Auditor General conducted a performance audit, which analyzed over 2,000 citizen complaints pertaining to water quality over the past five years. DEP's response to complaints was considered inadequate and the system for recording complaints was in disrepair. Not only did the DEP consistently fail to issue orders to well operators who had been determined to have contaminated water supplies, it also did a poor job in communicating the results of its investigation to citizens who had registered complaints. Furthermore, the agency did not always meet statutory timeframes for responding to citizen complaints (PA Department of the Auditor General, 2014).

In 2020, Pennsylvania Attorney General Josh Shapiro released a report on a two-year grand jury investigation of operations, regulations, and compliance, detailing Pennsylvania's "failure" of the state environmental and health departments to regulate shale gas development. These failures go back years, and while some progress has been made, there is still room for improvement. "There remains a profound gap between our constitutional mandate for clean air and pure water, and the realities of Pennsylvanians who live in the shadows of fracking giants and their investors." Shapiro spoke about residents who testified that their water has become "black sludge" and caused breathing problems when in the shower, and others testified that their air had become so polluted with emissions from the drilling pad that they could not leave their windows open or let their children play outside. Parents told of children waking in the night with severe nosebleeds. The grand jury took 287 hours of testimony from people living in rural areas and government officials.

The grand jury's report puts forth recommendations including expanding the minimum setback distance from homes to 2,500 feet (compared to the current 500 feet). Also recommended is making public all the fracking chemicals, and improving the disposal options for wastewater and solid wastes. The report recommends enacting strict regulations on gathering lines. The report calls for a full public health study about the impacts of shale gas operations (and one is currently underway at the state health department). The report also suggests that DEP employees should not have a revolving door into industry positions. It asks the DEP to stop relying only on civil penalties to address drilling violations, and have the Attorney General's office press criminal charges. The Attorney General also announced a phone and email hotline for reporting suspected violations: **(507) 904-2643**; fracking@attorneygeneral.gov.

U.S. EPA Clean Air Standards are monitored by the **DEP's Bureau of Air Quality**. One of the things DEP is tasked with is developing ways of implementing the federal Clean Power Plan regulating emissions from coal power plants. Because the state is out of compliance with the federal standards, the Bureau prepares a "state plan" demonstrating how the state will improve air quality. Using information which anticipates increases in natural gas drilling, the Bureau can influence drilling/production activity, and the placement of air quality monitors. According to Arlene Shulman, the head of the Air Resources Management in the Bureau of Air Quality, the state essentially determines the "when, where, and how" of future drilling (Shulman, 2011). The DEP is conducting a long-term study of ambient air quality in Washington County. With the 2017 announcement that the EPA intends to withdraw the Clean Power Plan, the state of Pennsylvania is under less pressure from the federal government to improve air quality.

The **Department of Economic Development** was granted a regulatory role when Governor Corbett allowed the Department Secretary to overturn permitting on the basis of economic need. The important role of economic development and its relationship to health concerns is clearly indicated in this decision.

The winds shifted somewhat in 2015, with the election of a new governor, Tom Wolf, and changes in the Governor's cabinet. One major change was when Governor Wolf tried to pass a shale gas severance tax (as is common in other shale gas-producing states). This tax was resisted in the Legislature by the other party, which argued that such a tax would reduce profitability and drive shale gas operations out of the state. One of Governor Wolf's first acts upon taking office was to ban new oil and gas leases in state parks and forests. The Department of Health and the DEP continue the work that started late in the previous administration on instituting better data collection and better follow-up to citizen reports and complaints. The DEP is working on getting improved reporting of all emissions – including leaks – at oil and gas sites.

In 2016, after working on this for five years, the DEP passed Chapter 78a, new rules governing drilling and hydraulic fracturing. This revision only covers unconventional wells (not conventional wells). The new rules allow the DEP to require additional measures to protect school property and playgrounds, parks and other public resources. There are better procedures to identify abandoned wells, the required closing or rebuilding of fluid impoundments, and stricter standards for processing solid waste. The rules increase the frequency of required waste reports from twice-yearly to monthly. If water supplies are degraded, operators must better restore drinking water. Operators will now have to file electronically, rather than on paper, in order to better track and monitor unconventional gas operations and to make drilling data more available to the public. The stricter laws went into effect on October 8, 2016. Five days later, the Marcellus Shale Coalition industry group filed suit asking Commonwealth Court to halt implementation of parts of the new rules (Legere, 2016). In August 2017, the DEP notice in the *Pennsylvania Bulletin* announced that the DEP will wait until the third quarter of 2018 to introduce a revised package of updated regulations for conventional oil and gas operators (Cusick). HB 2154 was introduced in the 2018 Pennsylvania legislative session but did not pass before the October close of session. In 2019, SB790 passed the PA Senate 26-23. These bills would roll back environmental protections for conventional oil and gas operations that were set forth in 2012 in Act 13, back to (and even weaker than, in the eyes of some) 1984 regulations.

The Pennsylvania DEP's Office of Environmental Justice, established in 2002 but minimally staffed in recent years, appointed a new director and set up "a mandate to review, for the first time, shale gas facilities that could increase the health and environmental risks in poor and minority communities" (Hopey, 2015). The office held a series of public listening sessions in local Environmental Justice communities in 2017.

One area that laws address is required setback distances for shale gas operations, from streams, residences, schools and the like. A Delphi study conducted by the SWPA-Environmental Health Project found that the 89% of the scientists, public health and medical professionals participating in the study favored a setback from places where people live, work or play of no less than one-quarter mile – and 50% favored at least a mile (SWPA-EHP, 2016). Another study found that setback distance requirements have usually been the product of political negotiations, rather than being based on information regarding risk of health impacts at given distances (Haley et al., 2016).

In their survey of shale-related environmental literature and study of West Virginia well sites, Ziemkiewicz, Quaranta and McCawley (2014) found that "construction practices, inspection and enforcement lagged." Among their recommendations to address these deficiencies are better training for industry and field inspectors; requiring specific waste transportation plans as part of the permitting process; continuous monitoring of air, noise and other factors; "performance-based regulatory approaches;" and "regulation focusing on established best industry practices combined with diligent enforcement on the part of the designated regulatory agencies." These recommendations could spur improvements in Pennsylvania, as well.

CODA

This resource guide has discussed some of the major issues and key research studies relevant to shale gas development and public health. It is by no means exhaustive. Much of the research has been conducted only recently. As with all research, there is a critique process within the academic world. Those who conduct research try to improve upon gaps in previous studies. Research becomes even more controversial as applied to the topic of shale gas development and public health because of the economic development issues and interests involved, and because the industry is developing at a rapid pace. Fortunately, research is a cumulative process, with new studies building on those previously conducted. Evidence from public health research is leading to more protective regulations and practices. Forthcoming research will shed more light on the health impacts of shale gas development, providing insights to help develop treatment protocols for patients, and informing the continuing refinement of shale industry practices.

REFERENCES

Adams, M.B. (2011). "Land Application of Hydrofracturing Fluids Damages a Deciduous Forest Stand in West Virginia." *Journal of Environmental Quality*, 40:4, 1340-1344. https://www.agronomy.org/publications/jeq/abstracts/40/4/1340

Adams, R. and Kelsey, T.W. (2012) Pennsylvania dairy farms and Marcellus Shale 2007-2010. Penn State Cooperative Extension, College of Agricultural Sciences. http://extension.psu.edu/publications/ee0020

AFL-CIO. (2016). *Death on the Job: The Toll of Neglect.* https://aflcio.org/reports/death-job-2016

Agency for Toxic Substances and Disease Registry (2016). Dimock Groundwater report.http://www.atsdr.cdc.gov/hac/pha/DimockGroundwaterSite/Dimock_Groundwater_Site_HC_05-24-2016_508.pdf

Akob DM, Mumford AC, Orem W, Engle MA, Klinges JG, Kent DB, Cozzarelli IM. Wastewater Disposal from Unconventional Oil and Gas Development Degrades Stream Quality at a West Virginia Injection Facility. *Environmental Science & Technology* **2016** *50* (11), 5517-5525 http://pubs.acs.org/doi/abs/10.1021/acs.est.6b00428

Allegheny Front, n.d. "Frequently Asked Questions about Ethane Crackers." Accessed 11/1/15 at http://www.alleghenyfront.org/story/frequently-asked-questions-about-ethane-crackers

Anderson SE, Shane H, Long C, Marrocco A, Lukomska E, Roberts JR, Marshall N, Fedan JS. Biological effects of inhaled hydraulic fracturing sand dust VIII Immunotoxicity. *Toxicology and Applied Pharmacology*, **408**, 1 December 2020, 115256 https://www.doi.org/10.1016/j.taap.2020.115256

Apergis N, Hayat T, Saeed T. Fracking and infant mortality: Fresh evidence from Oklahoma. *Environ Sci Pollut Res.* **26,** 32360-32367 (2019) https://doi.org/10.1007/s11356-019-06478-z

Appalachian Oil & Natural Gas Research Consortium. A geologic study to determine the potential to create an Appalachian Storage Hub for natural gas liquids. July 31, 2017. https://aongrc.wvu.edu/files/d/b0b6b967-5911-4bbe-957f-0b149851224f/ngls-study-report-ilovepdf-compressed.pdf

ArkansasOnline (2011, February 27) "4.7 Magnitude Quake Hits Central Arkansas." http://www.arkansasonline.com/news/2011/feb/27/47-magnitude-quake-hits-central-arkansas/

Arnsdorf, I. (2014, August 26) "Fracking links to birth defects probed in early research." *Bloomberg News*. http://www.bloomberg.com/news/2014-08-26/fracking-link-to-birth-defects-probed-in-early-research.html

Association of Schools of Public Health. (n.d.) "What Is Public Health?" Retrieved from http://www.whatispublichealth.org/what/index.html#Environmental

Bamber, A.M., Hasanali, S.H., Nair, A.S., Watkins, S.M., Vigil, D.I., Van Dyke, M., McMullin, T.S., & Richardson, K. (2019 June) A systematic review of the epidemiologic literature assessing health outcomes in populations living near oil and gas operations: Study quality and future recommendations. *International Journal of Environmental Research & Public Health* 16 (12): 2123 https://www.ncbi.nlm.nih.gov/pmc/articles/PMC6616936/

Bamberger, M. and Oswald, R. E., (2012). "Impacts Of Gas Drilling On Human And Animal Health." *New Solutions: A Journal of Environmental and Occupational Health Policy*, Vol. 22(1) 51-77.

Banerjee, N. (2012). "Study: Fracking May Increase Air Pollution Risks." *Los Angeles Times.* Retrieved from: http://articles.latimes.com/2012/mar/20/local/la-me-gs-fracking-increases-air-pollution-health-risks-to-residents-20120320

Banerjee, N. (2016, August 12) "EPA's Fracking Finding Misled on Threat to Drinking Water, Scientists Conclude." *Inside Climate News*. Retrieved from: https://insideclimatenews.org/news/12082016/epa-mislead-public-fracking-water-conclusion-its-own-scientists-conclude

Barron A.R. and Maguire-Boyle, S. J. (2014)."Organic compounds in produced waters from shale gas wells." *Environ. Sci.: Processes Impacts*. Published online Aug. 13, 2014.

Bauers, S. (2011). "Duke study finds methane in well water near gas drilling sites." *Philadelphia Inquirer* Retrieved at: http://articles.philly.com/2011-05-10/news/29528399_1_shale-gas-water-wells-gas-drilling

Baizel B., Steinzor, N. (2012). "PA's Gas and Oil Enforcement." Earthworks Gas Accountability Project. Retrieved at: http://www.earthworksaction.org/files/publications/FINAL-PA-enforcement-sm.pdf

Begos, K. (2012, July 22). "Experts: Some Fracking Critics Use Bad Science." AP -The Big Story. http://bigstory.ap.org/article/experts-some-fracking-critics-use-bad-science

Begos, K. (2012, September 26). "Report Criticizes Pennsylvania Gas Drilling Enforcement." *Wall Street Journal.* Retrieved at: http://www.earthworksaction.org/media/detail/report_criticizes_pa._gas_drilling_enforcement#.UoKNB_nBOSo

Birnbaum, L.S. (2012). "Environmental Chemicals: Evaluating Low-Dose Effects." *Envir. Health Perspect.* 2012 April; 120(4):a143-a144. http://www.ncbi.nlm.nih.gov/pmc/articles/PMC3339483/

Black, K.J., McCoy, S., Weber, J.G. Fracking and indoor radon: Spurious correlation or cause for concern? Under review - 2018.

Blair B.D., Brindley S., Dinkeloo, E., McKenzie, L.M., Adgate, J.L. Residential noise from nearby oil and gas construction and drilling, *Journal of Exposure Science and Environmental Epidemiology*. 2018-05-11. https://www.nature.com/articles/s41370-018-0039-8

Blair B.D., Hughes J., Allshouse W.B., McKenzie L.M., Adgate J.L.
Truck and multivehicle truck accidents with injuries near Colorado oil and gas operations. *Int J Environ Res Public Health* 2018 Aug 28;15(9). pii: E1861. doi: 10.3390/ijerph15091861. https://www.ncbi.nlm.nih.gov/pubmed/30154347

Blinn HN, Utz RM, Greiner LH, Brown DR.
Exposure assessment of adults living near unconventional oil and natural gas development and reported symptoms in Southwest Pennsylvania, USA
PLOS One. August 18, 2020
https://journals.plos.org/plosone/article?id=10.1371/journal.pone.0237325

Bombatch, Z. (Winter, 2013). "Frack to the Future," *Juris, The Duquesne Law School News Magazine*.

Borenstein, S. (2014). "Research: Leaky Wells, not Fracking, Tainted Water" *Pittsburgh Post-Gazette.* Retrieved from: http://powersource.post-gazette.com/powersource/latest-oil-and-gas/2014/09/15/Study-Leaky-wells-not-fracking-taint-water/stories/201409150153

Lisbeth A Boulé, Timothy J Chapman, Sara E Hillman, Christopher D Kassotis, Colleen O'Dell, Jacques Robert, Steve N Georas, Susan C Nagel, B Paige Lawrence; Developmental Exposure to a Mixture of 23 Chemicals Associated With Unconventional Oil and Gas Operations Alters the Immune System of Mice, *Toxicological Sciences*, Volume 163, Issue 2, 1 June 2018, Pages 639–654, https://doi.org/10.1093/toxsci/kfy066

Bousso, R. (September 21, 2020) Shell launches major cost-cutting drive to prepare for energy transition. Reuters.
https://www.yahoo.com/news/exclusive-shell-launches-major-cost-054503765.html

Boyle, M.E., Soneja. S., Quiros-Alcala, L., Dalemarre, L., Sapkota, A.R., Sangaramoorthy, T., Wilson, S., Milton, D. and Sapkota, A. (2017) A pilot study to assess residential noise exposure near natural gas compressor stations. *PLoS ONE.*
http://journals.plos.org/plosone/article?id=10.1371/journal.pone.0174310

Brown, D. (Nov. 9, 2012). *Integrated Guidance for Persons with Health Concerns from Water and Air Exposures During Natural Gas Extraction.* Presentation at conference on Health Effect of Shale Gas Extraction, University of Pittsburgh Graduate School of Public Health. Retrieved at:
http://mediasite.cidde.pitt.edu/mediasite/Viewer/?peid=f8ccd1606b5140048c09aacb4f466538

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.

Brown DR, Lewis C, Weinberger BI (2015). Human exposure to unconventional natural gas development: A public health demonstration of periodic high exposure to chemical mixtures in ambient air. *Journal of Environmental Science and Health*, Part A 50:460-472.
www.tandfonline.com/doi/full/10.1080/10934529.2015.992663

Busby, C. and Mangano, J.J. (2017) There's a World Going On Underground – Infant Mortality and Fracking in Pennsylvania. *J. Envir. Protection* (8) 4:381
https://www.scirp.org/Journal/PaperInformation.aspx?PaperID=75575

Bushkin-Bedient, S, Moore , G.E. (n.d.). Update on Hydraulic Fracturing, *News of NY.* Medical Society of the State of NY, (April 2012); 68(4), pp6-8 mssny.org)
Retrieved from: http://aapdistrictii.org/update-on-hydrofracking/

Caron-Beaudoin, E., Bouchard, M., Wendling, G., Barroso, A., Bouchard, M.F., Ayotte, P., Frohlich, K.L., & Verner, M-A. Urinary & hair concentrations of trace metals in pregnant women from Northeastern British Columbia, Canada: a pilot study. *J Exposure Science & Environmental Epidemiology* **29,** 613-623 (2019) https://www.nature.com/articles/s41370-019-0144-3

Casey JA, Ogburn EL, Rasmussen SG, Irving JK, Pollak J, Locke PA, Schwartz BS (2015). Predictors of Indoor Radon Concentrations in Pennsylvania, 1989-2013. *Environmental Health Perspectives*. doi:10.1289/ehp1409014 http://ehp.niehs.nih.gov/1409014/

Casey JA, Savitz DA, Rasmussen SG, Ogburn EL, Pollak J, Mercer DG, Schwartz BS. Unconventional Natural Gas Development and Birth Outcomes in Pennsylvania USA. Epidemiology. doi: 10.1097/EDE.0000000000000387 Published ahead of print September 30, 2015. http://journals.lww.com/epidem/Abstract/publishahead/Unconventional_Natural_Gas_Development_and_Birth.99128.aspx

Casey J.A., Goldman-Mellor S., Catalano R. Association between Oklahoma earthquakes and anxiety-related Google search episodes. *Environmental Epidemiology.* June 2018. *2* (2) p e016 https://journals.lww.com/environepidem/Fulltext/2018/06000/Association_between_Oklahoma_earthquakes_and.8.aspx

Casey, J.A., Goin, D.E., Rudolph, K.E., Schwartz, B.S., Mercer, D., Elser, H., Eisen,E., Morello-Frosch, R. (2019) Unconventional natural gas development and adverse birth outcomes in Pennsylvania: The potential mediating role of antenatal anxiety and depression. *Environmental Research,* 177: p. 108598 https://www.sciencedirect.com/science/article/pii/S0013935119303950

Campbell, J. (2014). "Fracking Critics Keep Pushing for State-Backed Health Study."*Politics on the Hudson.* Retrieved at http://www.lohud.com/story/news/politics/politics-on-the-hudson/2014/05/08/fracking-critics-keep-pushing-state-backed-health-study/8857609/

Center for Hearing and Communication (2013). *Noise and children's health, learning and behavior.* Found on 4/29/2013. Retrieved at: www.chchearing.org.

Center for International Law (CIEL) (February 2019). Plastic and Health: the Hidden Costs of a Plastic Planet. https://www.ciel.org/wp-content/uploads/2019/02/Plastic-and-Health-The-Hidden-Costs-of-a-Plastic-Planet-February-2019.pdf

Center for International Environmental Law (CIEL). (May 2019). Plastic and Climate: the Hidden Costs of a Plastic Planet. https://www.ciel.org/wp-content/uploads/2019/05/Plastic-and-Climate-FINAL-2019.pdf

Centers for Disease Control and Prevention, "Worker Exposure to Crystalline Silica During Hydraulic Fracturing," NIOSH Science Blog. Retrieved at: http://blogs.edc.gov/niosh-science-blog/2012/05/silica-fracking/

Cernansky, R. (2011). Fracking Wastewater Poisonous To Plants & Trees: US Forest Service. *Tree Hugger.* Retrieved at: http://www.treehugger.com/corporate-responsibility/fracking-wastewater-poisonous-to-plants-trees-us-forest-service.html

Chol, Charles Q. (2013, September 4,) "Confirmed: Fracking practices to blame for Ohio earthquakes." LiveScience, as reported on NBC News website. http://www.nbcnews.com/science/fracking-practices-blame-ohio-earthquakes-8C11073601

Choy, G.L., Rubenstein, J.L., Yeck, W.L., McNamara, D.E., Mueller, C.S., & Boyd, O.S. (2016) A rare moderate-sized (4.9) earthquake in Kansas: rupture process of the Milan, Kansas earthquake of 12 November 2014 and its relationship to fluid injection. *Seismological Research Letters,* 87. doi: 10.1785/0220160100

Clean Air Council (2014). "Health Impact Assessment of the Shell Chemical Appalachia Petrochemical Complex." http://cleanair.org/sites/default/files/CAC%20HIA%20FINAL_0.pdf

Clean Air Council (2015) "Title V: A Citizens' Guide to the Stationary Source Permitting Process." Philadelphia PA.

Colaneri, K. (2014, July 8). "How Oil And Gas States Handle Drilling Related Health Complaints" *State Impact.* Retrieved from: http://stateimpact.npr.org/pennsylvania/2014/07/08/ /#more-27492)

Colaneri, K. (2014, May 9). "Feds Consider Rules for Fracking Chemical Disclosure" *State Impact.* Retrieved from: http://stateimpact.npr.org/pennsylvania/2014/05/09/feds-consider-rules-for-fracking-chemical-disclosure/

Colaneri, K. (May, 2014). "EPA Reconsiders Permit for Clearfield County Waste Disposal Well" *State Impact.* Retrieved from: http://stateimpact.npr.org/pennsylvania/2014/21/09/ EPA-reconsiders- permit-for-Clearfield-County-waste-disposal-well

Colaneri, K. (2014, August,7). "Transparency About Fracking Chemicals Remains Illusive" *State Impact.* Retrieved from: https://stateimpact.npr.org/pennsylvania/2014/08/07/transparency-about-fracking-chemicals-remains-illusive/

Colborn T, vom Saal, F.S., Soto, A.M. (1993). "Developmental effects of endocrine-disrupting chemicals in wildlife and humans". *Environmental Health Perspectives.* 101 (5): 378–84. doi:10.2307/3431890. JSTOR 3431890.PMC 1519860. PMID 8080506.

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). Retrieved at: http://www.tandfonline.com/doi/abs/10.1080/100807039.2011.605662#preview

Colborn, T., Schultz, K., Herrick, L., & Kwiatkowski, C. (2012). An exploratory study of air quality near natural gas operations. *Human and Ecological Risk Assessment: An International Journal*. Retrieved at DOI**:**10.1080/10807039.2012.749447 (Peer reviewed and accepted for publication Nov. 9, 2012.)

Concerned Health Professionals of NY (2014). Compendium of Scientific, Medical and Media Findings Demonstrating Risks and Harms of Fracking (Unconventional Gas and Oil Extraction).

Concerned Health Professionals of NY & Physicians for Social Responsibility (October 14, 2015). Compendium of Scientific, Medical and Media Findings Demonstrating Risks and Harms of Fracking (Unconventional Oil and Gas Extraction). Third Edition. http://concernedhealthny.org/wp-content/uploads/2012/11/PSR-CHPNY-Compendium-3.0.pdf

Concerned Health Professionals of NY & Physicians for Social Responsibility (November 17, 2016). Compendium of Scientific, Medical and Media Findings Demonstrating Risks and Harms of Fracking (Unconventional Oil and Gas Extraction). Fourth Edition. (p.16, 137 – EPA, methane.) http://concernedhealthny.org/wp-content/uploads/2016/12/COMPENDIUM-4.0_FINAL_11_16_16Corrected.pdf

Concerned Health Professionals of NY & Physicians for Social Responsibility (March 2018). Compendium of Scientific, Medical and Media Findings Demonstrating Risks and Harms of Fracking (Unconventional Oil and Gas Extraction). Fifth Edition.
https://www.psr.org/wp-content/uploads/2018/04/Fracking_Science_Compendium_5.pdf

Currie, J., Greenstone, M., and Meckel, K. Hydraulic fracturing and infant health: New evidence from Pennsylvania. *Science Advances.* 13 Dec 2017. *3* (12)
http://advances.sciencemag.org/content/3/12/e1603021/tab-article-info

Cushing, L., Johnston, J., Franklin. M., *et al.* OP III – 3 Using satellite observations to estimate exposure to flaring; implications for future studies of the health impacts of unconventional oil and gas operations. *Occup Environ Med* 2018; **75**: A5-A6. https://oem.bmj.com/content/75/Suppl_1/A5.3

Cushing LJ, Vavra-Musser K, Chau K, Franklin M, Johnston JE. (2020) Flaring from unconventional oil and gas development and birth outcomes in the Eagle Ford shale in South Texas. ***Environmental Health Perspectives*** 128 (7) 15 July 2020
https://doi.org/10.1289/EHP6394

Cusick, M. (March 3, 2015) "Wolf budget includes $100K for Marcellus Shale health registry." NPR State Impact. https://stateimpact.npr.org/pennsylvania/2015/03/03/wolf-budget-includes-100k-for-marcellus-shale-health-registry/

Cusick, M. (March 9, 2015) "With new draft rules, DEP steps up oversight of drilling waste." NPR State Impact. https://stateimpact.npr.org/pennsylvania/2015/03/09/with-new-draft-rules-dep-steps-up-oversight-of-drilling-waste/

Cusick, M. (August 28, 2017). "Pennsylvania to increase fees for shale gas wells." *NPR State Impact*.
https://stateimpact.npr.org/pennsylvania/2017/08/28/pennsylvania-to-increase-fees-for-shale-gas-wells/

Czolowski, E. D., Santoro, R. L., Srebotnjak, T., & Shonkoff, S. B. C. (2017). Toward Consistent Methodology to Quantify Populations in Proximity to Oil and Gas Development: A National Spatial Analysis and Review. *Environmental Health Perspectives*, *125*(8), 086004.
http://doi.org/10.1289/EHP1535

Darrah, T.H., Vengosh, A., Jackson, R.B., Warner, N.R., 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.
http://www.pnas.org/cgi/doi/10.1073/pnas.1322107111

Davis, D. (2002).*When Smoke Ran Like Water: Tales of Environmental Deception and the Battle Against Pollution.* Basic Books.

Davis, D. (2007). *The Secret History of the War on Cancer*, Basic Books.

Deal, S (May 12, 2011). Blog on GoMarcellusShale.com
http://gomarcellusshale.com/forum/topics/gas-composition

Denham, A., Willis, M., Zavez, A., Hill, E. Unconventional natural gas development and hospitalizations: evidence from Pennsylvania, United States, 2003-2014. *Public Health* 168, 17-25. March 1, 2019.
https://www.sciencedirect.com/science/article/abs/pii/S0033350618303901?via%3Dihub

Dennis, L. (2016, May 4) “Environmental groups sue EPA, seek stricter rules over fracking waste linked to earthquakes.” *Washington Post.* https://www.washingtonpost.com/news/energy-environment/wp/2016/05/04/environmental-groups-sue-epa-seek-stricter-rules-over-fracking-waste-linked-to-earthquakes/?utm_term=.53ab2b7aea69

Derndach, J.C., May, J., & Kristi, K. (2014, March 1) “Robinson Township v. Commonwealth of Pennsylvania: Examination and Implications.” Widener Law School Legal Studies Research Paper No.14-10. Available at SSRN: http//ssrn.com/abstract=2412657 or http://dx.doi.org/10.2139/ssrn.2412657

Deziel NC, Humeau Z, Elliott EG, Warren JL, Niccolai LM (2018) Shale gas activity and increased rates of sexually transmitted infections in Ohio, 2000–2016. PLoS ONE 13(3): e0194203. https://doi.org/10.1371/journal.pone.0194203 https://journals.plos.org/plosone/article?id=10.1371/journal.pone.0194203

Deziel NC, Brokovich E, Grotto I, Clark CJ, Barnett-Itzakhi Z, Broday D, Agay-Shay K. Unconventional oil and gas development and health outcomes: A scoping review. *Environ Res* **182** March 2020, 109124 https://doi.org/10.1016/j.envres.2020.109124

Diamanti, K. (2012). "Endocrine-Disrupting Chemicals and Public Health Protection: A Statement of Principles from The Endocrine Society." Abstract. *Endocrinology.* Sept. 1, 2012, vol. 153 no. 9 http://endo.endojournals.org/content/153/9/4097.abstract

Earthworks, Noise Resources, found 4/15/11 at http://www.earthworksaction.org/noiseresources.cfm#OILGASNOISE

Earthworks (2015). Steinzor N & Baizel B. *Wasting Away: Four states’ failure to manage oil and gas field waste from the Marcellus and Utica shale.* https://www.earthworksaction.org/files/publications/WastingAway-FINAL-lowres.pdf

Earthworks (September 2019). Troutman, M. “Pennsylvania Oil and Gas Waste Report.” https://earthworks.org/cms/assets/uploads/2019/09/PA-Waste-Report-2019-FINAL-sm.pdf

Eddington, S. (2011). "Arkansas Quakes Decline Since Injection Well Closure." *Huffington Post.* Retrieved at: http://www.huffingtonpost.com/huff-wires/20110314/us-arkansas-earthquakes/

Eligon, J. (2013). "An Oil Boom Takes its Toll." *New York Times.* Retrieved from: http://www.nytimes.com/2013/01/28/us/boom-in-north-dakota-weighs-heavily-on-health-care.html

Elliott, E.G., Ma, X.,Leaderer B.P., McKay, L.A., Pedersen, C.J., Wang, C. Gerber, C.J., Wright, T.J., Sumner, A.J., Brennan, M., Silva, G,S,. Warren, J.L., Plata, D.L., Deziel, N.C. A community-based evaluation of proximity to unconventional oil and gas wells, drinking water contaminants, and health symptoms in Ohio. *Environmental Research*. November 2018. 167:550-557 https://www.sciencedirect.com/science/article/pii/S0013935118304596

Elser H, Goldman-Mellor S, Morello-Frosch R, Deziel NC, Ranjbar K, Casey JA. Petro-riskscapes and environmental distress in West Texas: Community perceptions of environmental degradation, threats, and loss. *Energy Research & Social Science*, **70**, 101798. (December 1, 2020) https://www.doi.org/10.1016/j.erss.2020.101798

Environmental Health Project. What is Public Health? http://www.environmentalhealthproject.org/about/

EPA Air Pollution Control Orientation Course (EPA, 2010).

EPA Investigation of Ground Water Contamination near Pavillion, Wyoming. Draft report, December 2011. Retrieved September 18, 2014 at http://www.achd.net/shale/pubs/DiGuiulio_et-al_EPA_ReportOnPavillion_Dec-8-2011.pdf

EPA Study of the Potential Impacts of Hydraulic Fracturing on Drinking Water Resources. Progress Report, December 2012, Retrieved September 18, 2014 at http://www2.epa.gov/sites/production/files/documents/hf-report20121214.pdf

EPA Science Advisory Board. (August 11, 2016) SAB Review of the EPA's Draft Assessment of the Potential Impacts of Hydraulic Fracturing for Oil and Gas on Drinking Water Resources. https://www.documentcloud.org/documents/3011057-EPA-SAB-16-005-Unsigned.html

Esswein, Eric J., Breitenstein, M., Snawder, J., Keifer. M., Sieber, W.K. (2013). "Occupational Exposures to Respirable Crystalline Silica During Hydraulic Fracturing." *Journal of Occupational and Environmental Hygiene,* 10:7, 347-356. http://dx.doi.org/10. 1080/15459624.2013.788532

Esswein, E.J., Snawder, J., King, B., Breitenstein, M., Alexander-Scott, M. (2014, August 21). "Preliminary Field Studies on Worker Exposure to Volatile Chemicals during Oil and Gas Extraction Flowback and Production Testing Operations." CDC NIOSH Science Blog. Retrieved September 9, 2014 at http://blogs.cdc.gov/niosh-science-blog/2014/08/21/flowback-2/

Esch, M. **"**New York Fracking Health Impacts To Be Reviewed Before Moratorium Lifted.**"** *AP Huffington Post*. Posted: 09/21/2012**;** retrieved Nov. 1, 2012.

Everley, S. (2012, April 6). "Cornell Veterinarians Go Into "Beast Mode" on Shale." Independent Petroleum Association of America's Energy In Depth website. http://energyindepth.org/national/cornell-veterinarians-go-into-beast-mode-on-shale/

Fabisiak, JP (2016, July 17) "One cracker = 36,000 cars." *Pittsburgh Post-Gazette.* http://www.post-gazette.com/opinion/Op-Ed/2016/07/17/Shell-and-others-shouldn-t-dismiss-community-concerns-about-the-Beaver-County-cracker-plant/stories/201607170023

Fair,M. (2014, July 1). "Doctor's Challenge to PA Fracking Gag Rule Gets Nixed." *Law 360*. Retrieved October 2, 2014 at http://www.law360.com/articles/553427/doctor-s-challenge-to-pa-fracking-gag-rule-gets-nixed

Federal Register Vol. 84 # 158 Thursday August 15, 2019 Occupational Exposure to Respirable Crystalline Silica –Specified Exposure Control Methods. (Proposed rules) (Pages 41667-41670) (Federal Doc No: 2019-17450) https://www.osha.gov/laws-regs/federalregister/2019-08-15

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." *Envir. Sci. Technol.*, 47 (7), 3472-3481. doi:10.1021/es301411q

Ferrar, K., Jackson, E., & Malone, S. (2019) Categorical review of health reports on unconventional oil and gas development: Impacts in Pennsylvania. FracTracker Alliance Issue Paper. https://www.delawareriverkeeper.org/sites/default/files/FracTrackerAlliance_DRKHealthReview_Final_4.25.19_0.pdf

Fieldstadt, Elisha (and AP) (2016, September 4). "State of Emergency Declared in Oklahoma After Magnitude 5.6 Earthquake." NBC News. http://www.nbcnews.com/news/us-news/state-emergency-declared-oklahoma-after-magnitude-5-6-earthquake-n642676

Finley, B. (2014, May 4). "Colorado Faces Oil Boom 'Death Sentence' for Soil, Eyes Microbe Fix. *The Denver Post.* Retrieved October 5, from http://www.denverpost.com/environment/ci_25692049/colorado-faces-oil-boom-death-sentence-soil-eyes

Fisher M.P., Mayer A., Vollet K., Hill E.L.. Haynes E.N. Psychosocial implications of unconventional natural gas development: Quality of life in Ohio's Guernsey and Noble counties. *Journal of Environmental Psychology*. February 2018. *55*: 90-98. https://www.sciencedirect.com/science/article/pii/S0272494417301858

Food & Water Watch. (February 2017). "How Fracking Support the Plastic Industry." https://www.foodandwaterwatch.org/sites/default/files/ib_1702_fracking-plastic-web.pdf

Food & Water Watch. (September 10, 2020) DRBC votes to delay decision on Delaware River fracked gas terminal. https://www.foodandwaterwatch.org/news/drbc-votes-delay-decision-delaware-river-fracked-gas-terminal

FracFocus Chemical Disclosure Registry (2014). Retrieved October 3, 2014 at http://fracfocus.org/welcome

Frazier, R. (August 6, 2015). "Enviro groups appeal air permit for Shell's ethane cracker." NPR State Impact. https://stateimpact.npr.org/pennsylvania/2015/08/06/enviro-groups-appeal-air-permit-for-shells-ethane-cracker/

Frazier, R (2016, September 9). "Could Shell's Ethane Cracker Erase Recent Gains in Air Quality?" Allegheny Front. http://www.alleghenyfront.org/could-shells-ethane-cracker-erase-recent-gains-in-air-quality/

Frazier, R. (April 24, 2020). The Allegheny Front. https://www.alleghenyfront.org/dep-approves-injection-well-in-plum-but-uncertain-economy-might-put-project-on-hold

Frohlich, C. (2012). "Two-year survey comparing earthquake activity and injection-well locations in the Barnett Shale, Texas." *Proceedings of the National Academy of Sciences of the USA*. http://www.pnas.org/content/early/2012/07/30/1207728109.abstract

Funk, J. (July 13, 2017). "Ohio ethane cracker plant closer to reality on former FirstEnergy property." *The Plain Dealer*. http://www.cleveland.com/metro/index.ssf/2017/07/ohio_ethane_cracker_plant_clos.html

Garber, A. (2014, August 19). Health Professionals Call for Investigation & Reform at PA Department of Health on Fracking. Penn Environment press release. Retrieved October 2, 2014 at http://www.pennenvironment.org/news/pac/health-professionals-call-investigation-reform-pa-department-health-fracking

Garland, M. (2018, June 2) U.S. Methanol CEO: Institute plant to open in late 2019. *Charleston Gazette-Mail* https://www.wvgazettemail.com/business/us-methanol-ceo-institute-plant-to-open-in-late/article_a2647172-0e7d-59dd-bcd6-f1d16815437f.html

George, C. (n.d.). *Marcellus Shale & Hydraulic Fracturing -- What You Need to Know*. PA House of Representatives Environmental Resources and Energy Committee.

Geeza, T.J., Gillikin, D.P., McDevitt, B., Van Sice, K., Warner N.R. Accumulation of Marcellus formation oil and gas wastewater metals in freshwater mussel shells. *Environmental Science & Technology,* **2018**, *52* (18): 10883 – 10892. https://pubs.acs.org/doi/ipdf/10.1021/acs.est.8b02727

Giammarise, K. (July 19, 2013). "PA Supreme Court Halts Shutdown of Rural Health Centers." *Pittsburgh Post-Gazette.* http://www.post-gazette.com/state/2013/07/19/Pa-Supreme-Court-halts-shutdown-of-rural-health-centers/stories/201307190113

Gibbs, G. Study ties fracking to radioactive wastewater. *The Dartmouth* September 28, 2018. http://www.thedartmouth.com/article/2018/09/study-ties-fracking-to-radioactive-wastewater

Goldsmith, D.F. and Clougherty, J. E. **(**2012)."Worker Exposures" Presentation at University of Pittsburgh Health Effects of Shale Gas Extraction Conference. Retrieved from: http://mediasite.cidde.pitt.edu/mediasite/Viewer/?peid=3de1dbb224b64741bd809184864427fb

Goldstein, B.D. (2011). "Potential Health Effects of Marcellus Shale: The Need for Public Health Surveillance." Center for Healthy Environments and Communities. University of Pittsburgh Graduate School of Public Health. Retrieved from: http://www.chec.pitt.edu/documents/Marcellus%20Shale/CHEC-Present-Goldstein-5.10.11-HealthMarcellus.pdf

Goldstein, B.D., Kriesky, J., Parliakova, B. (2013, January 10). "Missing from the Table: Role of the Environmental Public Health Community in Governmental Advisory Commissions Related to Marcellus Shale Drilling," NIEHS. Retrieved from http://www.psehealthyenergy.org/Missing_from_the_Table__Role_of_the_Environmental_Public_Health_Community_in_Governmental_Advisory_Commissions_Related_to_Marcellus_Shale_Drilling

Gorski, I. & Schwartz, B. (2019, February 25). Environmental Health Concerns from Unconventional Natural Gas Development. *Oxford Research Encyclopedia of Global Public Health*. https://oxfordre.com/publichealth/view/10.1093/acrefore/9780190632366.001.0001/acrefore-9780190632366-e-44

Graham J, Irving J, Tang X, Sellers S, Crisp J, Horwitz D, Mulenbachs L, Krupnick A, Carey D. (2015). Increased traffic accident rates associated with shale gas drilling in Pennsylvania. *Accident Analysis and Prevention* 74:203-209.
doi: 10.1016/j.aap.2014.11.003

Grossman, D. (2013). "Clean Air Report Card: CO, WY Counties get F's Due to Oil and Gas Pollution. *Environmental Defense Fund.* Retrieved from: http://blogs.edf.org/energyexchange/2013/04/29/clean-air-report-card-co-wy-counties-get-fs-due-to-oil-and-gas-pollution/

Groundwater Protection Council, and Interstate Oil and Gas Compact Commission. (May 2017). *Underground Gas Storage Regulatory Considerations: A Guide for State and Federal Regulatory Agencies.* 122 pages.
http://www.gwpc.org/sites/default/files/2017-GasStorageRegulatoryConsiderations-reduce.pdf

Guillen, A. (June 18, 2017) "The radical idea behind Trump's EPA rollbacks." *Politico.* http://www.politico.com/story/2017/06/18/pruitts-predecessors-pan-epa-originalism-philosophy-239669

Guza, M. (November 22, 2019). Cancer victims compel state to fund $3 million studies seeking link to gas wells. *TribLive.* https://triblive.com/local/regional/cancer-victims-compel-state-to-fund-3-million-studies-seeking-link-to-gas-wells/

Haley M, McCawley M, Epstein AC, Arrington B, Bjerke EF. 2016. Adequacy of current state setbacks for directional high-volume hydraulic fracturing in the Marcellus, Barnett, and Niobrara Shale Plays. Environ Health Perspect 124:1323–1333; http://dx.doi.org/10.1289/ehp.1510547

Hays J & Shonkoff SBC (2015) *Toward an understanding of the environmental and public health impacts of shale gas development: an analysis of peer-reviewed scientific literature, 2009-2015.* Working paper, PSE Healthy Energy. Accessed at http://www.psehealthyenergy.org/data/Database_Analysis_2015.6_.16_.pdf

Hays J, Shonkoff SBC (2016) Toward an Understanding of the Environmental and Public Health Impacts of Unconventional Natural Gas Development: A Categorical Assessment of the Peer-Reviewed Scientific Literature, 2009-2015. PLoS ONE 11(4): e0154164. http://dx.doi.org/10.1371/journal.pone.0154164

Health Effects Institute (HEI) Special Scientific Committee on Unconventional Oil and Gas Development in the Appalachian Basin. (October 2015). *Strategic Research Agenda on the Potential Impacts of 21st Century Oil and Natural Gas Development in the Appalachian Basin and Beyond. Boston, MA.* http://www.healtheffects.org/UOGD/UOGD.htm

Health Effects Institute- Energy (2019) Potential Human Health Effects Associated with Unconventional Oil & Gas Development: A Systemic Review of the Epidemiology Literature. Special Report 1. Final Report. https://hei-energy.org/publications https://hei-energy.org/system/files/hei-energy-epi-lit-review.pdf

Health Effects Institute - Energy (2019) Human Exposure to Unconventional Oil & Gas Development: A Literature Survey for Research Planning. Special Report 2. (Draft for Public Comment) https://hei-energy.org/publications https://hei-energy.org/system/files/hei-energy-exposure-lit-rev-draft.pdf

Heinkel-Wolfe, P. (August 31, 2011). "Breast cancer rate climbs up." *Denton-Record Chronicle,*. Accessed May 27, 2013 at http://www.dentonrc.com/local-news/special-projects/gas-well-drilling-headlines/20110831-breast-cancer-rate-climbs-up.ece

Helmig, D., Thompson,C.R., Evans, J., Boylan, P., Hueber, J., Park, J.H. (2014). "Highly Elevated Levels of Volatile Organic Compounds in the Uintah Basin, Utah." *Environ. Sci. Technol.*, 48 (9), pp.4407-4715. http://pubs.acs.org/doi/abs/10.1021/es405046r?source=cen

Hendryx M & Luo J. Natural gas pipeline compressor stations: VOC emissions and mortality. *The Extractive Industries and Society*, **7** (3), July 2020, 864-869. https://www.doi.org/10.1016/j.exis.2020.04.011

Hill, E.L. (2013). "The Impact of Oil and Gas Extraction on Infant Health: Evidence from Pennsylvania." (under review) Retrieved from: http://dyson.cornell.edu/research/researchpdf/wp/2012/Cornell-Dyson-wp1212.pdf

Hill, L.A.L., Czolowski, E.D., DiGuilio, D., Shonkoff, S.B.C. (15 July 2019) Temporal and spatial trends of conventional and unconventional oil and gas waste management in Pennsylvania, 1991-2017. *Science of the Total Environment* 674: 623-636. https://www.sciencedirect.com/science/article/pii/S0048969719314913?via%3Dihub

Hirji, Z. (2014, September 5). “Fracking’s Wastewater, Poorly Understood, is Analyzed for First Time.” *InsideClimate News*. Accessed September 9, 2014 at http://insideclimatenews.org/news/20140905/frackings-wastewater-poorly-understood-analyzed-first-time

Hirji, Z. (May 29, 2015) “Free of fanfare, Maryland adopts fracking moratorium.” Inside Climate News. Retrieved October 17, 2015 from: http://insideclimatenews.org/news/29052015/free-fanfare-maryland-adopts-fracking-moratorium

Hood, G. (2014). "What's in a Word? Is it Fracking or Frac'ing?" *Community Radio for Northern Colorado.* Retrieved from: http://www.kunc.org/post/what-s-word-it-fracking-or-frac-ing

Hopey, D. (2012, April 18). "Potential Health Effects of Marcellus Shale Activities," *Pittsburgh Post-Gazette.* Retrieved from http://webcache.googleusercontent.com/search?q=cache:4l351UVC8MgJ:energy.wilkes.edu/PDFFiles/Issues/Env10_Potential+Health+Effects+of+Marcellus+Shale+Activities.pdf+Marcellus+Shale+%252B+air+quality+%252B+health&hl=en&gl=us

Hopey, D. (August 31, 2015) “Groups push EPA to rewrite oil and gas disposal rules*.” Pittsburgh Post-Gazette.* http://powersource.post-gazette.com/news/environment/2015/08/31/Groups-push-EPA-to-rewrite-oil-and-gas-waste-disposal-rules/stories/201508270122

Hopey, D. (October 19, 2015) “Pa. agency to examine drilling’s impact on poor areas.” *Pittsburgh Post-Gazette.* http://powersource.post-gazette.com/news/state/2015/10/19/Pennsylvania-panel-to-examine-drilling-impacts-on-poor-communities/stories/201510190005

Hopey, D. and Hamill, S. (2011, April 20). "DEP Asks Drillers to Stop Disposing Wastes at Plant" *Pittsburgh Post-Gazette.* Retrieved at: http://www.post-gazette.com/stories/local/marcellusshale/dep-asks-drillers-to-stop-disposing-wastewater-at-plants-294239/

Hopey D. & Litvak A. (January 28, 2015) “High radiation not a byproduct of shale drilling, DEP finds.” *Pittsburgh Post-Gazette.*

Hopey, D. (2016, September 29) “Law unfairly gave shale drillers ‘special’ treatment, PA Supreme Court rules.” *Philly.com* http://www.philly.com/philly/business/energy/20160929_Law_unfairly_gave_shale_drillers__special__treatment__Pa__Supreme_Court_rules.html

Hopey, D (2016, October 28). “Doctors call for state ban on drilling and fracking.” *Pittsburgh Post-Gazette.* http://www.post-gazette.com/local/region/2016/10/27/Doctors-group-calls-for-moratorium-on-fracking-in-Pennsylvania/stories/201610270226

Hopey, D. (October 14, 2017) “Environmental groups map proximity of well sites, kids.” *Pittsburgh Post-Gazette*

Hopey, D. (May 13, 2020) “Methane leaks much worse than previously thought, study says.” *Pittsburgh Post-Gazette*. https://www.post-gazette.com/news/environment/2020/05/13/Methane-leaks-much-worse-than-previously-thought/stories/202005120163

Hopey, D & Legere, L. (June 26, 2020) AG: PA failed to regulate shale gas. *Pittsburgh Post-Gazette. https://www.post-gazette.com/news/environment/2020/06/25/Grand-jury-report-Pennsylvania-systemic-failure-regulation-fracking-shale-gas-industry-oil-Josh-Shapiro/stories/202006250132#:~:text=Pennsylvania%20Attorney%20General%20Josh%20Shapiro,shale%20gas%20industry%20and%20the*

Horwitt, D. Partnership for Policy Integrity. April 7, 2016. "Toxic Secrets: Companies Exploit Weak US Chemical Rules to Hide Fracking Risks."
http://www.pfpi.net/toxic-secrets-companies-exploit-weak-us-chemical-rules-to-hide-fracking-risks
http://www.pfpi.net/wp-content/uploads/2016/04/PFPI_ToxicSecrets_4-7-2016.pdf

Horwitt, D. Keystone Secrets. Partnership for Policy Integrity. September 11, 2018.
https://www.pfpi.net/wp-content/uploads/2018/09/PASecretFrackingChemicalsReportPFPI9.10.2018.pdf

Horwitt, D. Partnership for Policy Integrity (PFPI). (September 15, 2019)
"Ohio's Secret Fracking Chemicals."
http://www.pfpi.net/secret-fracking-chemicals-threaten-ohioans-health-drinking-water
http://www.pfpi.net/wp-content/uploads/2019/09/OH_SecFracChem_9.16.2019.pdf

Howarth, R. W. (2012, May 31) "Statement before the Subcommittee on Technology, Information Policy, Intergovernmental Relations and Procurement Reform". Committee on Oversight and Government Reform, Congress of the United States, U.S. House of Representatives. Retrieved 2013 at
http://www.sustainablefuture.cornell.edu/blog/docs/20120531-HowarthStatementToCongress.pdf

Howarth, R.W., Ingraffea, A., Santoro, R. (2012). PSE Analysis: API ANGA Report.
http://www.psehealthyenergy.org

Hull, N.M., Rosenblum, J.S., Robertson, C.E., Harris J.K., Linden K.G. Succession of toxicity and microbiota in hydraulic fracturing flowback and produced water in the Denver-Julesberg Basin, *Sci Total Environ*. December 10 2018.; *644*:183-192. Epub July 4 2018.
https://www.ncbi.nlm.nih.gov/pubmed/29981518

Hurdle, J. (June 5, 2017) PA DEP Approved 11th underground injection well for oil and gas waste. *NPR State Impact*.
https://stateimpact.npr.org/pennsylvania/2017/06/05/pa-dep-approved-11th-underground-injection-well-for-oil-and-gas-waste/

Hurdle, J. (July 27, 2017) "Senate budget measure would outsource environmental permit review." *NPR State Impact*.
https://stateimpact.npr.org/pennsylvania/2017/07/27/senate-budget-measure-would-outsource-environmental-permit-review/

Hurdle, J. (July 28, 2020) "DEP urged to close 'loopholes' in new regulation on VOCS and methane." State Impact Pennsylvania.
https://stateimpact.npr.org/pennsylvania/2020/07/28/dep-urged-to-close-loopholes-in-new-regulation-on-vocs-and-methane/

Hydrocarbon Processing. (2018, October 10) Primus Green Energy to finalize its first U.S. methanol processing plant. https://www.hydrocarbonprocessing.com/news/2018/10/primus-green-energy-to-finalize-its-first-us-methanol-plant

ICIS http://www.icis.com/Articles/2012/04/13/9550417/white-house-sets-up-federal-task-force-to-regulate-shale-gas.html

IHS Markit. Prospects to enhance Pennsylvania's opportunities in petrochemical manufacturing. March 2017. TEAM PA/PA DCED. https://teampa.com/wp-content/uploads/2017/03/Prospects_to_Enhance_PAs_Opportunities_in_Petrochemical_Mfng_Report_21March2017.pdf

Institute of Medicine (IOM) Report, 1995. *Nursing, Health & the Environment*: *Strengthening the Relationship to Improve the Public's Health*. Washington, DC: National Academy Press. http://www.nap.edu/openbook.php?record_id=4986&page=2

Jackson, E. The Falcon Pipeline: Technical Deficiencies. FracTracker Alliance. October 3, 2018. https://www.fractracker.org/2018/10/falcon-technical-deficiencies/

Jacquet, J. (2009). "Energy Boomtowns & Natural Gas: Implications for Marcellus Shale Local Government & Rural Communities." *NERCRD Rural Development Paper No. 4.* Retrieved at: http://energy.wilkes.edu/PDFFiles/Issues/Energy%20Boomtowns%20and%20Natural%20Gas.pdf

Jaeger, L., Weller, M., Wilkins, T. (January 17, 2017) Federal Court Sets Timeline for EPA to Reconsider Regulation of Oil and Gas Waste Under RCRA. Bracewell, Energy Legal Blog. https://www.energylegalblog.com/blog/2017/01/17/federal-court-sets-timeline-epa-reconsider-regulation-oil-and-gas-waste-under-rcra

Janitz, A.E., Dao, H.D., Campbell, J.E., Stoner, J.A., & Peck, J.D. (2019)
The association between natural gas activity and specific congenital anomalies in Oklahoma 1997-2009. *Environment International, 122,*381-388.
https://www.sciencedirect.com/science/article/abs/pii/S0033350618303901?via%3Dihub

Jemielita T, Gerton GL, Neidell M, Chillrud S, Yan B, Stute M, Howarth M, Saberi P, Fausti N, Penning TM, Roy J, Propert KJ, Panettieri RA, Jr. (2015) Unconventional Gas and Oil Drilling Is Associated with Increased Hospital Utilization Rates. PLoS ONE 10:e0131093
http://journals.plos.org/plosone/article?id=10.1371/journal.pone.0131093
Press release: http://www.eurekalert.org/pub_releases/2015-07/uops-hfl071315.php

Johnston, J. and Cushing, L. (2020-01-22) Chemical exposures, health and environmental justice in communities living on the fenceline of industry. *Current Environmental Health Report*, **7**, 48-57. https://www/doi.org/10.1007/s40572-020-00263-8

Johnston JE, Chau K, Franklin M, Cushing L. Environmental justice dimensions of oil and gas flaring in South Texas: Disproportionate exposure among Hispanic communities.
Environ. Sci. Technol. 2020 **54** (10) 6289-6298 https://doi.org/10.1021/acs.est.0c00410

Junkins, C. (August 30, 2017). "Ethane hub may yield 100K jobs." *The Times-Leader*.
http://www.timesleaderonline.com/news/local-news/2017/08/ethane-hub-may-yield-100k-jobs/

Junkins, C. (September 24, 2017) "Decision on Belmont County ethane cracker plant due by end of year." *The Parkersburg News and Sentinel*.
http://www.newsandsentinel.com/news/business/2017/09/decision-on-belmont-county-ethane-cracker-plant-due-by-end-of-year/

Kaiser Family Foundation. (March 2018). State Health Facts: Total Number of Professionally Active Nurses.
https://www.kff.org/other/state-indicator/total-registered-nurses/?currentTimeframe=0&sortModel=%7B“colId”:“Location”,“sort”:“asc”%7D

Kaktins, N.M. (n.d.) *Drilling the Marcellus Shale: Environmental Health Issues for Nurses.* Retrieved from:
http://www.ohiopha.org/admin/uploads/documents/Drilling%20the%20Marcellus%20Shale%20TC%20ANHE%20Kaktins%207%202011.pdf

Kassotis, C.D., Tillett, 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* 155:3, 897-907. Also described in University of Missouri School of Medicine News, “MU Researchers Find Fracking Chemicals Disrupt Hormone Function,” retrieved September 14, 2014 at http://medicine.missouri.edu/news/0214.php

Kassotis CD, Iwanowicz LR, Akob DM, Cozzarelli IM, Mumford AC, Orem WH, Nagel SC (2016). “Endocrine Disrupting Activities of Surface Water Associated with a West Virginia Oil and Gas Industry Wastewater Disposal Site.” *Science of the Total Environment* 557-558: 901-910.
http://www.sciencedirect.com/science/article/pii/S0048969716305356

Kelly, S. (2014). Research Shows Some Test Methods Miss 99 Percent of Radium in Fracking Waste. *Desmogblog.com.* Retrieved from: http://www.desmogblog.com/2014/03/23/some-testing-methods-can-miss-99-percent-radium-fracking-waste-new-research-reports

Keranen, K.M., Weingarten, M., Abers, G.A., Bekins, B.A. & Ge, S. (2014). "Sharp increase in central Oklahoma seismicity since 2008 induced by massive wastewater injection." *Science (25):* 448-451.Published online 3 July 2014 http://www.sciencemag.org/content/345/6192/13.summary

Keranen, K.M., Savage, H.M., Abers, G. A., Cochran, E.S. (2013). "Potentially Induced Earthquakes in Oklahoma, USA: Links Between Wastewater Injection and the 2011 M_w 5.7 Earthquake Sequence.” *Geology*, G34045.1, first published on March 26, 2013,doi:10.1130/G34045.1http://geology.gsapubs.org/search?author1=Elizabeth+S.+Cochran&sortspec=date&submit=Submit

Koch, W. (2014, September 10) “People near ‘fracking’ wells report health woes.” *USA Today*. Retrieved September 15, 2014 at http://www.usatoday.com/story/money/business/2014/09/10/people-near-fracking-wells-health-symptoms/15337797/

Krajnak K, Hong K, Russ KA, McKinny W, Waugh S, Zeng W, Kashon ML, Johnson C, Cumpston J, Fedan JS. Biological effects of inhaled hydraulic fracturing sand dust VIII Cardiovascular effects. *Toxicology and Applied Pharmacology*, **406,** 1 November 2020, 115242
https://www.doi.org/10.1016/j.taap.2020.115242

Kurutz, D.R. (2019, August 21). DEP revokes some permitting power of the Beaver County Conservation District. *Beaver County Times.* https://www.timesonline.com/news/20190821/dep-revokes-some-permitting-power-of-beaver-county-conservation-district

League of Women Voters of Indiana County (2009-2010) *Study Guide II, Marcellus Shale Natural Gas: Environmental Impact.* http://www.palwv.org/files/224_MarcellusShaleStudyGuideII.pdf

League of Women Voters of Indiana County (2009-2010) *Study Guide V, Regulation and Permitting of Marcellus Shale Drilling.* http://www.palwv.org/files/227_MarcellusShaleStudyGuideV.pdf

League of Women Voters of Virginia (2016). *Fracking in Virginia*. http://www.lwv-va-natres.org/wp-content/uploads/2016/10/Fracking_In_Virginia_10%2011%202016.pdf

Legere, L. (2010). "Hazards Posed by Natural Gas Drilling not Always Underground." *Times-Tribune.* Retrieved from: http://www.marcellus-shale.us/fragmentation.htm

Legere, L. (2014). "EPA Approves Waste Disposal Well in Clearfield County." *State Impact.* Retrieved from: http://stateimpact.npr.org/pennsylvania/2014/02/17/epa-approves-waste-disposal-well-in-clearfield-county/

Legere, L. (2014). "DEP aims to put abandoned oil and gas wells on the map." *Pittsburgh Post-Gazette.* Retrieved from: http://powersource.post-gazette.com/powersource/policy-powersource/2014/08/29/Mounting-fracking-foes-have-oil-industry-concerned/stories/201408290114

Legere, L. (2014). "DEP Considers Rules on Tremors and Fracking." *Pittsburgh Post-Gazette.* Retrieved from: http://www.post-gazette.com/powersource/policy-powersource/2014/07/08/DEP-considers-rules-on-tremors-and-fracking/stories/201407080021

Legere, L. (2014, September 9) "Water cases detailed." *Pittsburgh Post-Gazette*.

Legere, L. (January 30, 2015) "Gov. Wolf bans new leases for drilling on state lands." *Pittsburgh Post-Gazette.* http://powersource.post-gazette.com/powersource/home-powersource/2015/01/29/Governor-Wolf-signs-order-banning-new-gas-drilling-leases-on-Pennsylvania-public-lands/stories/201501290301

Legere, L. (October 6, 2015). "Industry seeks to learn from detailed report on oil and gas deaths." *Pittsburgh Post-Gazette.* http://powersource.post-gazette.com/powersource/policy-powersource/2015/10/06/Industry-seeks-to-learn-from-detailed-report-on-oil-and-gas-fatalities/stories/201510060007

Legere, L. (2016, March 10) "Jury awards last Dimock plaintiffs $4.2 million over water well contamination." *Pittsburgh Post-Gazette*. http://powersource.post-gazette.com/powersource/companies/2016/03/10/Jury-awards-last-Dimock-plaintiffs-4-2-million-over-water-well-contamination-Cabot-Marcellus-Shale/stories/201603100161

Legere, L. (2016, October 15) "Shale gas industry challenges Pa. drilling rules in court." *Pittsburgh Post-Gazette.* http://powersource.post-gazette.com/powersource/policy-powersource/2016/10/14/Gas-industry-files-suit-challenging-new-drilling-rules-in-Pennsylvania/stories/201610140177

Leiter, L. (June 26, 2017). Healthy Homes: Re-Framing Fracking Impacts. *FracTracker Alliance blogs.* https://www.fractracker.org/2017/06/healthy-home-re-framing-fracking/

Lewis C., Greiner, L.H., Brown D.R. Setback distances for unconventional oil and gas development: Delphi study results. *PLoS ONE*. August 16, 2018. *13*(8):e0202462 https://doi.org/10.1371/journal.pone.0202462

Li L, Blomberg AJ, Spengler JD, Coull BA, Schwartz JD, Koutrakis P. Unconventional oil and gas development and ambient particle radioactivity. *Nature Communications*. **11,** 5002 (2020) https://doi.org/10.1038/s41467-020-18226-w
https://www.theguardian.com/environment/2020/oct/13/airborne-radioactivity-increases-downwind-of-fracking-study-finds

Litvak, A (January 28, 2015) “Pennsylvania Department of Environmental Protection changes rules for oil and gas sludge at landfills.” *Pittsburgh Post-Gazette.* http://powersource.post-gazette.com/powersource/policy-powersource/2015/01/28/DEP-changes-rules-for-oil-and-gas-sludge-at-landfills/stories/201501280051

Litvak, A. (August 18, 2015) “EPA unveils tougher emissions rules for shale sites.” *Pittsburgh Post-Gazette.* http://powersource.post-gazette.com/powersource/policy-powersource/2015/08/18/EPA-unveils-new-rules-for-methane-VOC-emissions-for-oil-and-gas-sources/stories/201508180150

Litvak, A. (September 28, 2015) “Methane leak data in PA paints an uncertain picture.” *Pittsburgh Post-Gazette.* http://powersource.post-gazette.com/powersource/policy-powersource/2015/09/28/Methane-leak-data-in-Pa-paints-an-uncertain-picture/stories/201509280011

Litvak, A. (December 15, 2016), “Beaver County township delays permit approval for Shell cracker”. *Pittsburgh Post-Gazette*. http://www.post-gazette.com/powersource/policy-powersource/2016/12/14/Potter-Township-delays-approval-of-land-permit-for-Shell-cracker-asks-for-more-information/stories/201612150092

Litvak, A. (August 28, 2017). “Shell agrees to install fenceline air monitors at Beaver County ethane cracker plant.” *Pittsburgh Post-Gazette*. http://powersource.post-gazette.com/powersource/companies/2017/08/28/Royal-Dutch-Shell-ethane-cracker-plant-Beaver-County-fenceline-air-monitors-environment/stories/201708280137

Litvak, A. and Radwin, M. (2014, August 31) “Shale drillers’ landfill records don’t match that of Pennsylvania DEP.” *Pittsburgh Post-Gazette*. Retrieved September 15, 2014 at http://powersource.post-gazette.com/powersource/companies-powersource/2014/08/31/Shale-drillers-landfill-records-don-t-match-the-state-s-Pennsylvania/stories/201408310111

Loose, C. (June, 2012). "Shale Gas Workshop Explores Needed Research on Fracking," *Environmental Factor,* NIEHS. Retrieved from http://www.niehs.nih.gov/news/newsletter/2012/6/file72690.pdf#search=fracking

Lustgarten, A. and Kusnetz, N. (Sept. 16, 2011). "Science Lags as Health Problems Emerge Near Gas Fields." *ProPublica*. Retrieved at: http://www.propublica.org/article/science-lags-as-health-problems-emerge-near-gas-fields

Lutz, B.D., Lewis, A.N., Doyle, M.W. (2013). "Generation, transport, and disposal of wastewater associated with Marcellus Shale gas development," *Water Resource Research* (Accepted Article). DOI: 10.1002/wrcr.20096

Lyderson, K. (n.d.). "The Rush to Mine 'Frac Sand' in the Midwest," American Planning Association News Briefs.

Malin, S. Depressed democracy, environmental injustice: the negative mental health implications of unconventional oil and gas production in the United States. *Energy Research & Social Science*, **70**, 101720. (December 1, 2020). https://www.doi.org/10.1016/j.erss.2020.101720

Mamula, K. & Litvak, A. Officials believe landslide may have triggered massive gas pipeline explosion in Beaver County. September 10, 2018. *Pittsburgh Post-Gazette.* http://www.post-gazette.com/local/west/2018/09/10/gas-explosion-in-center-township-Beaver-County/stories/201809100067

Marcellus Drilling News. (June 27, 2017). "Shell Gets Important Wastewater Permit for Beaver Cracker Plant." http://marcellusdrilling.com/2017/06/shell-gets-important-wastewater-permit-for-beaver-cracker-plant/

Marcellus Drilling News. (May 27, 2020) PTT further delays Ohio cracker decision to 2021. https://marcellusdrilling.com/2020/05/ptt-further-delays-ohio-cracker-decision-to-2021/

Marcellus Shale Coalition (2013). "MSC, PIOGA to Study Radioactivity Levels in Shale Operations." Press Release. Retrieved at: http://marcelluscoalition.org/2013/11/msc-pioga-to-study-radioactivity-levels-in-shale-operations/

Marcellus Shale Coalition (April 9, 2015). "Five Facts About Natural Gas Development and Radon Claims." http://marcelluscoalition.org/2015/04/five-facts-about-natural-gas-development-radon-claims/
Maryland Marcellus Shale Public Health Study (2014). University of Maryland School of Public Health. Milton, D., Wilson, S., Jiang, C., Dalemarre, L. Sapkota, A., Sangaramoorthy, T., Boyle. M. Retrieved September 14, 2014, via http://phpa.dhmh.maryland.gov/OEHFP/EH/SitePages/MarcellusShale.aspx and at http://www.marcellushealth.org/uploads/2/4/0/8/24086586/2014.06.28_public_health_study_progreport_2.pdf

Marusic, K. (April 15, 2019) "After a decade of research, here's what scientists know about the health impacts of fracking." *Environmental Health News* https://www.ehn.org/health-impacts-of-fracking-2634432607.html

Maykuth, A. (September 19. 2015). "Turzai: GOP to propose 'Keystone Energy Zones' to help shale gas industry." *Philadelphia Inquirer.* http://articles.philly.com/2015-09-19/business/66681990_1_turzai-severance-tax-gas-industry

McCawley, M.A. (2017) Does increased traffic flow around unconventional resource development activities represent the major respiratory hazard to neighboring communities?; knowns and unknowns. *Current Opinion in Pulmonary Medicine.* (23) 2: 161-166. doi.10.1097/MCP.0000000000000361 http://journals.lww.com/co-pulmonarymedicine/Citation/2017/03000/Does_increased_traffic_flow_around_unconventional.10.aspx

McDermott-Levy, R., Katkins, N. (2012) *Preserving health in the Marcellus region*. College of Nursing, Villanova University, USA. Retrieved at: http://www.ncbi.nlm.nih.gov/pubmed/23155825

McElfish J and Stares D (July 2014). *Getting the Boom without the Bust: Guiding Southwestern Pennsylvania through Shale Gas Development.* Washington and Jefferson College. http://www.eli.org/sites/default/files/eli-pubs/getting-boom-final-paper-exec-summary-2014-07-28.pdf

McKelvey, W. Pa. budget loser: Bump in environmental protection budget does little to stem legacy of cuts. Penn Live. February 7, 2018. https://www.pennlive.com/politics/index.ssf/2018/02/wolf_budget_environmental_prot.html

McKenzie, LM., Witter, R.Z., Newman, L.S., and Adgate, J.L., (2012). "Human Health Risk Assessment of Air Emissions from Development of Unconventional Natural Gas Resources." *Science Of The Total Environment*. Retrieved at: http://cogcc.state.co.us/library/setbackstakeholdergroup/Presentations/Health%20Risk%20Assessment%20of%20Air%20Emissions%20From%20Unconventional%20Natural%20Gas%20-%20HMcKenzie2012.pdf

McKenzie, L.M., Guo, R., Witter, R.Z., Savitz, D.A., Newman, L.S., and Adgate J.L. (2014). "Birth Outcomes and Maternal Residential Proximity to Natural Gas Development in Rural Colorado." *Environmental Health Perspectives*. Retrieved at: http://ehp.niehs.nih.gov/wp-content/uploads/122/1/ehp.1306722.pdf

McKenzie, L.M., Crooks, J., Peel, J.L., Blair, B.D., Brindley, S., Allshouse, W.B., Malin, S., Adgate, J.L. (2019 March) Relationships between indicators of cardiovascular disease and intensity of oil and gas activity in Northeastern Colorado. *Environmental Research*, 170: 56-64. https://www.sciencedirect.com/science/article/pii/S0013935118306339

McKenzie, L.M., Allshouse, W., Daniels, S. (November 2019) Congenital heart defects and intensity of oil and gas well site activities in early pregnancy. *Environment International* 132, 104949 https://www.sciencedirect.com/science/article/pii/S0160412019315429?via%3Dihub

McLaughlin, M.C., Borch, T. & Blotevogel, J. (2016) Spills of hydraulic fracturing chemicals on agricultural topsoil: biodegradation, sorption, and co-contaminant interactions. *Environmental Science & Technology*, *50* (11). doi: 10.1021/acs.est.6b00240

McNamara DE, Rubinstein JL, Myers E, Smoczyk G, Benz HM, Williams RA, Earle P (2015). Efforts to monitor and characterize the recent increasing seismicity in central Oklahoma. *The Leading Edge* 34 (6). doi: 10.1190/tle34060628.1

Mehalik, M. (2017) Presentation to Regional Visioning session, October 4, 2017.

Michanowicz D, Ferrar K, Malone S, Kelso M, Kriesky J, Fabisiak JP (2013*). Pittsburgh Regional Environmental Threats Analysis (PRETA) Report: Hazardous Air Pollutants.* University of Pittsburgh Graduate School of Public Health, Center for Healthy Environments and Communities. http://www.heinz.org/UserFiles/Library/PRETA_HAPS.pdf

Mickley,S.and Blake, U. (May 7, 2012) "Institute of Medicine Roundtable: Need Better Perspective on Shale Gas." Independent Petroleum Association of America's Energy In Depth website. http://energyindepth.org/marcellus/institute-of-medicine-roundtable-needbetter-perspective-on-shale-gas/

Minnesota Environmental Quality Board (March 20, 2013) Final Report on Silica Sand. http://www.eqb.state.mn.us/documents/23.%20March%20Final%20Silica%20Sand%20report.pdf

Moench, B. (2014, May 25) "Dead babies and Utah's carbon bomb," *Truthout*. http://truth-out.org/opinion/item/23885-dead-babies-and-utahs-carbon-bomb

Morris, J. (2014). "Texas Family Plagued with Ailments Gets $3M in First-of-its-Kind Fracking Judgment, *CNN.* Retrieved at: **http://www.cnn.com/2014/04/25/justice/texas-family-wins-fracking-lawsuit/**

Morris, J. (2018, December 21). Death in the oilfields. *Texas Tribune*. https://www.texastribune.org/2018/12/21/death-oilfields-fossil-fuel-boom-brings-mounting-risks/

Mosier, J. (February 3, 2017). "Wise County couple that sued Plano gas company may lose their $2.9 million judgment." *Dallas News*.
https://www.dallasnews.com/business/energy/2017/02/03/couple-featured-gasland-part-2-29-million-jury-award-reversed

Mullen KR, Rivera BN, Tidwell LG, Ivanek R, Anderson KA, Ainsworth DM.
Environmental surveillance and adverse neonatal health outcomes in foals born near unconventional gas development activity. *Science of the Total Environment*, 20 August 202. Vol. 731, 138497
https://doi.org/10.1016/j.scitotenv.2020.138497

Nagel SC, Kassotis CD, Vandenberg LN, Lawrence BP, Robert J, Balise VD. Developmental exposure to a mixture of oil and gas chemicals: A review of experimental effects on adult health, behavior, and disease. *Molecular and Cellular Endocrinology*. March 5, 2020. 110722.
https://doi.org/10.1016/j.mce.2020.110722

National Institute of Occupational Safety and Health (NIOSH). Fact Sheet: Oil and Gas Workers: How to Prevent Fatigued Driving at Work."
https://www.cdc.gov/niosh/docs/2018-126/

New York State Department of Environmental Conservation (June 29, 2015). "New York State Officially Prohibits High-Volume Hydraulic Fracturing" http://www.dec.ny.gov/press/102337.html
Findings Statement: http://www.dec.ny.gov/docs/materials_minerals_pdf/findingstatehvhf62015.pdf

New York State Department of Health. (2014). A Public Health Review of High Volume Hydraulic Fracturing for Shale Gas Development. Albany, NY.
http://www.health.ny.gov/press/reports/docs/high_volume_hydraulic_fracturing.pdf

Nobel, J. (April 1, 2020) Nature scores a big win against fracking in a small Pennsylvania Town. *Rolling Stone*. https://www.rollingstone.com/politics/politics-news/rights-of-nature-beats-fracking-in-small-pennsylvania-town-976159/

Nocera, J. (2013, October 4). "A Fracking Rorschach Test." *New York Times*. Retrieved at:
http://www.nytimes.com/2013/10/05/opinion/a-fracking-rorschach-test.html?_r=0

NRDC, Friedman R, Guerrero M & Ong K. (May 11 2020). NRDC and CMK file brief to block fracking in Delaware Basin. https://www.nrdc.org/experts/marisa-guerrero/nrdc-cmk-file-brief-block-fracking-delaware-basin

Occupational Health and Safety Memo (5/24/12). "NIOSH Sounds Alarm on Fracking Silica Exposure." Retrieved at: http://ohsonline.com/articles/2012/05/24/niosh-sounds-alarm-on-fracking-silica-expos

O'Connell, J. (2014, October 2). "Senators Ask How to Address Fracking-Related Health Issues." *Times-Leader*. Retrieved October 2, 2014 at http://www.timesleader.com/news/local-news-news/50413624/

Oil & Gas Journal (June, 2014). "Link Strengthened between Wastewater Injection and Oklahoma Earthquakes." Retrieved from: http://www.ogj.com/articles/uogr/print/volume-2/issue-3/link-strengthened-between-wastewater-injection-and-oklahoma-earthquakes.html

Oil and Gas Threat Map 2.0 (2018) Produced by Earthworks, Clean Air Task Force, and FracTracker Alliance. https://oilandgasthreatmap.com/threat-map/pennsylvania/

Olaguer EP, Erickson M, Wijesinghe A, Neish B, Williams J and Colvin J (2016). "Updated methods for assessing the impacts of nearby gas drilling and production on neighborhood air quality and human health." *Journal of the Air & Waste Management Association* Vol 66: Issue 2. http://dx.doi.org/10.1080/10962247.2015.1083914

Operation Clean Sweep® (2012-2015). Operation Clean Sweep® Program Manual. Accessed 11/1/2015 at http://www.opcleansweep.org/Standalone-Content/Operation-Clean-Sweep-Manual-PDF-Version.pdf

Oppel Jr. RA (June 30, 2015). "Oklahoma court rules homeowners can sue oil companies over quakes." *The New York Times*. http://www.nytimes.com/2015/07/01/us/oklahoma-court-rules-homeowners-can-sue-oil-companies-over-quakes.html?emc=edit_tnt_20150630&nlid=66402583&thtemail0=y&_r=0

Oreskes, N. and Conway, E. (2010). *Merchants of Doubt: How a Handful of Scientists Obscured the Truth on Issues from Tobacco Smoke to Global Warming.* Bloomsbury Press, New York.

OSHA Infosheet (n.d.) "Silica Exposure During Hydraulic Fracturing." Retrieved at: http://www.osha.gov/dts/infosheets/silicahydraulic fracturing.html

OSHA-NIOSH Hazard Alert, (May 2012). Worker Exposure to Silica During Hydraulic Fracturing, Retrieved from: http://www.osha.gov/dts/hazardalerts/hydrolic_frac_hazard_alert.html

PA Department of the Auditor General (2014). "Auditor General DePasquale Says Rapid Shale Gas Development Outpaced DEP's Ability to Oversee Industry, Protect Water Quality." Retrieved at: http://www.auditorgen.state.pa.us/press-releases/auditor-general-depasquale-says-rapid-shale-gas-development-outpaced-dep%E2%80%99s-ability-to-oversee-industry-protect-water-quality,

PA.GOV News Release (January 19, 2016) "Governor Wolf Announces New Methane Rules to Improve Air Quality, Reduce Industry Loss." https://www.governor.pa.gov/governor-wolf-announces-new-methane-rules-to-improve-air-quality-reduce-industry-loss/

Papoulias, D. & MacKenzie, T. (2013, August 8). "Hydraulic Fracturing Fluids Likely Harmed Threatened Kentucky Fish Species." USGS Newsroom. http://www.usgs.gov/newsroom/article.asp?ID=3677

Paterson, L. and S-Brock, J.W. (2014, September 5). "If You Read Only One Story on Health and Fracking, Read This One." Wyoming Public Media. Retrieved at http://wyomingpublicmedia.org/post/if-you-read-only-one-story-health-and-fracking-read-one

Patnode KA, Hittle E, Anderson, Zimmerman L, Fulton JW (2015). Effects of High Salinity Wastewater Discharges on Unionid Mussels in the Allegheny River, Pennsylvania. *Journal of Fish and Wildlife Management:* June 205, Vo 6, No. 1,. Pp. 55-70. http://www.fwspubs.org/doi/10.3996/052013-JFWM-033

Paulik, L.B., Hobbie, K.A., Rohlman, D., Smith, B.W., Scott, R.P., Kincl, L., Haynes, E.N., Anderson, K.A. Environmental & individual PAH exposures near rural natural gas extraction. (2018) *Environmental Pollution,* 241: 397-405. https://www.sciencedirect.com/science/article/pii/S0269749117347176?via%3Dihub

Paulson, J. & Barnett, C. (2010). "Who's in Charge of Children's Environmental Health at School?" *New Solutions 20 (1):3-23.* doi: 10.2190/NS.20.1.b.

Pelley, J. (May 30, 2020) How air pollution messes with our minds. *Chemical & Engineering News*. Vol. 98, Issue 21
https://cen.acs.org/biological-chemistry/neuroscience/air-pollution-messes-minds/98/i21#:~:text=Air%20pollution%20inflames%20the%20brain,such%20as%20dementia%20and%20autism

Peng L, Meyerhoefer C, Chou S-Y. The health implications of unconventional natural gas development in Pennsylvania. *Health Economics*. 2018;*27*:956–983. https://doi.org/10.1002/hec.3649

Penn Medicine (April 2013). "Penn Pilot Study Finds that Group of Bradford County, PA Residents Concerned About Health Effects of Hydraulic Fracturing." Retrieved from: http://www.uphs.upenn.edu/news/News Releases/2013/04/fracking/

Pennsylvania Department of Environmental Protection (2015). Technologically Enhanced Naturally Occurring Radioactive Materials (TENORM) study report. http://www.elibrary.dep.state.pa.us/dsweb/Get/Document-105822/PA-DEP-TENORM-Study_Report_Rev._0_01-15-2015.pdf

Pennsylvania Department of Environmental Protection (2015). Air Quality Program. Plan Approval Permit #04-00740A Shell Chemical Appalachia LLC Potter Township, Beaver County Issue Date: June 18, 2015. Expiration Date: June 18, 2019.
http://files.dep.state.pa.us/RegionalResources/SWRO/SWROPortalFiles/Shell_FINAL/PA-04-00740A%20Issued%20Signed%206-18-15.pdf

Pennsylvania Department of Environmental Protection (2015). Bureau of Point and Non-Point Source Management. Authorization to Discharge Under the National Pollutant Discharge Elimination System Discharge Requirements for Industrial Wastewater Facilities. NPDES Permit No: PA0002208. Shell Chemical Appalachia, LLC. Effective July 1, 2015. Expires: June 30, 2020.
http://files.dep.state.pa.us/RegionalResources/SWRO/SWROPortalFiles/Shell_FINAL/NPDES%20PA0002208.pdf

Pennsylvania Department of Environmental Protection Oil and Gas Reports. Retrieved October 21, 2016. http://www.dep.pa.gov/DataandTools/Reports/Oil%20and%20Gas%20Reports/Pages/default.aspx

Pennsylvania Department of Environmental Protection. PA Oil and Gas Mapping.
Retrieved October 16, 2017.
http://www.depgis.state.pa.us/PaOilAndGasMapping/

Pennsylvania Department of Environmental Protection. e-Facts. Authorization search (permit) Retrieved October 25, 2019
https://www.ahs.dep.pa.gov/eFACTSWeb/searchResults_singleAuth.aspx?AuthID=1232430

Phillips, S. (2011, October 13). "Former DEP Official Says State Lacks in Air Quality Enforcement." *StateImpact: A Reporting Project of Local Public Media and NPR*. Retrieved from http://stateimpact.npr.org/pennsylvania/2011/10/13/former-dep-official-says-state-lacks-in-air-quality-enforcement-and-updated-regulations-for-gas-drilling/)

Phillips, S. (2011, September 22). "Burning Question: Where Are Pennsylvania's Deep Injection Wells?" *StateImpact: A Reporting Project of Local Public Media and NPR*. Retrieved from: http://stateimpact.npr.org/pennsylvania/2012/11/08/ where-are-pas-deep-injection-wells/

Phillips, S. (2011, December 5). "Burning Question: What Would Life Be Like without the Halliburton Loophole?" *StateImpact: A Reporting Project of Local Public Media and NPR*. Retrieved from: http://stateimpact.npr.org/pennsylvania/2011/12/05/burning-question-what-would-life-be-like-without-the-halliburton-loophole/

Phillips, S. (2012, Nov. 8). "New Injection Wells Planned for Elk and Clearfield Counties." *StateImpact: A Reporting Project of Local Public Media and NPR*. Retrieved from: http://stateimpact.npr.org/pennsylvania/2012/11/08/ new-deep-injection-wells-planned-for-elk-and-clearfield-counties/

Phillips, S. (2013, January 24). "PA DEP to Study Radiation in the Marcellus Shale" *StateImpact: A Reporting Project of Local Public Media and NPR*. Retrieved from: http://stateimpact.npr.org/pennsylvania/2013/01/24/pa-dep-to-study-radiation-related-to-marcellus-shale/

Phillips, S. (2016, April 28) "Spate of small earthquakes shuts down fracking activity in Lawrence County." *NPR State Impact. https://stateimpact.npr.org/pennsylvania/2016/04/28/spate-of-small-earthquakes-shuts-down-fracking-activity-in-lawrence-county/*

Phillips, S. (2017, September 13) "DRBC takes a step toward banning fracking in Northeast Pa." *NPR State Impact*. https://stateimpact.npr.org/pennsylvania/2017/09/13/drbc-takes-a-step-toward-banning-fracking-in-northeast-pa/

Pittsburgh Post-Gazette (December 8, 2019) Study: Shale gas job gains don't offset the damage done. https://www.post-gazette.com/news/health/2019/12/08/shale-development-natural-gas-drilling-fracking-costs-health-study-pennsylvania-cmu/stories/201912060038

Pope, A.M., Snyder, M.A. and Mood, L.H., Eds. (1995). *Nursing, Health and Environment*. Institute of Medicine, National Academy Press, p. 2.
Potter, M.A. (2008) "Public Health in Pennsylvania: Where Do We Go From Here?" *Commonwealth: A Journal of Political Science* 14 (1).

PSE Healthy Energy (2015). Toward an understanding of the environmental and public health impacts of shale gas development: an analysis of the peer-reviewed scientific literature, 2009-2015. Physicians, Scientists and Engineers for Healthy Energy. July 2015 update: http://www.psehealthenergy.org/data/Database_Analysis_2015.6_.16_.pdf

PSE Healthy Energy Repository for Oil and Gas Research (ROGER). https://psehealthyenergy.org/ourwork/shale-gas-research-library/

PTT Global Chemical America, Belmont County OH project website. http://pttgcbelmontcountyoh.com/

Rabinowitz, P.M., Slizovskiy, I.B., Lamers, V., Trufan, S.J., Holford, T.R., Dziura, J.D., Peduzzi, P.M., Kane, M.J., Reif, J.S., Weiss, T.R., Stowe, M.H. (2014) "Proximity to Natural Gas Wells and Reported Health Status: Results of a Household Survey in Washington County, Pennsylvania." *Environ Health Perspect* advance online publication, retrieved September 15, 2014 at http://ehp.niehs.nih.gov/1307732/

Rando R.J., Vacek P.M., Glenn R.E., Kwon C.W., Parker J.E. Retrospective assessment of respirable quartz exposure for a silicosis study of the industrial sand industry. *Annals of Work Exposures and Health*. October 15 2018. *62* (8): 1021-1032. https://www.ncbi.nlm.nih.gov/pubmed/30016388

Rasmussen SG, Ogburn EL, McCormack M, Casey JA, Bandeen-Roche K, Mercer DG, Schwartz BS. Association Between Unconventional Natural Gas Development in the Marcellus Shale and Asthma Exacerbations. *JAMA Intern Med.* 2016;176(9):1334-1343. doi:10.1001/jamainternmed.2016.2436 http://archinte.jamanetwork.com/article.aspx?articleid=2534153

Rasmussen, S.G., Schwartz, B.S., and Casey, J.A. (August 25, 2016). "Fracking and health: What we know from Pennsylvania's natural gas boom." *The Conversation.* Retrieved at: https://theconversation.com/fracking-and-health-what-we-know-from-pennsylvanias-natural-gas-boom-63911

Rattner, M. & Tiemann, M. (2014, January 23). "An Overview of Unconventional Oil and Natural Gas: Resources and Federal Actions." Congressional Research Service. Accessed October 3, 2014 at http://fas.org/sgp/crs/misc/R43148.pdf

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 at http://www.velj.org/uploads/1/2/7/0/12706894/2._rawlins_-_barnett_shale.pdf

Range Resources, (n.d.). "Natural Gas, Range Resources and the Marcellus Shale."

Reber, C., Rogers, C., Sweeney, M.B., Ferraro J., Jimenez-Jacobs, P, VanCise-Watta, D., Bonnet, V., Shotts, A., Rittle, L., McClure, S., Hess, S., *Marcellus Shale Natural Gas Extraction Study Guide Addenda: Developments in Air Quality*, League of Women Voters of Pennsylvania. Retrieved from: http://www.palwv.org/Issues/Natural-Resources/Marcellus-Shale.asp

Resick L.K., Knestrick, J.M. (2013). "Health and the Natural Gas Industry: What Every NP Needs to Know." Presented at: American Association of Nurse Practitioners 2013 National Conference. June 19-23, 2013; Las Vegas. *Clinical Advisor.* Retrieved at: http://www.clinicaladvisor.com/be-aware-of-health-problems-near-fracking-sites/article/300741/

Rich, A. and 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.* Volume 23, No. 2, 117-136.

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.

Royte, E. (2012). "Fracking our Food Supply." *The Nation.* Retrieved from: http://www.thenation.com/article/171504/fracking-our-food-supply

Saberi P, Propert KJ, Powers M, Emmett E, Green-McKenzie J. (2014). Field survey of health perceptions and complaints of Pennsylvania residents in the Marcellus shale region. *International Journal of Environmental Research and Public Health* 11:6517-6527. doi:10.3390/ijerph110606517

Sapouckey, S.A., Kassotis C.D., Nagel, S.C., Vandenburg, L.N. Prenatal exposure to unconventional oil and gas operation chemical mixtures altered mammary gland development in adult female mice. *Endocrinology*. 2018 Mar. 1; *159* (3): 1277-1289. https://www.ncbi.nlm.nih.gov/pubmed/29425295

Save EPA https://saveepaalums.info/rollback+tracker Accessed 10/14/18

Science and Environmental Health Network, (January, 1998). "Wingspread Conference and the Precautionary Principle." Retrieved at: http://www.sehn.org/wing.html

Science Daily, (2012). "Analysis of Marcellus Flowback Finds High Levels of Ancient Brines" Retrieved from: http://www.sciencedaily.com/releases/2012/12/121218203537.htm

Science Daily, (2013). "Many Stressors Associated With Fracking Due to Perceived Lack of Trust" Retrieved from: http://www.sciencedaily.com/releases/2013/04/130429130550.htm

Scofield, H. (2011, May 13) "Study: Fracking Health Impacts Underestimated." *The Durango Herald* http://durangoherald.com/article/20110513/NEWS01/705139921/0/s/Study:-Fracking-health-impacts-underestimated

Setti L, Passarini F, De Gennaro G, Barbieri P, Pallavicini A, Colao A, Miani A. Searching for SARS-COV-2 on particulate matter: A possible early indicator of COVID-19 epidemic recurrence. *Int. J. Environ. Res. Public Health.* 2020, 17 (9) 2986. https://doi.org/10.3390/ijerph17092986

Shirzaei, M., Ellsworth, W.L., Tiampo, K.F., Gonzalez, P.J., & Manga, M. (2016) Surface uplift and time-dependent seismic hazard due to fluid injection in eastern Texas. *Science*, 353 (6306). doi:10.1126/science.aag0262

Shogren, E. (2012, May 15). " 'Close Encounters' with Gas Well Pollution." NPR. http://www.npr.org/2012/05/15/149998263/close-encounters-with-gas-well-pollution

Shonkoff, S.B. Hays, J. & Finkel, M.L. (2014)." Environmental Public Health Dimensions of Shale and Tight Gas Development." *Environmental Health Perspectives.* doi: 10.1289/ehp.1307866.

Shulman A. (2011). (personal communication). Quoted in "Environmental Impact," *LWV Study Guide II*, Retrieved at: http://www.palwv.org/files/224_MarcellusShaleStudyGuideII.pdf

Snawder, J., Esswein, E., King, B., Breitenstein, M., Alexander-Scott, M., Retzer, K., Kiefer, M., Hill, R. (2014, May 19). "Reports of Worker Fatalities at Flowback Operations." NIOSH Science Blog. Retrieved September 14, 2014 at http://blogs.cdc.gov/niosh-science-blog/2014/05/19/flowback/

Socha, E. (2013). "Degenstein Foundation gives $1 million to Geisinger for study of drilling effects." *The Daily Item.* Retrieved at: http://dailyitem.com/0100_news/x766091919/ Degenstein-Foundation-gives-1-million-to-Geisinger-for-study-of-drilling-effects

Song, L. (2012). "Hazardous Air Pollutants Detected at Fracking Sites" *Bloomberg.* Retrieved from: http://www.bloomberg.com/news/2012-12-03/hazardous-air-pollutants-detected-near-fracking-sites.html

Soraghan, M. (2013, July 22) "Earthquakes: 'Do Not Operate' Quake-Linked Disposal Wells – EPA Draft Report." *E&E*. Retrieved October 5, 2014 at http://www.eenews.net/stories/1059984752

Southwest Pennsylvania Environmental Health Project.
Retrieved at: http://www.environmentalhealthproject.org/about/

Southwest Pennsylvania Environmental Health Project, Medical Resources. Retrieved at: http://www.environmentalhealthproject.org/resources/medical-resources/

Southwest Pennsylvania Environmental Health Project, "Good Things to Do if you Live Near Gas Drilling." Retrieved at: http://www.environmentalhealthproject.org/wp-content/uploads/2012/03/3-Steps-02.15.12-FINAL.pdf

Southwest Pennsylvania Environmental Health Project (2015) Weinberger B, Curtis L, Kriesky J, He AL, Brown D. White paper: *The Case for an Unconventional Natural Gas Development Health Registry*. http://www.environmentalhealthproject.org/wp-content/uploads/2015/10/Registry-White-Paper-09.08.15-PDF.pdf

Southwest Pennsylvania Environmental Health Project (2016, May 9). "The Problem of Setback Distance for Unconventional Oil and Gas Development: An analysis of expert opinions." *Technical Reports*, Issue 2. Retrieved from: http://www.environmentalhealthproject.org/researchers/resources

Southwest Pennsylvania Environmental Health Project. (2017). Environmental Health Project Shale Gas & Oil Health Registry and Resource Network. http://www.environmentalhealthproject.org/health-effect-registry

Stacy SL, Brink LL, Larkin JC, Sadovsky Y, Goldstein BD, Pitt BR, Talbott EO. (2015) Perinatal Outcomes and Unconventional Natural Gas Operations in Southwest Pennsylvania. PLoS ONE 10:e0126425 http://journals.plos.org/plosone/article?id=10.1371/journal.pone.0126425

Stacy, S.L. (2017). A Review of the Human Health Impacts of Unconventional Natural Gas Development. *Curr Epidemiol Rep*. DOI 10.1007/s40471-017-0097-9 https://link.springer.com/article/10.1007/s40471-017-0097-9

Stares, D. (2013) "Framing Sustainability Questions for Marcellus Shale Development" Washington & Jefferson College, Center for Energy Policy & Management. PowerPoint presentation retrieved at law.widener.edu/Spiffs/.../~/media/Files/.../StaresChallengesv2.ashx

State Impact Topics (n.d.). "DEP: The Department that Regulates and Oversees Drilling." Retrieved at: http://stateimpact.npr.org/pennsylvania/tag/department-of-environmental-protection

State Impact Topics (n.d.). "Dimock, PA: 'Ground Zero' in the Fight over Fracking." Retrieved from: http://stateimpact.npr.org/pennsylvania/tag/dimock/

Stein, R. (2012, May 15). "Sick from Fracking? Doctors, Patients Seek Answers." NPR. Retrieved from: http://www.npr.org/2012/05/15/152268475/sick-from-fracking-doctors-patients-seek-answers

Steinzor, N., Subra, W. and 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,* Vol. 23(1) 55-83.

Stephan, Dominik (2016, July 9) "Will They or Won't They: Shell's Plans for Its Six Billion Dollar Ethane Project."PRO*CESS Worldwide http://www.process-worldwide.com/will-they-or-wont-they-shells-plans-for-its-six-billion-dollars-ethane-project-a-542730/

Stephan, Dominik (2016, August 10) "Shale Fuels Megaplants in the US: Shell and PPT Go Ahead with Cracker Projects." PRO*CESS Worldwide http://www.process-worldwide.com/shale-fuels-megaplants-in-the-us-shell-and-ptt-go-ahead-with-cracker-projects-a-545315/

Stolz, J. (2013) “The Woodlands: a case study of well water contamination related to unconventional gas extraction.” Presentation at “Facing the Challenges” Research on Shale Gas Extraction Symposium, Duquesne University, November 26, 2013.

Stonesifer, J. (2019, February 4) Shell to build innovation center at Potter Township cracker plant site. *Ellwood City Ledger* https://www.ellwoodcityledger.com/news/20190204/shell-to-build-innovation-center-at-potter-township-cracker-plant-site

Sutter County General Plan, Background Report. Found 4/15/11 Retrieved at: http://ceres.ca.gov/planning/genplan/sutter/index.html

Sweeney, M.B., McClure, S., Chandler, S., Reber, C., Ferraro, J., Jimenez-Jacobs, P., VanCise-Watta, D., Rogers, C., Bonnet, V., Shotts, A., Rittle, L., Hess, S. (2009). "Marcellus Shale Natural Gas: Environmental Impact." League of Women Voters of Pennsylvania. Retrieved from: http://www.palwv.org/files/224_MarcellusShaleStudyGuideII.pdf

Tasker T.L., Burgos W.D., Piotrowski P., Castillo-Meza L., Blewett T.A., Ganow K.B., Stallworth A., Delompré P.L.M., Goss G.G., Fowler L.B., Vanden Heuvel J.P., Dorman F., and Warner, N.R.. Environmental and Human Health Impacts of Spreading Oil and Gas Wastewater on Roads. *Environmental Science & Technology* **2018** *52* (12), 7081-7091 https://pubs.acs.org/doi/10.1021/acs.est.8b00716

Templeton, D. & Hopey, D. (2019, May 14) Are the 27 cases of Ewing sarcoma near Pittsburgh a cluster? *Pittsburgh Post-Gazette*. https://newsinteractive.post-gazette.com/ewing-sarcoma-cancer-cluster-pittsburgh-washington-westmoreland/

Templeton, D. & Hopey, D. (2019, October 7) Health officials’ claim of no cancer cluster angers Canon-McMillan crowd. *Pittsburgh Post-Gazette*. https://www.post-gazette.com/local/washington/2019/10/07/Canon-mcmillan-ewing-sarcoma-cluster-cancer-meeting-UPMC/stories/201910070110

Texas Department of Agriculture, Office of Natural Resources (1985). *Agricultural Land and Water Contamination: From Injection Wells Used in Oil and Gas Production* (pp.5,12-15). Austin, TX: Deprat. of Agriculture, Office of Natural Resources.

Texas Department of State Health Services (2014, July 30). “Updated Summary Report: Occurrence of Cancer In Zip Codes 75022 & 75028, Flower Mound, Denton County, Texas, 2002-2011.” Retrieved September 15, 2014 via https://www.dshs.state.tx.us/news/releases/20140730.aspx

The Endocrine Disruption Exchange (n.d.), TEDX*, Chemicals in Natural Gas Operations*. Retrieved at: http://www.endocrinedisruption.com/chemicals.introduction.php

Thompson, C., (2012). ″University at Buffalo Closes its Shale Gas Research Institute Amid Accusations of Undisclosed Industry Ties." *Huffington Post.* Retrieved at: http://www.huffingtonpost.com/2012/11/20/university-at-buffalo-shale-gas-research_n_2165101.html

Tran KV, Casey JA, Cushing LJ, Morello-Frosch R. Residential proximity to oil and gas development and birth outcomes in California: A retrospective cohort study of 2006-2015 births. ***Environmental Health Perspectives*** 128 (6) June 3, 2020 67001 https://doi.org/10.1289/EHP5842

Tustin AW, Hirsch AG, Rasmussen SG, Casey JA, Bandeen-Roche K, Schwartz BS (2016). Associations between Unconventional Natural Gas Development and Nasal and Sinus, Migraine Headache, and Fatigue Symptoms in Pennsylvania. Environ Health Perspect; http://ehp.niehs.nih.gov/ehp281/#tab1

University of Pittsburgh (2013, February 28). "Act 13 in 3-D: Drilling, Doctors and Disclosure." Symposium held by the *Pittsburgh Journal of Environmental and Public Health Law.*

Urbina, I. (2011, February26,) "Regulation Lax as Gas Wells' Tainted Water Hits Rivers." *New York Times.* Retrieved at: http://www.nytimes.com/2011/02/27/us/27gas.html?pagewanted=all

Urbina, I., (2012, May 14). "Deadliest Danger isn't at the Rig but on the Road," *New York Times*. Retrieved at: http://www.nytimes.com/2012/05/15/us/for-oil-workers-deadliest-danger-is-driving.html?_r=4&hp& and http://www.nytimes.com/interactive/2012/05/03/us/death-on-the-job.html?ref=us

U.S. Congress, H.R. 2576, The Frank R. Lautenberg Chemical Safety for the 21st Century Act, "to modernize the Toxic Substances Control Act." (2016) https://www.congress.gov/114/bills/hr2576/BILLS-114hr2576enr.pdf

U.S. Congress, (5/09/2017). S. 1075 - Appalachian Ethane Storage Hub Study Act https://www.congress.gov/bill/115th-congress/senate-bill/1075/text?format=txt

U.S. Department of Labor, Occupational Safety and Health Administration (2016). OSHA's Final Rule to Protect Workers from Exposure to Respirable Crystalline Silica. https://www.osha.gov/silica/

U.S. Environmental Protection Agency (2010, January 29). Air Pollution Control Orientation Course. Retrieved from: http://www.epa.gov/apti/course422/index.html

U.S. EPA. Effluent Guidelines. Unconventional Extraction in the Oil and Gas Industry. http://www2.epa.gov/eg/unconventional-extraction-oil-and-gas-industry (Retrieved 2015)

U.S. EPA. Assessment of the Potential Impacts of Hydraulic Fracturing for Oil and Gas on Drinking Water Resources (External Review Draft). U.S. Environmental Protection Agency, Washington, DC, EPA/600/R-15/047, 2015. http://cfpub.epa.gov/ncea/hfstudy/recordisplay.cfm?deid=244651#_ga=1.85464090.207662039.1445135640
Executive Summary:
http://www2.epa.gov/sites/production/files/2015-07/documents/hf_es_erd_jun2015.pdf

U.S. Environmental Protection Agency. (October 2, 2017). Draft FY 2018-2022 EPA Strategic Plan. Public Review Draft.
https://www.eenews.net/assets/2017/10/04/document_pm_02.pdf

Van Hampton, T. (2012). "OSHA Studies Frac Sand, Puts Brakes on Silica Rules," *ENR Engineering News-Record*: 10/29/12 Vol. 269. P1-1
Retrieved at: http://ehis.ebscohost.com/ehost/delivery?sid=de20eb7d-07fc-466b-a4a5-560347leb4b6%40

Vandenburg, L.N., Colborn, T., Hayes, T.B., Heindel, J.J., Jacobs, D.R., Duk-Hee,L., Shioda, T., Soto, A.M., vom Saal, F.S., Welshons, W.V., Zoeller, R.T., Myers, J.P. (2012). "Hormones and Endocrine-Disrupting Chemicals: Low-Dose Effects and Nonmonotonic Dose Responses." *Endocr Rev.* June 2012; 33(3): 378-455. http://www.ncbi.nlm.nih.gov/pmc/articles/PMC3365860/

Veazey, M.V. (September 22, 2015) Ohio Valley labor crunch puts ethane cracker project on hold. *Rig Zone*. http://www.freerepublic.com/focus/f-news/3340217/posts

Vincent, M. (2009). *Examining our assumptions-- Have oversimplifications jeopardized our ability to design optimal fracture treatments?* Lecture presented at Society of Petroleum Engineers conference on hydraulic fracturing technology, The Woodlands, Texas.

Warner, N.R., Christie, C.A., Jackson, R.B., and Vengosh, A. (2013) "Impact of Shale Gas Wastewater Disposal on Water Quality in Western Pennsylvania." *Environmental Science and Technology*., 47 (20), pp 11849-11857. http://pubs.acs.org/doi/abs/10.1021/es402165b . Also reported in Bloomberg Businessweek, Efstathiou, J. (October 2, 2013) "Radiation in Pennsylvania Creek Seen as Legacy of Fracking." http://www.businessweek.com/news/2013-10-02/radiation-in-pennsylvania-creek-seen-as-legacy-of-fracking-waste#p1

Watson, B., University of Dayton School of Law. (July 23, 2016) "Hydraulic Fracturing Tort Litigation Summary."
https://www.udayton.edu/directory/law/documents/watson/blake_watson_hydraulic_fracturing_primer.pdf

Webb E, Hays J, Dyrszka D, Rodriguez B, Cox C, Huffling K, Bushkin-Bedient S. Potential hazards of air pollutant emissions from unconventional oil and natural gas operations on the respiratory health of children and infants. *Rev Environ Health* 2016;aop
https://www.degruyter.com/abstract/j/reveh.ahead-of-print/reveh-2014-0070/reveh-2014-0070.pdf

Weinberger, B., Greiner, L.H., Walleigh, L., Brown, D. (December 2017) Health symptoms in residents living near shale gas activity: A retrospective record review from the Environmental Health Project. *Preventive Medicine Reports*, (8) 112-115.
https://doi.org/10.1016/j.pmedr.2017.09.002

Werner AK, Vink S, Watt K, Jagals P. (2015) Environmental health impacts of unconventional natural gas development: A review of the current strength of evidence.
Science of the Total Environment 505:1127-1141.

West Virginia DEP (re: U.S. Methanol)
https://dep.wv.gov/daq/Documents/February%202017%20Drafts%20and%20IPR/039-00669_IPR_13-3351.pdf
https://dep.wv.gov/daq/Documents/February%202017%20Drafts%20and%20IPR/3351-Eval.pdf
https://dep.wv.gov/daq/Pages/NSRPermitsforReviewCurrent.aspx
https://dep.wv.gov/daq/Documents/February%202016%20Applications/051-00225_APPL_PD16-002.pdf

West Virginia DEP (re: Primus Green Energy)
https://dep.wv.gov/daq/Documents/October%202016%20Applications/051-00061_APPL_13.3343.pdf
https://dep.wv.gov/daq/Documents/February%202017%20Drafts%20and20%IPR/3343-Eval.pdf
https://dep.wv.gov/daq/Documents/March%202017%20Permits%20and%20Evals/051-00061_PERM_13-3343.pdf

Wetherbee O, Mecher JR, Devoto C, Penning TM, Moore JH, Boland MR. WellExplorer: an integrative resource linking hydraulic fracturing chemicals with hormonal pathways and geographic location, *Database*, Volume 2020, 2020, baaa053
https://doi.org/10.1093/database/baaa053

White, E. I., (October 2012). "Consideration of Radiation in Hazardous Waste Produced from Horizontal Hydrofracking," Retrieved at: http://www.grassrootsinfo.org/pdf/whitereport.pdf

Whitehead, S. January 23, 2018. Study overstating Marcellus methane emissions retracted. Energy In Depth. https://eidclimate.org/study-overstating-marcellus-methane-emissions-retracted/

Whitworth K.W., Marshall A.K., Symanski E. (2017) Maternal residential proximity to unconventional gas development and perinatal outcomes among a diverse urban population in Texas. *PLoS ONE* (12) 7: e0180966. https://doi.org/10.1371/journal.pone.0180966

Willis, M.D., Jusko, T.A., Halterman, J.S., Hill, E.L. Unconventional natural gas development and pediatric asthma hospitalizations in Pennsylvania. *Environmental Research*, October 2018. *166*: 402-408. https://doi.org/10.1016/j.envres.2018.06.022

Wogan, D. (2012). "University of Texas Fracking Study Has Industry Ties According to New Report." *Huffington Post.* Retrieved at: http://www.huffingtonpost.com/2012/07/24/university-of-texas-fracking-study_n_1699391.html

World Health Organization, *Guidelines for Community Noise*, Found 4/15/11
Retrieved at: http://whqlibdoc.who.int/hq/1999/a68672.pdf

World Health Organization, "Burden of disease from environmental noise: Quantification of healthy life years lost in Europe," Retrieved at:
http://docs.wind-watch.org/WHO-burden-of-disease-from-environmental-noise-2011.pdf

Wray, D. (2016, March 28). "The Way We Currently Monitor Air Pollution Near the Ship Channel Sucks, Researchers Say." *Houston Press. http://www.houstonpress.com/news/the-way-we-currently-monitor-air-pollution-near-the-ship-channel-sucks-researchers-say-8263528*

Xu, M. & Xu, Y. Fraccidents: The impact of fracking on road traffic deaths. *Journal of Environmental Economics and Management*, **101**, May 2020, 10239.
https://www.doi.org/10.1016/j.jeem.2020.102303

Ziemkiewicz, P., Quaranta, J.D., McCawley, M. (2014) "Practical Measures for Reducing the Risk of Environmental Contamination in Shale Energy Production." *Environ. Sci.: Processes Impacts* April 2014, (16), 1692-1699.
http://pubs.rsc.org/en/Content/ArticleLanding/2014/EM/c3em00510k#!divAbstract

NOTES: