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Fracking with "Forever Chemicals" in West Virginia

Oil and Gas Companies Used PFAS in West Virginia Wells; Extent of Use Obscured by 70 Million Pounds of Trade Secret Chemicals

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Cover photo: Gas well in Doddridge County, W.Va. Photo credit: courtesy of Diane Pitcock, WV Host Farms Program. **Maps:** Matt Kelso, FracTracker Alliance. **We thank the following for their contributions to this report:** Linda Aller, Hydrogeologist, Bennett & Williams Environmental Consultants, Inc.; Jenna Dodson, M.S., Staff Scientist, West Virginia Rivers; Angie Rosser, M.A., Executive Director, West Virginia Rivers; Evan Hansen, M.S., Principal, Downstream Strategies. **Graphic Design:** twocatsgraphics.com

EXECUTIVE SUMMARY

Over the past decade, wells drilled horizontally for natural gas have been responsible for a surge in gas production in West Virginia. Information unearthed and analyzed by Physicians for Social Responsibility (PSR) shows that since 2013, oil and gas companies have hydraulically fractured or "fracked" some of these wells with a class of extremely toxic and persistent chemicals known as PFAS. During that same period, the companies injected nearly 2,000 horizontal gas wells with a total of almost 70 million pounds of unidentified chemicals, some of which could be PFAS. The companies withheld these chemicals' identities from the public as "trade secrets," a practice allowed by state law.

PFAS, or per-and polyfluoroalkyl substances, are a class of laboratory-created chemicals that have been widely used for decades in consumer products and for industrial purposes. The chemicals are useful because of their resistance to heat, oil, stains, grease, and water. But their value comes with a high cost. PFAS are known for their toxicity at extraordinarily low levels, their multiple negative health effects, and their persistence in the environment, leading to their nickname, "forever chemicals." Among the health effects that can be caused by PFAS are kidney cancer, testicular cancer, thyroid disease, high cholesterol, preeclampsia, ulcerative colitis, and decreased vaccine response.

PFAS' negative health effects first came to light as a result of litigation in the Parkersburg, West Virginia area around the year 2000, when Dupont was sued for polluting the area with a dangerous PFAS. In 2023, West Virginia's government enacted the PFAS Protection Act to protect residents from PFAS-related pollution. The legislation was a response to a study, ordered by the state legislature in 2020, in which scientists from the U.S. Geological Survey found PFAS in dozens of groundwater and surface water sources for West Virginia's public drinking water systems. West Virginia Rivers, a nonprofit, placed the figure of contaminated water sources at 130, relying on raw data from the USGS study and updated health advisory levels from the U.S. Environmental Protection Agency. The USGS study, published in 2022, did not examine the sources of PFAS pollution, but the PFAS Protection Act, among other provisions, directs the West Virginia Department of Environmental Protection (WVDEP) to develop action plans to identify and address such sources. It also requires certain facilities to disclose the use of specified types of PFAS.

Relatively little study has been conducted on the link between oil and gas operations and PFAS pollution, perhaps because the use of PFAS in oil and gas extraction has only recently come to light. But in November 2023, perhaps the first peer-reviewed study to examine the connection in West Virginia found some evidence of PFAS pollution from oil and gas operations, particularly in three private water wells where nearby oil and gas operations were the only identifiable sources of PFAS within more than 1.24 miles.

This report suggests that some of the sources of PFAS in West Virginia could be oil and gas wells or facilities where solid waste and enormous volumes of toxic wastewater from oil and gas production are taken for disposal.

Data publicly disclosed by the oil and gas industry shows that in West Virginia between 2013 and 2023, five oil and gas companies injected the PFAS known as PTFE or Teflon into a total of 43 horizontal gas wells located in eight counties in northern West Virginia. **However, this small number of industry-reported instances may significantly underrepresent the reality of PFAS use in West Virginia's oil and gas wells, given crucial gaps in state reporting rules**.

One major hindrance to quantifying the use of PFAS chemicals is oil and gas companies' extensive use of "trade secret," "proprietary," or "Confidential Business Information" designations to conceal the identities of fracking chemicals that must otherwise be disclosed to the public. Between 2013 and 2022, oil and gas companies injected 1,912 horizontal gas wells in 15 West Virginia counties with at least one trade secret chemical per well. Almost 400 of

* This report refers to "oil and gas companies" or the "oil and gas industry" even when discussing only horizontal gas wells, as some of the companies that operate horizontal gas wells also operate oil wells, whether in West Virginia or other states.

these wells were injected with incompletely identified chemicals that may be fluorosurfactants, a class of chemical that includes multiple PFAS. **Should only a fraction of the unidentified chemicals used in West Virginia's oil and gas wells be PFAS, they could pose a significant threat to human health**.

Four other gaps under West Virginia rules that may conceal wider use of PFAS in oil and gas wells include 1) missing information in "well site safety plans" designed to show what chemicals are being used at oil and gas well sites; 2) the absence of chemical disclosure requirements for oil and gas wells (such as vertical wells) that do not meet the definition of "horizontal gas wells"; 3) lack of chemical disclosure requirements for chemical manufacturers, the companies that know best what chemicals are in the products used in oil and gas wells; and 4) no disclosure requirements for chemicals unintentionally injected into oil and gas wells, such as in water that is contaminated with PFAS from industrial emissions or earlier fracks.

Overall, these multiple reporting gaps prevent the public from knowing how widely PFAS – to say nothing of other toxic chemicals – have been used in West Virginia's oil and gas wells. That fact, when taken with our findings that PFAS have in fact been used, raise concerns that West Virginians may unknowingly be exposed to highly hazardous PFAS chemicals. This potential may be particularly high in rural areas where most oil and gas drilling occurs and people often rely on groundwater for drinking water.

An interactive map showing the locations of West Virginia horizontal gas wells injected with PFAS and trade secret chemicals is available here: https://ft.maps.arcgis.com/apps/webappviewer/index.html?appid=7294f90f7a194216a2d6126e973a823a. Users can zoom in to identify wells near them.

In light of these findings, PSR recommends the following:

- **Halt PFAS use in oil and gas extraction.** West Virginia and the U.S. Environmental Protection Agency (EPA) should prohibit PFAS from being used, manufactured or imported for oil and gas extraction. Many PFAS are replaceable with less-persistent and less-toxic alternatives. In taking this step, West Virginia would be following the lead of Colorado, a major oil- and gas producing state that in June 2022 passed legislation banning the use of PFAS in oil and gas wells.

- **Expand public disclosure.** West Virginia should greatly expand its requirements for public disclosure of oil and gas chemicals. The state could again follow the example offered by Colorado by requiring disclosure of all individual chemicals used in oil and gas wells, without exceptions for trade secrets. This action can be taken while still protecting product formulas as trade secrets. West Virginia should also require chemical disclosure prior to permitting for all oil and gas wells, as do California and Wyoming, and should require disclosure on the part of chemical manufacturers, as does Colorado. This provision would enable the WVDEP to identify and address sources of PFAS using the PFAS Protection Act. Finally, West Virginia should expand the disclosure requirements in the PFAS Protection Act to cover oil and gas production and waste disposal facilities, to the extent that they are not already covered.

- **Increase testing and tracking.** West Virginia and/or the U.S. EPA should determine where PFAS have been used in oil and gas operations in the state and where related wastes have been deposited. They should test nearby residents, water, soil, flora, and fauna for PFAS, both for the particular type(s) of PFAS used and for organic fluorine to detect the presence of other PFAS and/or their breakdown products. They should use testing equipment sensitive enough to detect PFAS at concentrations below proposed or adopted maximum contaminant levels and/or other relevant regulatory guidelines or recommended limits. Such testing and tracking should be made a part of the action plans under the PFAS Protection Act for water sources near oil and gas production or waste disposal sites.

- **Require funding and cleanup.** Oil and gas companies and the firms that manufacture the oil and gas chemicals used should be required to fund environmental testing for PFAS in their areas of operation and, should PFAS be found, to fund cleanup. If cleanup of water sources is impossible, companies responsible for the use of PFAS should pay for alternative sources of water for homes, schools, hospitals, agriculture and other uses for as long as needed.

- **Remove West Virginia's oil and gas hazardous waste exemption.** West Virginia exempts oil and gas industry wastes from state hazardous waste rules. The state should follow New York's lead and remove its hazardous waste exemption for the oil and gas industry.

- **Reform West Virginia's regulations for oil and gas production wells and underground injection disposal wells.** The state should prohibit production wells and underground wastewater disposal wells in buffer zones near underground sources of drinking water and near homes, health care facilities and schools. The size of the zones should be determined by scientific evidence specific to West Virginia. The state should also require groundwater monitoring for contaminants near the wells and, for disposal wells, require full public disclosure of chemicals in the wastewater.

- **Transition to renewable energy and better regulation.** Given the use of highly toxic chemicals in oil and gas extraction, including but not limited to PFAS, as well as the climate impacts of oil and gas extraction and use, West Virginia should transition away from fracking, move toward renewable energy and efficiency, and provide economic support and job training for displaced oil and gas workers. As long as drilling and fracking continue, the state should better regulate these practices so that West Virginians are not exposed to toxic substances; it should also empower local governments to regulate the industry.

When doubt exists as to the existence or danger of contamination, the rule of thumb should be, "First, do no harm."

CH. 1 PFAS: A LABORATORY-MADE THREAT TO HEALTH AND THE ENVIRONMENT

a. PFAS Used in West Virginia's Horizontal Gas Wells

Physicians for Social Responsibility (PSR) has identified evidence from publicly reported oil and gas industry* records that a highly dangerous class of chemicals, known as per- and polyfluoroalkyl substances (PFAS), has been used in West Virginia's horizontal gas** wells for hydraulic fracturing ("fracking") and that such use could be much more extensive than reported. PFAS are known for their toxicity at extremely low levels,[1] their multiple negative health effects including cancer,[2] and their persistence in the environment, which has endowed them with their nickname "forever chemicals."[3] These properties, and the multiple pathways of potential exposure in oil and gas extraction, mean that West Virginians could face unrecognized health risks from the use of these chemicals for fracking in horizontal gas wells. These risks may also be posed by other stages and methods of oil and gas extraction, including the drilling that precedes fracking and non-horizontal (vertical) wells drilled for oil and/or gas.

b. Laboratory-made and Dangerous: PFAS's History and Health Effects

PFAS are a class of thousands of synthetic chemicals manufactured to have properties that are valuable in multiple industrial contexts, including being slippery, oil- and water-repellant, and able to serve as dispersants or foaming agents.[4] PFAS have been called PFCs or perfluorinated chemicals, though the term currently preferred by EPA is per- and polyfluoroalkyl substances or PFAS.[5]

The first PFAS to be sold commercially was created by a chemist at Dupont and was patented as Teflon. Since 1949, it has been used in thousands of products, from nonstick cookware to waterproof clothing to plastics to dental floss.[6] Other PFAS chemicals, the most prominent of which are known as PFOA and PFOS, were used in food packaging, fire-fighting foam, and in 3M's widely used fabric protector, Scotchgard.[7] EPA reported in 2021 that about 650 types of PFAS remained in commerce.[8] Weak chemical disclosure laws make it difficult for the Agency to identify which PFAS chemicals are used, and where.

Between the 1960s and 1990s, researchers inside Dupont and 3M became aware that at least some of the PFAS they were manufacturing or using, particularly PFOA and PFOS, were associated with health problems including cancers and birth defects, had accumulated in people's bodies worldwide, and persisted in the environment.[9] Many of these facts were kept internal by the companies but came to light after attorney Rob Bilott filed lawsuits in 1999 and 2001. The suits accused Dupont of causing pollution in and around Parkersburg with PFOA, a type of PFAS then used in making PTFE (Teflon).[10]

In December 2011, as part of Dupont's settlement of the 2001 lawsuit, a team of epidemiologists completed a study of the blood of 70,000 West Virginians and found a probable link between PFOA and multiple health effects[11] including kidney cancer, testicular cancer, thyroid disease (over or under-production of hormones by the thyroid gland),[12] high cholesterol, pre-eclampsia (a potentially dangerous complication during pregnancy characterized by high blood pressure and signs of damage to other organ systems, most often the liver and kidneys),[13] and ulcerative colitis (a disease causing inflammation and ulcers in the large intestine or colon).[14]

Current peer-reviewed scientific research on PFAS suggests that exposure to certain levels of some PFAS may lead to adverse health outcomes. Research findings differ, as different studies have examined different PFAS chemicals, different types or levels of exposure, or different exposed

* This report refers to "oil and gas companies," the "oil and gas industry," etc., even when discussing only horizontal gas wells because at least some of the companies that operate horizontal gas wells also operate oil wells, whether in West Virginia or other states.

** Gas, the principal component of which is methane, is also known as "natural" gas, "fossil" gas and "fracked" gas.

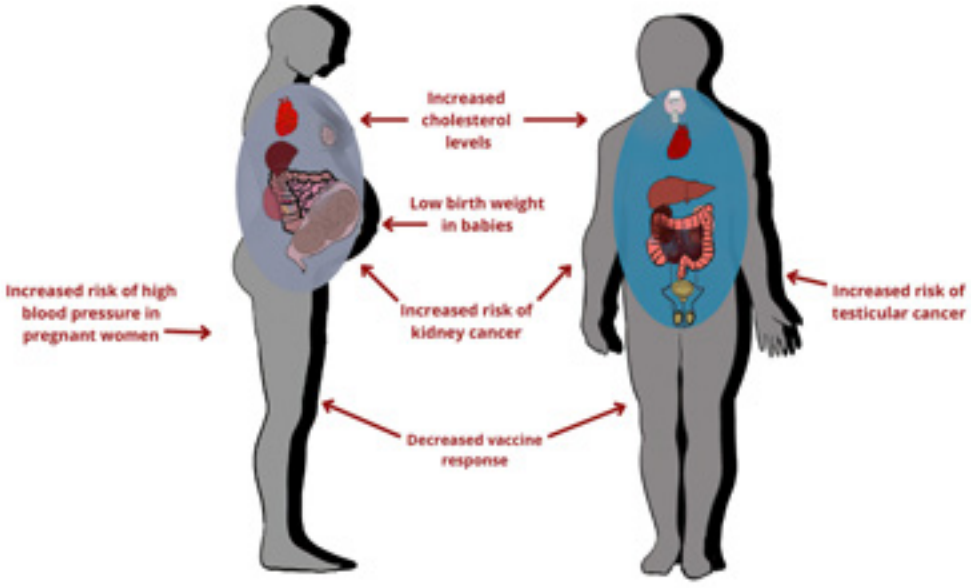
populations. However, some findings are more widely endorsed; for example, the U.S. Environmental Protection Agency (EPA)[15] and the U.S. Centers for Disease Control and Prevention's Agency for Toxic Substances and Disease Registry (ATSDR)[16] agree that exposure to high levels of certain PFAS may lead to increased risk of high blood pressure in pregnant women; low birth weight in babies; increased risk of kidney and testicular cancer; decreased vaccine response; and increased cholesterol levels. Research is ongoing to determine the health effects of different levels of exposure to different PFAS, including the health effects of long-term, low-level PFAS exposure, especially in children.

PFAS are not only highly toxic; they also demonstrate extreme persistence in the environment. PFAS' nickname "forever chemicals" reflects their chemistry – created by chemical manufacturers – that features a bond between fluorine and carbon atoms that is among the strongest in chemistry and rarely if ever exists in nature. The result: chemicals that are extremely resistant to breaking down,[17] whether in the environment or in the human body. PFAS are also extremely mobile in water,[18] making them able to spread through the environment via groundwater or surface water. Another risk, discussed later in this chapter, is that PFAS may compound the health effects caused by other dangerous chemicals used in oil and gas production.

c. EPA Recognizes Risks of PFAS

EPA has been slow to regulate PFAS, but the agency has taken actions, particularly in recent years, that recognize PFAS's extraordinary risks. In June 2022, reflecting growing public concern about PFAS, EPA significantly lowered its non-binding health advisory level for PFOA and PFOS in drinking water. Previously, EPA had set the combined health advisory level for these two chemicals at 70 parts per trillion.[19] "The new published peer-reviewed data and draft EPA analyses [citation omitted] indicate that the levels at which negative health outcomes could occur are much lower than previously understood," EPA wrote in June 2022.[20] EPA lowered its new interim health advisory level for PFOA

Figure 1: Potential Health Effects of PFAS Exposure



Exposure to PFAS chemicals can result in a variety of serious health effects including those indicated above. Source: U.S. Environmental Protection Agency, Agency for Toxic Substances and Disease Registry. Graphic by Astra Robles.

in drinking water to 0.004 parts per trillion and its interim health advisory level for PFOS to 0.02 parts per trillion.[21] EPA also set new final health advisory levels for two other PFAS, known as GenX and PFBS, at 10 parts per trillion and 2,000 parts per trillion, respectively.[22]

EPA explained that its interim health advisory levels were intended to provide guidance until enforceable drinking water regulations for PFAS take effect,[23] further stating that its health advisory level

> is designed to be protective of noncancer effects over a lifetime of exposure, including sensitive populations and life stages, and is typically based on data from experimental animal toxicity and/or human studies.[24]

The agency wrote that exposure to PFOA, PFOS, and Gen X is associated with cancer, but the agency had not yet developed cancer risk concentrations in water for these substances. EPA added that, at least for PFOA and PFOS, the interim health advisory levels could change following review by its Science Advisory Board.[25] EPA then in March 2023 released proposed legally enforceable "Maximum Contaminant Levels" (MCL) for six PFAS in drinking water. These regulations, unlike health advisories, must take into account whether a particular level of protection can be achieved and at what cost.[26] For this reason, they may be much less stringent than the health advisories.

The MCLs proposed by EPA included a level of four parts per trillion for both PFOA and PFOS. EPA also proposed an MCL Goal or non-enforceable target of zero for both of these PFAS. In addition, the agency proposed that drinking water providers limit the combined levels of four other types of PFAS: PFNA, PFHxS, PFBS, and/or GenX Chemicals.[27] EPA commented that it was regulating the four types of PFAS together because "low levels of multiple PFAS, that individually would not likely result in adverse health effects, when combined in a mixture are expected to result in adverse health effects."[28] The MCLs would require public water systems to monitor for the six PFAS, notify the public about the levels of these PFAS, and reduce levels of the six PFAS in drinking water if levels exceeded the MCLs.[29] In early 2023, the agency said that it expected to finalize the regulations by the end of 2023,[30] but has extended that timetable to early 2024.[31] The state of Pennsylvania has forecast, however, that the rules may not take effect until several years later.[32]

Even the higher MCL figures demonstrate the extraordinary toxicity of some types of PFAS. At a level of four parts per trillion, one cup of PFOA could contaminate 28 billion gallons of water,[33] almost three times the 10 billion gallons of water that West Virginia American Water provides to Charleston and surrounding communities each year.[34]

Several experts told PSR that because of the extreme potency of certain types of PFAS and the fact that chemical makers have created thousands of these forever chemicals, they would recommend the use of testing equipment that can detect PFAS in microscopic concentrations below proposed or adopted maximum contaminant levels and/or other relevant regulatory guidelines or recommended limits. They further recommended testing for total organic fluorine in addition to testing for specific types of PFAS. Total organic fluorine is a marker that would indicate the presence of PFAS even if a specific PFAS were not detected. Testing for specific PFAS only might fail to detect other forms of PFAS present in the sample.

The experts recommending these testing protocols are Linda Aller, a hydrogeologist with Bennett & Williams Environmental Consultants, Inc, who has consulted with the Little Hocking (Ohio) Water Association on all aspects of PFAS since 2002 (Little Hocking was impacted by PFAS pollution from Dupont's factory in Parkersburg) as well as other PFAS-impacted areas:[35] Linda Birnbaum, Ph.D., D.A.B.T., A.T.S., a board-certified toxicologist and former director of the National Institute of Environmental Health Sciences;[36] Zacariah Hildenbrand Ph.D., research professor in Chemistry and Biochemistry at the University of Texas at El Paso;[37] and Wilma Subra, holder of a master's degree in chemistry and recipient of a John D. and Catherine T. MacArthur Foundation "Genius" grant for her work helping to protect communities from toxic pollution.[38]

d. PFAS: Among Many Dangerous Chemicals Used in Fracking, Drilling

Chemicals used in the fracturing stage of oil and gas production serve a variety of purposes including killing bacteria inside the wellbore, reducing friction during high-pressure fracking, and thickening the fluid so that the sand, suspended in the gelled fluid, can travel farther into underground formations.[39] When chemicals used in fracking come into contact with people or the environment, they can produce serious negative health effects.[40] The use of PFAS in fracking operations could add to the cumulative human exposure to a host of toxic substances, multiplying the health risks.

In its 2016 study of fracking and drinking water, the EPA identified 1,606 chemicals used in fracking fluid and/or found in fracking wastewater. While the agency found high-quality information on health effects for only about 10 percent (173) of these chemicals, that information was troubling. EPA found that health effects associated with chronic oral exposure to these chemicals include carcinogenicity, neurotoxicity, immune system effects, changes in body weight, changes in blood chemistry, liver and kidney toxicity, and reproductive and developmental toxicity.[41] Chemicals used in the drilling stage that precedes actual fracturing can also pose health risks, including developmental toxicity and the formation of tumors, according to EPA regulators.[42] A disclosure form filed with the state of Ohio, one of only two states to explicitly require public disclosure of drilling chemicals (Colorado is the other),[43] shows that Statoil, Norway's state oil company (since renamed Equinor), has used the neurotoxic chemical xylene in drilling.[44] Xylene can cause effects ranging from headaches, dizziness and confusion to loss of muscle coordination, and in high doses, death.[45] West Virginia requires some disclosure of drilling chemicals under its "site safety plan" requirements, discussed in Chapter 4.

e. Oil and Gas Operations Provide Many Potential Routes of Exposure to PFAS

Oil and gas operations in West Virginia deserve scrutiny as a possible source of PFAS contamination, given the documented use of PFAS in the state's horizontal gas wells and the potential that people could be exposed to such PFAS via multiple pathways. EPA in a 2016 national report on fracking and drinking water found that fracking-related pollution could follow several pathways that could impact surface water and groundwater. The agency cited the following possible pathways to exposure:

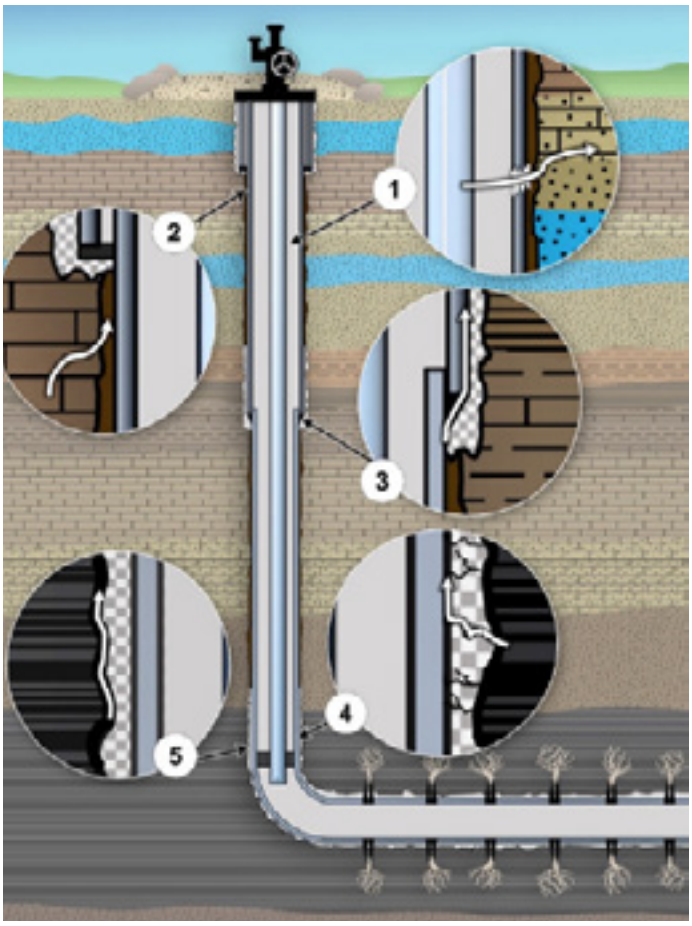


Diagram from U.S. Environmental Protection Agency's 2016 report on fracking and drinking water (p. ES-29) shows the various pathways through which fluid can migrate up an oil or natural gas well and potentially pollute groundwater including through leaks in the steel casing or cement designed to seal off the casing from the groundwater. EPA noted that the diagram is not to scale.

- spills of fracking fluid that seep into groundwater;
- injection of fracking fluid into wells with cracks in the casing or cement, allowing the fluid to migrate into aquifers;

- injection of fracking fluids directly into groundwater;
- underground migration of fracking fluids through fracking-related or natural fractures;
- intersection of fracking fluid with nearby oil and gas wells,
- spills of wastewater after the fracking process is completed, and
- inadequate treatment and discharge of fracking wastewater to surface water supplies.[46]

Another important potential pathway for PFAS contamination during oil and gas extraction is through the drilling that precedes fracking. During drilling, companies bore deep holes in the earth in successive stages. With each subsequent stage, companies bore deeper until the production zone is reached where the oil and/or gas are located.[47] During the first stage of drilling, these holes typically pass directly through groundwater.[48] Chemicals can be injected in this stage of the process to help keep the drill bit cool and to help lift rock cuttings out of the well.[49] A 2020 paper noted that PFAS had been proposed for use in drilling fluids.[50] Further investigation of this possible use is needed, as EPA has indicated that any chemicals used during this first stage of the drilling process would be highly likely to leach into groundwater, since only after drilling through the groundwater zone is completed do oil and gas companies insert steel pipe and cement to seal off the well from groundwater.[51] Two other important potential routes of exposure to PFAS related to oil and gas extraction are discussed in more detail in Chapter 6: disposal of oil and gas wastewater in underground injection wells, a pathway that EPA did not examine in its 2016 report,[52] and airborne releases.

f. Oil, Gas Well Proximity Are Associated with Disease

A robust and reliable body of scientific studies of PFAS in oil and gas operations – both their presence and their health effects – does not yet exist. Nor are there many studies focusing on the potential health impacts of oil and gas operations specifically on West Virginians. However, peer-reviewed scientific studies of people living near oil and gas operations have in multiple states correlated proximity to active well sites with a variety of diseases and other negative health effects. It is not unreasonable to think that, should PFAS have been used in those oil and gas operations, it could be associated with some of those harmful health effects.

A 2021 study comparing health data in Pennsylvania and New York counties atop the Marcellus Shale formation found that years of exposure to unconventional natural gas operations in Pennsylvania were associated with higher hospitalization and death rates from acute myocardial infarction (heart attack) than was found in New York, where no unconventional gas operations took place.[53] The study was made possible by the natural experiment created by New York's moratorium and later ban on fracking and Pennsylvania's decision to pursue shale gas extraction.[54] Similarly, researchers from Johns Hopkins University analyzed data on more than 12,000 heart failure patients in Pennsylvania and compared those with hospitalizations and those without hospitalizations. They found that heart failure patients living near unconventional gas extraction sites were significantly more likely to be hospitalized.[55] The authors of both the New York/Pennsylvania study and the study focused solely on Pennsylvania suggested that particulate matter emitted from fracking operations and the stress associated with living nearby might have played a role in the findings. Neither study examined PFAS exposure, but one of the health impacts associated with PFAS exposure is high cholesterol that is, in turn, associated with heart attacks.[56] These associations, and the known use of PFAS in oil and gas operations, point to the need for more study of the use of PFAS in oil and gas operations and associated health effects.

PSR has collaborated with Concerned Health Professionals of New York to produce the Compendium of Scientific, Medical, and Media Findings Demonstrating Risks and Harms of Fracking (Unconventional Gas and Oil Extraction). This encyclopedic document compiles and summarizes the substantial and growing number of scientific studies that have found serious health effects associated with oil and

Halliburton fracking operation in Wetzel County, W.Va., Jan. 1, 2016. Photo credit: Bill Hughes.

gas operations. At least two of these health effects, low birth weight in babies and heart disease (that can be linked to high cholesterol), are generally associated with exposure to PFAS, though the research to date has not investigated whether these health effects are specifically linked to PFAS used in oil and gas operations. Low birthweight is a leading contributor to infant death in the United States.[57]

PSR is not aware of published studies that have analyzed whether the use of PFAS at oil and gas well sites is related to health effects in people living near the wells or near well waste disposal sites. This lack of analysis is regrettable but not surprising. There were few if any grounds to test for PFAS in connection with oil and gas operations prior to July 2021, when PSR first publicized the use of these chemicals in oil and gas extraction. Now that we know PFAS have been used in oil and gas operations for years, scientists should determine where this use takes place and whether there are connections between this use and health effects, both for PFAS chemicals individually and as a compounding factor in conjunction with exposure to other fracking chemicals.

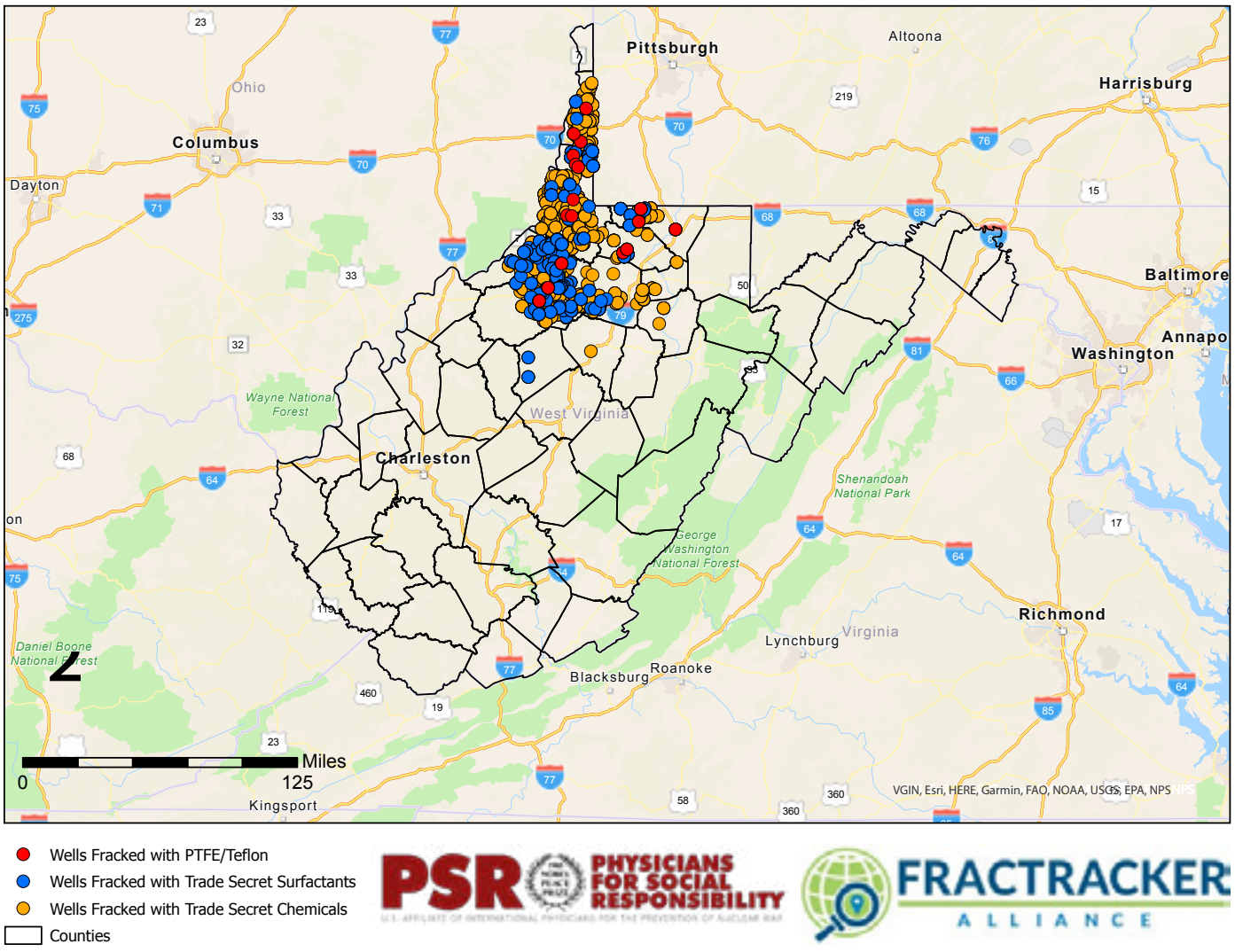
PFAS USE IN WEST VIRGINIA'S OIL AND GAS WELLS AND GROWING EVIDENCE OF PFAS POLLUTION

a. PTFE Injected into Horizontal Gas Wells in Eight West Virginia Counties

The West Virginia horizontal gas wells PSR has identified as having been injected with PFAS consist of 43 wells injected with PTFE, also known as Teflon and identified by the U.S. Environmental Protection Agency (EPA) as a PFAS.[58] The wells are located in eight counties, primarily in northern West Virginia: Brooke, Doddridge, Marion, Marshall, Monongalia, Ohio, Tyler, and Wetzel (see Table 1 in Chapter 3).

The larger story, however, is the disclosure gaps in West

Figure 3. West Virginia Horizontal Gas Wells Fracked with PFAS and Trade Secret Chemicals that Could Include PFAS, 2013-2022



This map shows the location of horizontal gas wells in West Virginia known to have been fracked between January 1, 2013 and September 29, 2022 using PTFE/Teflon (a known PFAS), trade secret chemicals, and/or trade secret surfactants. An interactive version of the map is available at https://ft.maps.arcgis.com/apps/webappviewer/index.html?appid=7294f90f7a194216a2d6126e973a823a where users can zoom in to identify wells near them. For a detailed explanation of data sources, see the Appendix.

Virginia law. These gaps shield vital data from disclosure, preventing scientists and the public from knowing the extent of the use of PTFE and other PFAS in the state's oil and gas operations. The use of PFAS in oil and gas production in other states was first documented in 2021 in a report by PSR that relied on industry records disclosed to the nongovernmental organization FracFocus. Later that year, a report by Public Employees for Environmental Responsibility showed a limited use of PFAS in West Virginia's oil and gas wells through an analysis of EPA records.[59] PSR's findings in this report, however, go even further. Based on a more comprehensive review of fracking chemical disclosures made to FracFocus, PSR is able to identify not only the horizontal gas wells definitively known to have been injected with PFAS between 2013 and 2022, but also the wells injected with unidentified "trade secret" chemicals and the staggering quantities of these unidentified substances. Figure 3 (page 8) shows the locations of the horizontal gas wells injected with disclosed PFAS, undisclosed trade secret chemicals, and a subset of trade secret chemicals (discussed in Chapter 4) known as surfactants.

Fracking is the stage of oil and gas operations that typically involves high-pressure injections into oil and gas wells of up to tens of millions of gallons of water, sand, and chemicals to fracture rock formations and free up trapped oil and gas.[60]*** Over the past two decades, oil and gas companies have increased gas and oil production by combining fracking with horizontal drilling. Drilling horizontal wells involves drilling down vertically to a target depth, then steering the drill bit horizontally to create a horizontal portion of the well often called a "lateral." This technique allows well operators to access more of the targeted oil and/or gas production zone.[61] Horizontal gas wells are responsible for the surge in gas production over the past decade that made West Virginia the nation's fourth-leading gas-producing state in 2022.[62] It is possible that PFAS have been used not only in fracking in horizontal gas wells in West Virginia, but also in other stages and methods of oil and gas production, including vertically drilled wells and the drilling that precedes fracking.

b. PFAS Use in Oil and Gas Operations May Threaten West Virginia's Water Supplies, Add to PFAS from Other Sources

Evidence shows that PFAS has already contaminated surface water and groundwater in West Virginia, and some of the findings implicate oil and gas operations as a potential source of the pollution. Investigation of the link between oil and gas operations in West Virginia and PFAS pollution has been performed by researchers from several institutions including Yale University and published in a peer-reviewed paper in November 2023. **The researchers found that oil and gas operations in five counties in northern West Virginia were associated with PFAS pollution and that, in several cases, these operations likely caused the pollution**. The researchers found that all eight surface water samples and 60 percent of the 45 private wells in their study contained at least one of the 21 types of PFAS for which they tested. They also reported that four of the private wells had concentrations above EPA's proposed maximum contaminant level in drinking water for PFOA.[63] The researchers found that three water wells appear likely to have been contaminated with PFAS from oil and gas wells because these water wells "exhibited individual PFAS concentrations above those likely from atmospheric sources even when considering historic deposition" from the former Dupont facility in Parkersburg (now called Chemours Washington Works) where the health and environmental impacts of PFAS first came to light. The researchers added that "Industrial operations related to oil and gas development were the only identifiable sources within 2 km of [the three water wells] even considering agricultural activity and possible biosolids applications."[64]

*** In this report, the term "fracking" is used to discuss a particular stage in oil and/or gas production as distinct from other stages or methods of production such as drilling that precedes fracking. The terms "oil and gas production," "oil and gas extraction," and "oil and gas operations" cover the entire process of producing oil and/or gas.

The counties where the study was conducted – Doddridge, Marshall, Ritchie, Tyler, and Wetzel – include horizontal gas wells into which oil and gas companies reported injecting PTFE and/or trade secret chemicals, according to PSR's analysis in this report. The researchers noted that these counties were home to more than 3,000 completed unconventional oil and gas wells in production. Unconventional wells are typically synonymous with horizontal oil and gas wells.[65] The researchers also found that the five-county area contains 14,000 active conventional oil and gas wells. Conventional wells are typically vertical and may or may not involve hydraulic fracturing.[66] Based on data cited later in this report by PSR, it is possible that PFAS has been used in both conventional and unconventional oil and gas wells (see Chapter 5). The authors further concluded that "within the larger data set, PFOA detections and concentrations in private water wells were significantly associated with proximity to recently drilled (2018-2020) UOG [unconventional oil and gas] well pads…."[67] However, the researchers cautioned that "observed concentrations were indistinguishable from levels plausibly attributable to atmospheric sources…."[68] They said that their research highlights the need for further studies to determine the sources of PFAS in private water wells, "particularly in regions where reliance on private water wells co-occurs with spatially distributed industrial sources, like oil and gas development."[69]

A 2022 study by the U.S. Geological Survey (USGS) showed that PFAS had polluted dozens of water supplies in West Virginia and that groundwater might be at a high risk of contamination. The USGS sampled drinking water supplies for 279 public water systems and detected PFAS more often and in higher concentrations in groundwater than in surface water sources. West Virginia Rivers, a nonprofit, placed the figure of contaminated water sites at 130, relying on raw data from the USGS study and updated health advisory levels from the U.S. Environmental Protection Agency. The USGS did not investigate the sources of this pollution;[70] however, some concentrations of the pollution were found in northern West Virginia,[71] the region of most of the state's horizontal gas wells, including those in which the use of PFAS has been disclosed (compare Figure 3, page 8, with Figure 4).

The USGS report indicated that West Virginia's groundwater supplies might be especially likely to be contaminated with PFAS due to the relatively young age of recharge water in West Virginia's aquifers. The agency noted that groundwater age has been identified as a leading indicator of PFAS contamination in groundwater in the eastern U.S. and that aquifers containing recharge-water less than 60 years old have higher rates of PFAS occurrence. The USGS also stated that age-tracer data from previous studies on West Virginia's groundwater resources showed that all aquifers of West Virginia contain recharge-water less than 60 years old. This fact, the USGS found, "indicates that all the groundwater aquifers in the State are potentially susceptible to PFAS contamination [citation omitted] if a source of contamination exists within the recharge area of the aquifer…."[73] The report also found that

> a surface water intake may be vulnerable to contamination from PFAS if a source exists within its catchment area [also known as its watershed], but concentrations may be highly variable due to environmental conditions or because of operations at the specific source.[74]

West Virginians may, therefore, be at especially high risk of exposure to PFAS from oil and gas operations, given that at least some oil and gas operations involve PFAS, oil and gas extraction can contaminate groundwater, and the state's aquifers are particularly vulnerable to PFAS contamination.

More research is needed about the extent and sources of PFAS pollution in West Virginia and whether oil and gas operations could be contributing to such contamination. This need is especially critical, given that almost 40 percent of West Virginians receive their drinking water from groundwater, according to the USGS.[75] The USGS 2022 report stated that it did not test private water wells for PFAS and that the tests it conducted could not be used to

extrapolate PFAS concentrations in groundwater in aquifers that underlie much of the state. "PFAS exposure to private homeowners who rely on these aquifers as a primary drinking-water source is currently unknown," the agency wrote. The USGS proposed testing private water wells for PFAS as a potential subject for future study and suggested

Figure 4. Sites in W.Va. Where U.S. Geological Survey Detected PFAS in Groundwater and Surface Water

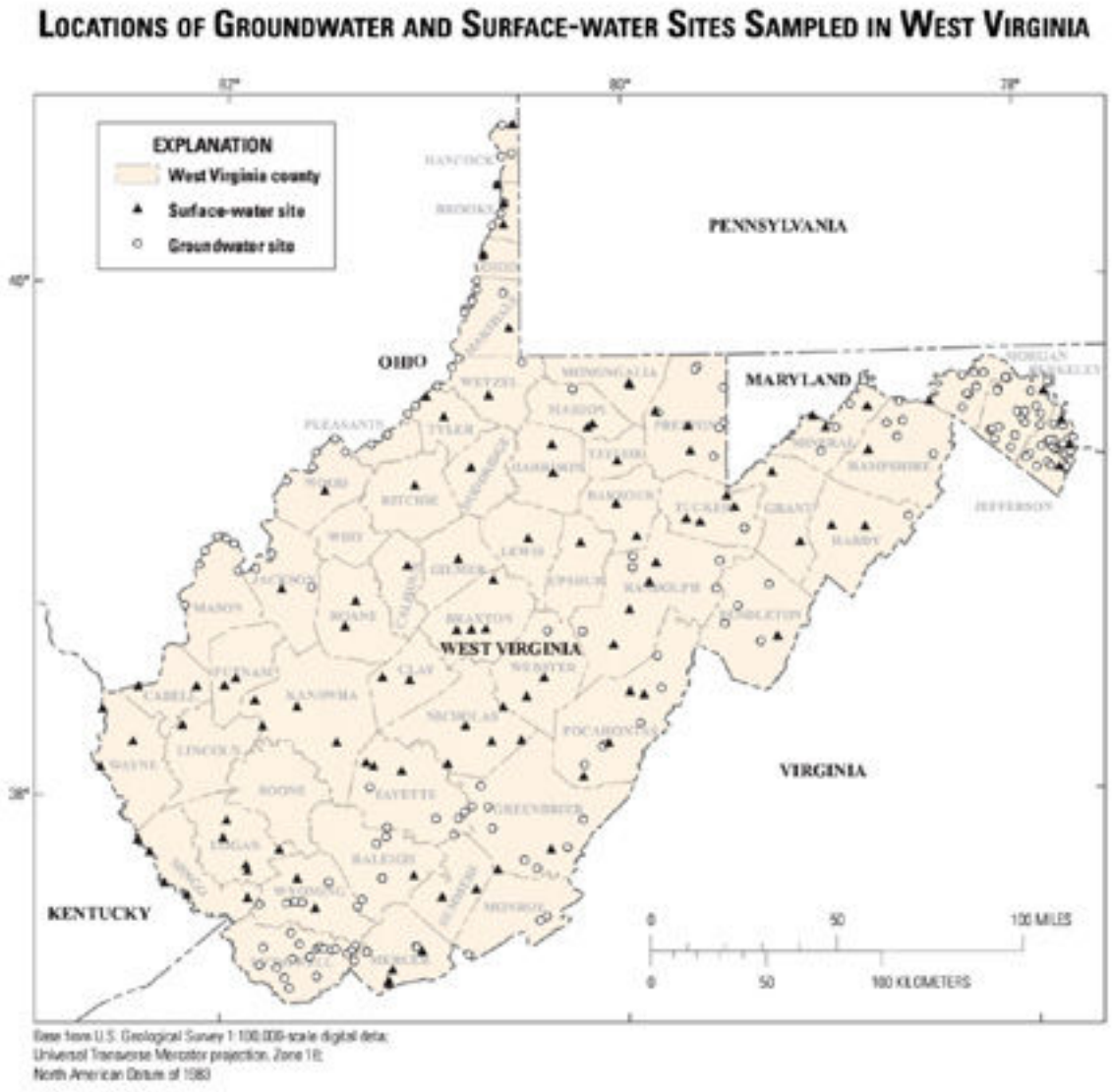


Figure 4 shows a map from the U.S. Geological Survey's report by Mitchell McAdoo et at., "Occurrence of Per- and Polyfluoroalkyl Substances and Inorganic Analytes in Groundwater and Surface Water Used as Sources for Public Water Supply in West Virginia" (2022).[72] The map depicts groundwater and surface water sites in West Virginia where USGS scientists detected PFAS, as well as the concentrations of PFAS detected at each site. The sites provide source water for public drinking water systems. Concentrations are reported in parts per trillion. The reporting level (the level at which the laboratory reported a detected value without qualification) is approximately 3.8 parts per trillion. Therefore, concentrations of PFAS at the sites marked in green ranged from about 3.8 to 20 parts per trillion. The USGS does not provide precise information about the locations of the tests because "West Virginia State Law § 22-26-4 and USGS policy concerning the release of sensitive water related information prohibits the release of public water system infrastructure location information."

that "the major sources and exposure pathways of PFAS in West Virginia" could be the focus of future investigation.[76]

Studies indicating an association between PFAS pollution and oil and gas extraction echo related findings in neighboring Pennsylvania. A 2023 study by scientists from the USGS and Pennsylvania Department of Environmental Protection (PADEP) reported concentrations of PFAS in Pennsylvania streams located in areas that featured both high numbers of oil and gas wells and combined sewer overflow outfalls.[77] The authors wrote that

> Research documenting the impacts of OG [oil and gas] development on PFAS contamination in surface waters is limited, but in this study the CSO [combined sewer overflow outfalls] surrounded by OG development in local catchments could be a potential source of PFAS to surrounding streams.[78]

Also in 2023, the PADEP tested a water well for PFAS at a home in Washington County in response to a homeowner's complaint that nearby oil and gas operations had contaminated his water with PFAS.[79] The PADEP reported that it found some PFAS in the water (PFOS at 2.3 parts per trillion, as well as PFHxS and PFOSA). While they found no evidence that PFAS was used in the nearby oil and gas operations, specifically two unconventional gas wells operated by Chevron about 500 feet from the home in question,[80] the PADEP speculated that the source of the PFAS could be, among many potential sources, water that already contained PFAS being used for fracking in the unconventional gas wells. Pennsylvania's regulations – and West Virginia's – do not require testing for or disclosure of chemicals contained in water used in fracking.[81] It is possible that water used for fracking could be contaminated with PFAS by prior fracking operations, as a significant portion of water used in fracking in Pennsylvania – and West Virginia – is reused fracking wastewater.[82]

CH. 3 PFAS USED IN WEST VIRGINIA'S OIL AND GAS WELLS: WHAT, AND WHERE

a. PTFE, a PFAS, Used for Fracking in West Virginia's Horizontal Gas Wells

The type of PFAS disclosed as being used in West Virginia's horizontal gas wells is PTFE, a fluoropolymer and a type of plastic.[83] The major concerns about PTFE and other fluoropolymers raised by scientists[84] and environmentalists[85] are related less to these substances themselves, and more to the associated toxic impacts of their production, use, and disposal. The production of PTFE and other fluoropolymers relies on the use of other, highly toxic PFAS that are used as production aids. As noted in a peer-reviewed study published in 2020, these other PFAS have included fluorosurfactants such as PFOA, whose risks are discussed in Chapter 1, and GenX, which is similarly harmful and has replaced PFOA in fluoropolymer production.[86] PTFE and other fluoropolymers may contain these more toxic PFAS fragments, and those fragments may leach out of the PTFE during use.[87] The authors of the 2020 paper noted that

> The levels of leachables…in individual fluoropolymer substances and products depend on the production process and subsequent treatment processes; a comprehensive global overview is currently lacking.[88]

In addition, PTFE may generate other PFAS if the PTFE breaks down under heat.[89]

The 2020 paper authors noted that the persistence in the environment of PTFE and other fluoropolymers could pose problems during disposal, observing that "Landfilling of fluoropolymers leads to contamination of leachates with PFAS and can contribute to release of plastics and microplastics.[90] One of the authors added in an email to PSR that if PTFE were used in oil and gas wells that have especially high-temperatures, defined in publications by oilfield services company Schlumberger as 300° to 350° F or higher for so called "high-pressure, high-temperature wells,"[91] the PTFE could undergo a process called thermolysis and generate toxic PFAS called perfluoroalkyl carboxylic acids (PFCAs). As a result, he wrote, "there could be some additional problems that need some investigation."[92] A representative from the West Virginia Department of Environmental Protection (WVDEP) said that the department was not aware of such wells in the state.[93]

In 2021, a coalition of national environmental organizations including the Center for Environmental Health, Clean Water Action, Ecology Center, Environmental Working Group, Natural Resources Defense Council, Safer States, and the Sierra Club voiced several environmental and health concerns regarding the risks of fluoropolymers such as PTFE, based on their review of multiple scientific articles. Among these concerns were the release into the environment of other toxic PFAS used to produce fluoropolymers, including PFOA[94] and perfluorocarboxylic acids (PFCAs).[95] These PFAS can be released both when fluoropolymers are manufactured and when they are used. PFOA's health concerns are discussed above. Evidence suggests that PFCAs may be associated with various health impacts including effects on the liver, thyroid, kidney and immune system.[96] The groups also noted that fluoropolymers are manufactured with chemicals that over a 20-year period are much more powerful at warming the climate than carbon dioxide.[97]

b. Data Show Which Companies Fracked Horizontal Wells with PTFE, and Where

Oil and gas companies that have disclosed using PTFE for fracking in West Virginia (Table 1, next page) include Irving, Texas-based ExxonMobil Corp.,[98] the nation's largest publicly traded oil and gas company;[99] and Denver-based Antero Resources Corp.[100] According to West Virginia University, which received a $4 million gift from Antero in 2023, Antero is the largest producer of natural gas and natural gas liquids in West Virginia.[101] Natural gas liquids include, among several types of fluids, propane that is used for small stoves and barbecues and ethane that is used in plastics production.[102]

PSR was able to identify wells injected with PTFE through oil and gas industry records disclosed to FracFocus that include Chemical Abstracts Service (CAS) numbers, unique numeric identifiers assigned to millions of chemicals by the American

Table 1. Disclosed Use in Fracking of PTFE in West Virginia Horizontal Gas Wells, 2013-2022

County	Number of wells injected with PTFE	Mass of PTFE (lbs.)	Well Operator(s)
Brooke	2	11	Chesapeake Operating, Inc.
Doddridge	12	369	Antero Resources Corporation
Marion	4	13	XTO Energy/ExxonMobil
Marshall	4	no data available	Chesapeake Operating, Inc.
Monongalia	9	20	Northeast Natural Energy LLC
Ohio	4	no data available	Chesapeake Operating, Inc.
Tyler	6	164	Antero Resources Corporation
Wetzel	2	23	Southwestern Energy; Chesapeake Operating, Inc.
Total	**43**	**602**	**five companies**

This table shows by county the number of West Virginia's horizontal gas wells in which oil and gas companies injected PTFE for fracking between January 1, 2013 and September 29, 2022 as well as the name(s) of the companies making the injections. "No data available" means that records in FracFocus showed the use of PTFE in several wells but provided insufficient data to calculate how much was used. For a more detailed explanation of data sources, see the Appendix.

Chemical Society.[103] Scientists consider CAS numbers the best way to identify chemicals because chemicals can have multiple names or trade names but only one CAS number.[104] PSR identified PTFE through its CAS Number, 9002-84-0. However, the FracFocus records make it difficult to know for what precise purpose PTFE was used in these wells; well operators listed either no purpose or various purposes for multiple chemical products, and the individual chemical components of these products were listed in a separate portion of the disclosure form, making it impossible to know which components were part of which product.[105] PTFE, which is marketed as Teflon, is known for its slipperiness, suggesting it might have been used as a friction reducer, a common purpose for fracking chemicals.[106]

CH. 4 CHEMICAL DISCLOSURE LAWS SHIELD CHEMICAL IDENTITIES

a. West Virginia's Lax Chemical Disclosure Rules Could Conceal PFAS Use

West Virginia's system of oil and gas chemical disclosure makes it impossible to know how widely PTFE, other PFAS, or other toxic chemicals have been used in the state's oil and gas wells. One salient feature of the state's rules that frustrate the public's right to know is the use of trade secret claims that allow oil and gas companies to hide the identities of fracking chemicals. The rules appear to require something akin to full chemical disclosure for horizontal gas wells – even for non-fracking chemicals – under a "well site safety plan." But upon closer inspection, the disclosures under at least some of these plans are riddled with gaps that thwart full knowledge of chemicals used at horizontal gas wells. Additionally, West Virginia's rules allow chemical manufacturers – the companies who know best what chemicals are being used in oil and gas operations – to avoid full disclosure of chemical ingredients. Finally, the chemical disclosure rules apply only to specifically defined horizontal gas wells, meaning that they do not apply to other oil or gas wells, including vertical wells. Most wells drilled over the past decade in West Virginia have been horizontal gas wells, but some vertical wells continue to be drilled, and vertical wells make up the bulk of wells drilled historically in West Virginia.

b. West Virginia's Fracking Chemical Disclosure Law

Since 2011, West Virginia has required disclosure of chemicals used for hydraulic fracturing or "stimulation"

A drilling rig in Marshall County, W.Va., Jan. 26, 2018. Photo credit: Ted Auch, FracTracker Alliance.

of horizontal gas wells.[107] "Stimulation" is not currently defined under West Virginia law,[108] but it is often synonymous with fracking.[109] (A previous version of West Virginia law requiring fracking chemical disclosure defined "stimulate" as "any action taken by a well operator to increase the inherent productivity of an oil or gas well, including, but not limited to, fracturing, shooting or acidizing, but excluding cleaning out, bailing or workover operations."[110]) A horizontal gas well is defined as

> any [gas] well site, other than a coalbed methane well, drilled using a horizontal drilling method, and which disturbs three acres or more of surface, excluding pipelines, gathering lines and roads, or utilizes more than two hundred ten thousand gallons of water in any thirty day period.[111]

If a horizontal gas well uses more than 210,000 gallons of water from water sources located in West Virginia in any thirty-day period, the well operator must make fracking chemical disclosures both before[112] and after[113] fracking or stimulation of the well. If the well uses less than 210,000 gallons of water from water sources located in West Virginia in any thirty-day period but meets the other definitions for a horizontal gas well, the well operator or service provider is required to make fracking chemical disclosures only after fracking or stimulation.[114] All disclosures after fracking or stimulation must be made to the FracFocus database.[115] This database, maintained by the Groundwater Protection Council, a nonprofit comprised of regulators from state agencies that regulate groundwater,[116] contains well-by-well hydraulic fracturing chemical disclosure for the oil and gas industry.[117] Fracking chemical disclosure prior to fracking must be made to the Secretary of the Department of Environmental Protection as part of the application for the well's work permit.[118]

PSR's analysis of FracFocus data for more than 2,500 fracking treatments on West Virginia's horizontal gas wells between 2013 and 2022 found that oil and gas companies used an average of more than 14 million gallons of water per treatment – more than 19 times the amount that triggers the disclosure requirement. Only four fracking treatments during this period involved less than 210,000 gallons of water. It is unclear whether all of the water reported for fracking treatments was used within a 30-day period or whether the water came from sources located in West Virginia, but fracking treatments usually occur over a period of less than 14 days[119] and water for fracking is usually obtained close to the fracking operations, as EPA reported in its 2016 report on fracking and drinking water. On that basis, it is probable that almost all the fracking treatments that PSR analyzed in this report met West Virginia's threshold for disclosure of fracking chemicals.

c. Extensive Use of "Trade Secret" Claims Veils Chemical Use in Horizontal Gas Wells

Under West Virginia's fracking chemical disclosure system for horizontal gas wells, perhaps the most prominent measure that could conceal wider use of PFAS is the ability for oil and gas companies to withhold from the public the identities of fracking chemicals that are deemed trade secrets.[120] Over the past decade, oil and gas companies have used this exception extensively. PSR found that between 2013 and 2022, oil and gas companies, while disclosing the use of fracking chemicals in more than 2,500 wells, also injected more than 1,900 wells of those wells – almost 75 percent – with at least one trade secret fracking chemical.[121] The CAS numbers for these chemicals were not revealed, preventing the public from knowing whether or not these unidentified chemicals were PFAS. **The weight of these chemicals, injected into horizontal gas wells located across 15 counties, totaled 69 million pounds.**[122] If even a small fraction of this weight were PFAS, that fraction could pose significant health and environmental risks.

Furthermore, oil and gas companies injected almost 400 of the 1,900 wells with trade secret surfactants,[123] a category of chemical that includes a subcategory known as fluorosurfactants, some of which are known to be PFAS. These wells were spread across 12 counties. According to EPA, surfactants are commonly used in fracking,[124] including to generate and stabilize foam fracking fluids and to help

Table 2. Disclosed Use of Trade Secret Chemicals in West Virginia Horizontal Gas Wells, 2013-2022

County	No. of wells injected with at least one trade secret chemical	Mass of all trade secret records (lbs.)	No. of wells injected with at least one trade secret surfactant	Mass of trade secret surfactants (lbs.)
Barbour	6	1,730,000	0	0
Brooke	12	1,430,000	2	11,200
Doddridge	369	9,670,000	84	230,000
Gilmer	3	138,000	2	496
Harrison	80	1,280,000	10	23,300
Lewis	1	4,800	0	0
Marion	43	786,000	7	8,050
Marshall	327	14,100,000	70	460,000
Monongalia	103	3,980,000	23	11,300
Ohio	117	3,980,000	1	5,450
Pleasants	13	365,000	7	33,400
Ritchie	151	6,760,000	19	40,800
Taylor	17	221,000	0	0
Tyler	357	16,500,000	145	577,000
Wetzel	240	8,180,000	24	119,000
Total	**1,912**	**69,100,000**	**394**	**1,520,000**

This table shows by county the number of West Virginia horizontal gas wells into which oil and gas companies disclosed that they injected at least one trade secret fracking chemical and/or at least one trade secret surfactant between January 1, 2013, and September 29, 2022. It also shows the total combined weight of these chemicals by county and statewide. The total weight figures reflect the sum of all records for which we have enough information to calculate a chemical's weight. Because many fracking chemical disclosures lack sufficient data to perform this calculation, the total weight figures may represent an undercount. The wells injected with trade secret surfactants are a subset of the wells injected with trade secret chemicals. For a more detailed explanation of data sources, see the Appendix.

one unmixable fluid disperse into another unmixable fluid "by reducing the interfacial tension between the two liquids to achieve stability."[125] Compared to other surfactants, fluorosurfactants are said to be "superior in their aqueous surface tension reduction at very low concentrations and are useful as wetting and leveling agents, emulsifiers, foaming agents, or dispersants."[126] At least some fluorosurfactants are PFAS, including the dangerous chemicals PFOA and PFOS,[127] and 8:2 fluorotelomer alcohol,[128] a nonionic fluorosurfactant[129] that can break down into PFOA.[130]

How many of the trade secret surfactants are PFAS is impossible to determine from the available FracFocus data. Operators' names for these chemicals were vague, including "proprietary nonionic surfactant"[131] and "nonionic surfactant."[132] The weight of these trade secret surfactants totaled more than 1.5 million pounds. Should even a small percentage of them be PFAS, they could pose significant and long-lasting threats to human health and the environment. Table 2 above shows county-by-county where trade secret chemicals and trade secret surfactants were used to frack horizontal gas wells in West Virginia.

Table 3. Oil and Gas Companies that Fracked Horizontal Gas Wells in West Virginia Using Trade Secret Chemicals and Trade Secret Surfactants, 2013-2022

Operator Name	No. of wells injected with at least one trade secret chemical	Mass of all trade secret chemicals (lbs.)	No. of wells injected with at least one trade secret surfactant	Mass of all trade secret surfactants (lbs.)
Antero Resources Corporation	686	30,200,000	228	902,000
EQT Production	258	5,800,000	10	757
Southwestern Energy	202	6,000,000	10	57,400
Tug Hill Operating, LLC	165	3,600,000	28	8,000
Noble Energy, Inc.	117	8,150,000	45	7,290
Northeast Natural Energy LLC	98	3,980,000	18	10,200
Chesapeake Operating, Inc.	74	3,300,000	3	445,000
Jay-Bee Oil & Gas, Inc.	62	583,000	31	72,800
Stone Energy Corporation	56	2,200,000	0	0
Chevron USA Inc.	32	1,050,000	0	0
Triad Hunter LLC.	24	238,000	3	4,370
XTO Energy/ExxonMobil	24	222,000	7	8,050
CONSOL Energy Inc.	22	1,910,000	2	2,450
CNX Gas Company LLC	16	288,000	5	1,090
Arsenal Resources	14	292,000	0	0
American Energy – Marcellus, LLC	14	117,000	0	0
PDC Energy	14	no data available	0	0
Mountaineer Keystone, LLC	12	437,000	0	0
Statoil USA Onshore Properties Inc.	10	no data available	0	0
Tribune Resources, LLC	5	380,000	0	0
American Petroleum Partners Operating, LL	4	206,000	4	951
Ascent Resources – Marcellus, LLC	4	163,000	0	0
Total	**1,913***	**69,100,000**	**394**	**1,520,000**

This table shows the oil and gas companies that disclosed that they fracked horizontal gas wells in West Virginia with trade secret chemicals and trade secret surfactants between January 1, 2013, and September 29, 2022. The wells injected with trade secret surfactants are a subset of the wells injected with trade secret chemicals. "No data available" means that records in FracFocus showed the use of trade secret chemicals but provided insufficient data to calculate how much was used. For a more detailed explanation of data sources, see the Appendix. Please note: Separate companies in this table could now be the same company as a result of subsequent mergers and/or name changes.* The total number of horizontal gas wells that companies operating in West Virginia injected with at least one trade secret chemical (1,913) differs slightly in this table from the total number reported in Table 2 (1,912) because one well was fracked more than once, but by different operators, and that well is counted twice in this table.

The use of these chemicals is particularly alarming as West Virginia's gas production increased nearly ten times from about 256 billion cubic feet in 2010 to more than 2.6 trillion cubic feet in 2022, according to data available from the U.S. Department of Energy.[133] While these increases mean more tax revenue for the state,[134] higher gas production also means more wells being drilled and fractured, with the associated risk of pollution from PFAS and other toxic substances.[135]

Multiple oil and gas companies have injected oil and gas wells in West Virginia with trade secret chemicals that

Table 4. Examples of Individual Horizontal Gas Wells

Well Operator	Well Number	County	Year Fracking Completed	Chemical used in Well	CAS Number	Trade Name	Mass (lbs.)
Antero Resources Corporation	4701706699	Doddridge	2017	PTFE	9002-84-0	not reported	63
Chesapeake Operating, Inc.	4710302973	Wetzel	2014	PTFE	9002-84-0	ambiguous	23
Tug Hill Operating, LLC	4705102327	Marshall	2022	proprietary non-ionic surfactant	proprietary	ProHib 100	513
Jay-Bee Oil & Gas, Inc.	4707302558	Pleasants	2018	nonionic surfactant	proprietary	not reported	2745
Noble Energy, Inc.	4702105747	Gilmer	2013	surfactant mixture	proprietary	not reported	243

This table shows a sample of wells injected with the types of fracking chemicals referenced in the larger table above, including trade secret surfactants such as "proprietary non-ionic surfactant" and "nonionic surfactant" as well as PTFE. The examples cover a range of years and represent wells fracked in several West Virginia counties. Even the smallest mass shown for a proprietary chemical (243 pounds for "surfactant mixture") could be a highly dangerous amount if this proprietary chemical were PFAS.

could be PFAS or other toxic substances. Table 3 identifies the companies responsible for this activity, as well as the quantities of trade secret chemicals and trade secret surfactants they injected.

FracFocus data show that in some cases, oil and gas companies have injected hundreds or even thousands of pounds of trade secret chemicals into individual horizontal gas wells for fracking. Table 4 provides selected examples of horizontal gas wells in West Virginia injected with particular chemicals, whether PTFE or trade secret substances, and the weight of these substances. If the toxicities of some of these chemicals were similar to those of PFOA or PFOS, these quantities would be enough to contaminate vast amounts of water.

d. Some disclosure is required, but not to the public

West Virginia provides two limited scenarios in which oil and gas companies can be required to disclose the identities of trade secret chemicals. Upon request by the chief of the Office of Oil and Gas or the chief's designee(s), well operators or service providers (companies that typically conduct hydraulic fracturing)[136] can be required to disclose trade secret chemical identities to state regulators as part of an investigation involving a trade secret chemical. However, the Office of Oil and Gas chief or designee(s) must keep the information confidential.[137]

Similarly, upon request by a health professional to address a medical emergency or for diagnostic or treatment purposes, well operators or service providers must provide trade secret chemical identities and potentially other confidential information about trade secret chemicals. The health professionals must keep this information confidential.[138] Neither the public nor first responders such as firefighters have a right to see the confidential chemical identities under West Virginia law. The federal Toxic Substances Control Act allows first responders and the public to access trade secret chemical identities under certain circumstances, but it is unclear how quickly such information could be obtained in the event of an emergency.[139] Similarly, federal rules under the Occupational Safety and Health Administration allow health professionals to access trade secret chemical information under certain scenarios, but these rules do not appear to provide similar rights to firefighters.[140]

e. "Well Site Safety Plan" Disclosures Could Conceal PFAS Use at Horizontal Gas Wells

To a limited degree, West Virginia has exceeded the chemical disclosure requirements of many oil- and gas-producing states by requiring some disclosure of both fracking and non-fracking chemicals used in horizontal gas wells. (Most oil- and gas-producing states require disclosure only of chemicals used in fracking.[141]) West Virginia implements this broader disclosure through a "well site safety plan," required to be filed with the Department of Environmental Protection in order for an oil and gas company to obtain a permit to begin work on a horizontal gas well.[142] As part of the plan, oil and gas companies must provide to the DEP and others, including the surface land owner and local emergency planning officials, Safety Data Sheets "for the chemical components added to the hydraulic fracturing fluid, and completion, production, and work-over activities." Safety Data Sheets identify the health or physical (e.g. fire) hazards associated with a chemical product.[143] Under federal regulations that establish uniform, nationwide standards, chemical manufacturers must ensure that chemical distributors and employers that use the chemicals are provided with Safety Data Sheets so that employers and employees can be warned about these hazards. The terms "completion," "production," and "work-over" in West Virginia's rules are not defined. However, it is apparent from the inclusion of these terms that the Safety Data Sheets apply beyond the fracking phase of operations. The actual disclosures reflect this interpretation.

However, the disclosures are significantly incomplete, apparently reflecting multiple weaknesses in Safety Data Sheets. PSR carefully examined the disclosures for one of the wells featured above in Table 4: Antero Resources' well fracked in Doddridge County in 2017.[144] We also examined some of the disclosures for a second well in Table 4: Jay-Bee Oil & Gas Inc.'s well fracked in Pleasants County in 2018.[145] (More examination was beyond the scope of this report because the records are voluminous: Antero Resources disclosed 431 pages of Safety Data Sheets for its well in Doddridge County, while Jay-Bee Oil & Gas Inc. disclosed 1,732 pages of Safety Data Sheets for its well in Pleasants County; furthermore, the documents were not easily searchable.) While the Safety Data Sheets provided information about drilling chemicals and other non-fracking chemicals, they had many gaps, including the following for Antero Resources' well in Doddridge County:

- The PFAS known as PTFE was not listed on the Safety Data Sheets as one of the chemicals used at the well site, even though the company listed it in the FracFocus records as being used for fracking.

- Several other chemicals listed in FracFocus also did not appear to be listed in the Safety Data Sheets, including alcohols, C12-14, ethoxylated; alcohols, C14-15, ethoxylated; and methanol.

- More than a dozen substances in the Safety Data Sheets were listed as "proprietary" or "confidential," meaning that their identities were not revealed.

- Multiple Safety Data Sheets included unlisted chemicals defined as "non-hazardous" but with no further information.

Multiple Safety Data Sheets listed ingredients for a chemical product that added up to less than 100 percent of the product. For example, a product called AIRFOAM-HD listed one chemical component, glycol ethers, that made up between 7 to 13 percent of the product, but no other ingredients were listed. A product called SWF listed the same component, glycol ethers, as comprising 15 to 40 percent of the product, but again, no other ingredients were listed. A third product, called BIO CLEAR® 2000, listed the ingredient 2,2-dibromo-3-nitrilopropionamide as making up 20 percent of the product; no other ingredients were listed.

Some of these same types of shortcomings were apparent in the Safety Data Sheets for the well in Pleasants County fracked by Jay-Bee Oil & Gas Inc.

Well Site Safety Plans Difficult to Access

West Virginia's well site safety plans provide at least some additional information about chemicals used at horizontal gas well sites. However, the chemical information in these plans, contained on Safety Data Sheets, was difficult to access.

To obtain the information, PSR had to receive a web link from the West Virginia Department of Environmental Protection (WVDEP) – a link that would have been difficult to find online without the Department's assistance. The WVDEP also supplied username and password information for the web site and detailed instructions for accessing the information – necessary pieces that again were not readily available on the web site. PSR was able to locate chemical disclosure information for only four of five wells we searched for. That information was voluminous: The smallest file for the four wells contained 431 pages of Safety Data Sheets; the largest contained 1,762 pages of Safety Data Sheets. These pages were initially viewable one at a time. Once exported, the files could be scrolled through, but they were not searchable by key words. We made one of the documents somewhat searchable by key words with the help of software. Still, it took roughly 10 hours to review and compile the chemicals used for just one horizontal gas well.

Drilling site and fluids impoundments in West Virginia, 2012. Photo credit: West Virginia Surface Owners' Rights Organization.

The chemical information in the Well Site Safety Plans, though incomplete, is of some use to the public, first responders, and others. But it is much more difficult to access than the information in FracFocus, in which fracking chemicals appear in a succinct searchable list for each well. The obstacles encountered by a would-be reader or analyst make the Well Site Safety Plans and their respective Safety Data Sheets of limited value in identifying potentially harmful chemicals used in West Virginia wells.

f. Safety Data Sheet Rules' Loopholes Prevent Full Chemical Disclosure

Researchers at Harvard University wrote in 2013 that the rules for creating Safety Data Sheets are unlikely to result in complete disclosure of fracking chemicals; these chemicals would include PFAS. The researchers observed that the rules limit disclosure to chemicals previously studied for workplace exposure. Many chemicals used in fracking might not meet this standard, they suggested, and therefore might not be disclosed in Safety Data Sheets.[146] The researchers also suggested that manufacturers might not list some substances in Safety Data Sheets because of a rule that manufacturers are not required to test a chemical to identify its hazards.[147] Instead, manufacturers can use existing data that may not show hazards of a particular chemical. Such chemicals would then not be required to be disclosed on a Safety Data Sheet even if the chemical were in fact hazardous.[148] These chemicals, in turn, would not be disclosed to companies in the fracking chemical supply chain, leaving the companies unable to disclose these chemicals to the public. The rules for Safety Data Sheets also allow chemical makers to withhold chemical ingredients as trade secrets.[149] These holes in the disclosure

rules for Safety Data Sheets may explain many of the gaps we observed in chemical disclosure under West Virginia's well site safety plans.

Litigation in Pennsylvania revealed additional cases in which chemical manufacturers omitted critical information from Safety Data Sheets, thus preventing oil and gas companies from making full disclosure of the chemicals they used in oil and gas wells. In 2014, four attorneys with years of experience litigating oil- and gas-related cases in Pennsylvania filed a petition with the state's Commonwealth Court in which they wrote that Safety Data Sheets (then called Material Safety Data Sheets or MSDS) often do not include complete lists of chemical ingredients:

> Many times, a vendor of a hydraulic fracturing fluid product merely re-labels product manufactured by another company without ever knowing anything about the chemical make-up of the product it has relabeled other than what may be contained in the manufacturer's MSDS. If that MSDS does not list the full chemical content of the product the vendor obtained, the vendor has no way of discerning the full chemical make-up of the hydraulic fracturing fluid. Thus, if a service provider or vendor never had possession of the entire chemical content of hydraulic fracturing fluid, then it is impossible for the vendor or service provider to pass that information along to the operator who then cannot possibly disclose to the Department [of Environmental Protection].[150]

The attorneys provided as support a record filed in a separate case by well operator Range Resources in which Range suggested that it was relying on MSDS from manufacturers to reply to a request for the chemicals used to fracture or stimulate its wells. Range said that the chemical information in these sheets could be incomplete. "The MSDS are often useful for developing some understanding of what is in a particular chemical or product," Range wrote, continuing,

> However, they vary widely in terms of usefulness. Some manufacturers include very little information about the actual components of a particular product. As a result, Range is currently in the process of seeking additional information from manufacturers that have failed to provide enough information about their products in the MSDS.[151]

In one case, Range said that a fracking or stimulation product called "MC SS-5075" was

> an Ammonium Bisulfite Solution manufactured by Multi-Chem. The MSDS describes the formula as 45-70% ammonium bisulfite by weight. Range is currently seeking information on the 30-55% missing from the formula.[152]

In another case, Range mentioned that a chemical known as "MC S-2510T," also made by Multi-Chem, contained "Ethylene Glycol (30%-60% by weight)" and "Sodium Hydroxide (5% by weight)." Range acknowledged that "we recognize that this formula fails to account for at least 35% of the weight, so we have contacted Multi-Chem for an explanation."[153]

g. Chemical Manufacturers' Exemption May Obscure PFAS Use in Oil & Gas Wells

Chemical manufacturers are in the best position to know the identities of individual fracking chemicals, whether these chemicals are used individually or as ingredients in fracking chemical products. Yet there is no requirement under West Virginia law that chemical manufacturers disclose the ingredients in their products to the well operators and service providers who must ultimately disclose the fracking chemicals to the public.[154] This omission may also obscure the extent of PFAS use in oil and gas wells. In fact, the well site safety plans show that in at least some cases, chemical manufacturers have not disclosed all of their fracking chemicals to well operators who, as a result, are unable to disclose these chemicals publicly.

A congressional investigation shows that the chemical manufacturers' lack of disclosure of oil and gas chemicals goes back at least more than a decade. In 2011, the U.S. House

of Representatives' Committee on Energy and Commerce minority staff issued a report on hydraulic fracturing chemicals in which they asked the 14 leading oil and gas service companies to "disclose the types and volumes of the hydraulic fracturing products they used in their fluids between 2005 and 2009 and the chemical contents of those products."[155] While the committee staff found, among other things, that the companies used products containing 29 chemicals that are known or possible human carcinogens, they also found that the companies could not completely respond to the committee staff's request because of chemical information withheld by chemical manufacturers.[156]

As a result of incomplete disclosure by chemical manufacturers, it is likely that well operators and service providers are using at least some fracking chemicals unknowingly and therefore cannot disclose these chemicals publicly. Some of these chemicals could be PFAS.

One situation exists that might make disclosure more likely: where service providers are also chemical manufacturers. Baker Hughes[157] and Halliburton,[158] for example, are service providers that conduct fracking and are also chemical manufacturers. If such companies conducted fracking and supplied their own fracking chemicals, they would know exactly what chemicals they were using and could make full public disclosure if they opted not to assert trade secret claims. However, companies may prefer to shield chemical identities behind trade secret provisions.

h. West Virginia's Chemical Disclosure Rules Cover Only Horizontal Gas Wells

A final shortcoming in West Virginia's chemical disclosure rules is that the rules apply only to horizontal gas wells, even though vertical wells have also often been hydraulically fractured with chemicals[159] and can be injected with chemicals in other stages or methods of extraction, such as the drilling that precedes fracking.[160] Companies that operate vertical wells or horizontal wells that do not meet the definition of "horizontal gas wells" under West Virginia law would not have to disclose their chemicals, either under requirements specifically focused on fracking chemicals or as part of a well site safety plan.

According to data from the WVDEP, most wells drilled in the state between January 1, 2013 and December 31, 2022 — 2,554, to be precise — were horizontal gas wells for which chemical disclosure requirements applied, compared to only 38 vertical wells and 29 horizontal wells that were not considered "horizontal gas wells."[161] Oil and gas operators were not required to disclose chemical usage for these 67 wells – a very small number.[162] However, operators were not required by law to disclose chemical usage for any oil and gas wells in West Virginia before 2011, when fracking chemical disclosure rules and well site safety plan rules went into effect.[163] That exempts a massively larger number of wells from chemical disclosure: The West Virginia Geological and Economic Survey reported as of June 2009, that 145,000 oil and gas wells had been drilled in West Virginia over the past 150 years.[164] West Virginians could be unknowingly exposed to dangerous chemicals used in those older wells, potentially including long-lasting PFAS chemicals.

CH. 5 EVIDENCE SUGGESTS WIDER PFAS USE THAN REPORTED IN WEST VIRGINIA'S OIL & GAS WELLS

Several sources say that PFAS have a history of use in the oil and gas industry. This little-known evidence increases the concern that at least some of the trade secret chemicals and other undisclosed chemicals in West Virginia's oil and gas wells could be PFAS.

In the 2023 study of PFAS in Pennsylvania's streams referenced in chapter 2, researchers from the U.S. Geological Survey and PADEP recognized oil and gas wells as among "facilities that have been documented as potential sources of PFAS."[165] In making this determination, the authors relied on three sources that suggest that the use of PFAS in oil and gas wells dates back decades and encompasses a variety of extraction techniques. One was a paper published in 2008 in the peer-reviewed *Open Petroleum Engineering Journal* by two authors, one of whom was identified as an employee at DuPont. This paper noted that

> while fluorosurfactants have been used in gas and oil exploration for four decades, the increased demand for petroleum and the greater understanding of the benefits of fluorosurfactants have led to growing acceptance for fluorosurfactants throughout the petroleum industry.[166]

The authors did not explicitly say that fluorosurfactants used in oil and gas operations were PFAS, but they described the fluorosurfactants in ways that are commonly used to describe PFAS. They wrote that

> The use of fluorosurfactants is a recent but growing trend due to (i) the exceptional hydrophobic [water-repellent] and oleophobic [oil-repellent] nature of the perfluoroalkyl and perfluoroalkyl ether groups... The bond strength of the carbon-fluorine bond in perfluoroalkyl and perfluoroalkyl ether groups has been demonstrated as the key to remarkable overall stability for fluorochemicals and fluoropolymers.[167]

This evidence suggests that any time an unidentified fluorosurfactant or unidentified surfactant is used in oil and gas production, there exists the potential that it is a PFAS.

The second source was a paper published in 2020 in *Environmental Science: Processes and Impacts* in which the authors showed that since 1956, PFAS including fluorosurfactants had been used or proposed to be used globally in oil and gas extraction techniques; these included chemical-driven gas production, chemical flooding, fracking, and the drilling that precedes fracking and other oil and gas production techniques.[168] The fact that these two papers date the use or potential use of PFAS in oil and gas wells as far back as the 1950s or 1960s indicates that in addition to horizontal oil and gas wells, PFAS may have been used in vertical oil and gas wells. Vertical wells were predominant[169] until the mid-2000s when horizontal wells combined with hydraulic fracturing became "the industry standard" according to EPA.[170]

The third source is a 2022 paper published in the peer-reviewed *Advances in Colloid and Interface Science* in which several authors from the Center for Integrative Petroleum Research at King Fahd University of Petroleum & Minerals in Saudi Arabia stated that "The fluorinated surfactants are very attractive to oilfield industries due to their distinct surface/interface properties and excellent thermal/chemical stabilities."[171] The authors also cited the 2008 *Open Petroleum Engineering Journal* paper in stating that "Fluorinated surfactants are efficient in numerous enhanced oil recovery (EOR) processes including modification of surface properties of reservoir formation, enhancing the wetting of subterranean, [sic] and increasing foams stability." Like the authors of the 2008 article, the authors of the 2022 paper described fluorosurfactants in ways typically used to describe PFAS including as having "both water and oil repellency" and having a carbon-fluorine bond.[172] However, the authors concluded that "Despite the enormous potential of fluorinated surfactants in the petroleum industry, their usage seems to be limited dueto environmental concerns."[173] The multiple regulatory gaps that allow oil and gas companies to withhold the identities of their chemicals from the public in West Virginia and other states make this statement impossible to verify.

CH. 6 EXPOSURE PATHWAYS TO PFAS ASSOCIATED WITH WEST VIRGINIA OIL AND GAS OPERATIONS

a. Disposal of Waste Intensifies Pollution Concerns in West Virginia

As indicated by EPA and discussed in Chapter 1 of this report, there are multiple pathways through which PFAS and other contaminants associated with oil and gas operations could jeopardize health and the environment. In this chapter we examine some of those pathways, including leaks and spills at well sites and wastewater disposal sites; underground migration of wastes into groundwater from abandoned wells and wastewater disposal sites; spreading of wastewater on roads for dust suppression and deicing; and air pathways.

The risk that PFAS and other chemicals associated with oil and gas drilling could pollute the environment is especially high in West Virginia because of the staggering volumes of wastewater and solid waste generated by oil and gas extraction, particularly for horizontal gas wells. The volumes are so high largely because operating horizontal gas wells involves injecting millions of gallons of fracking fluid, a portion of which returns to the surface in the form of wastewater known as "flowback." The flow of flowback out of the well can last for several weeks.[174] In 2016, the EPA reported that flowback in the Marcellus and Utica shale formations in West Virginia[175] and other states can total between 300,000 and one million gallons per well over the first 10 days.[176] In addition, following flowback, huge volumes of naturally occurring water from underground formations, known as "produced water," flow out of the wells, potentially for years.[177] In 2016, EPA reported that five years after a typical well was drilled in the Marcellus shale, it would still be producing wastewater at a rate of hundreds of gallons per day.[178] In total, the wastewater, whether flowback or produced water, can contain a variety of dangerous substances. These may be the chemicals intentionally added to the fracking fluid, such as PFAS; naturally occurring contaminants in underground formations, such as radium, that occurs in significant concentrations in wastewater from West Virginia,[179] or chemicals that are products of reactions that occur in underground formations.[180] Intentionally added drilling fluids used to drill wells prior to fracking, or naturally occurring water encountered during drilling, may also be part of the wastewater mix, according to EPA.[181]

These vast quantities of chemical-laden wastewater are sometimes reused to fracture other wells. The majority of oil and gas wastewater, however, is disposed of by being forced into underground injection wells.[182] Whether wastewater is disposed of or reused, it often requires transport by truck,[183] with the attendant risk of accidents and spills.[184] Over the past decade, scientists and regulators have identified several likely or potential cases of pollution from oil and gas wastewater in West Virginia. These studies raise concerns that if PFAS were present in oil and gas wastewater, it could contaminate water and perhaps other resources. Unfortunately, there is no evidence that wastewater has been tested for PFAS.

- In a paper published in 2016, scientists from the U.S. Geological Survey reported the results of a study of contaminants downstream of an underground injection well in West Virginia into which oil and gas wastewater had been pumped for disposal.[185] Underground injection into disposal wells is the leading method of disposal of oil and gas wastewater.[186] Compared with background measurements upstream of the facility, the researchers found elevated concentrations downstream of contaminants including types of chloride, calcium, sodium, strontium, and barium. These substances are associated with unconventional oil and gas wastewater and with naturally occurring water from the Appalachian basin that includes the Marcellus and Utica shale formations then being drilled for natural gas. Sediments downstream were also high in radium, which is associated with oil and gas wastewater in West Virginia.[187] The researchers noted that while they could not determine the pathways for contamination, "these data provide evidence demonstrating that activities at the disposal facility are impacting a nearby stream and altering the biogeochemistry of nearby ecosystems."[188]

- In another paper published in 2016, scientists shared the results of a study of markers for endocrine

disruptors near another West Virginia underground injection disposal well for oil and gas waste.[189] Endocrine disruptors, which include PFAS,[190] are chemicals that can interfere with the endocrine system.[191] The endocrine system comprises hormones that control or regulate various biological processes, for example, blood sugar levels and the functioning of reproductive organs.[192] In comparison to water samples upstream, the scientists found several markers for endocrine-disrupting chemicals adjacent to and downstream from the disposal well. The scientists concluded that "these data raise concerns for human and animal health nearby."[193]

- In a paper published in 2015, researchers from Duke University, Dartmouth College, and Stanford University reported finding elevated levels of iodide, bromide, and ammonium in samples of wastewater from fracking operations in both the Marcellus shale, located in part in West Virginia, and the Fayetteville Shale, located in Arkansas. The researchers found elevated levels of iodide and ammonium in discharged effluents from oil and gas wastewater treatment sites in Pennsylvania and in wastewater from an oil and gas wastewater spill in West Virginia. The scientists wrote that "Bromide, iodide, and ammonium in surface waters can impact stream ecosystems and promote the formation of toxic brominated-, iodinated-, and nitrogen disinfection byproducts during chlorination at downstream drinking water treatment plants. Our findings indicate that discharge and accidental spills of OGW [oil and gas wastewater] to waterways pose risks to both human health and the environment."[194]

Drilling the wells also generates vast quantities of waste material, in this case solid waste. Horizontal wells involve boring into the earth thousands of feet vertically and thousands of additional feet horizontally.[195] The West Virginia Geological and Economic Survey reported that in 2019 the average combined depth and length of 2,758 horizontal wells reporting production of natural gas or natural gas liquids in the Marcellus shale was 14,131 feet.[196] Drilling these wells produces tons of rock shards known as "drill cuttings" that could be contaminated with human-made or naturally occurring toxics.[197] These toxics could include PFAS, which may be used in drilling as a foaming agent.[198]

b. Oil and Gas Waste Can Impact Communities Miles from Production Wells

Sites far from oil and gas production wells can also be impacted by oil and gas wastes potentially containing PFAS. In neighboring Pennsylvania, the state tracks where oil and gas wastes from each production well are shipped. The records show that these wastes can be transported miles from well sites, including to disposal sites in West Virginia. Pennsylvania's records of waste disposal show that the potential for oil and gas waste to contain PFAS is not just hypothetical, according to an analysis of state records in 2022 by Environmental Health News.[199] The publication found that eight unconventional gas wells in Pennsylvania injected with PTFE produced more than 23 million gallons of liquid waste and 30,390 tons of solid waste between 2012 and 2022.[200] A map, (see next page) below, developed for the publication by FracTracker Alliance showed that this waste was transported to at least 97 sites for reuse or disposal in Pennsylvania, Ohio, and West Virginia.[201]

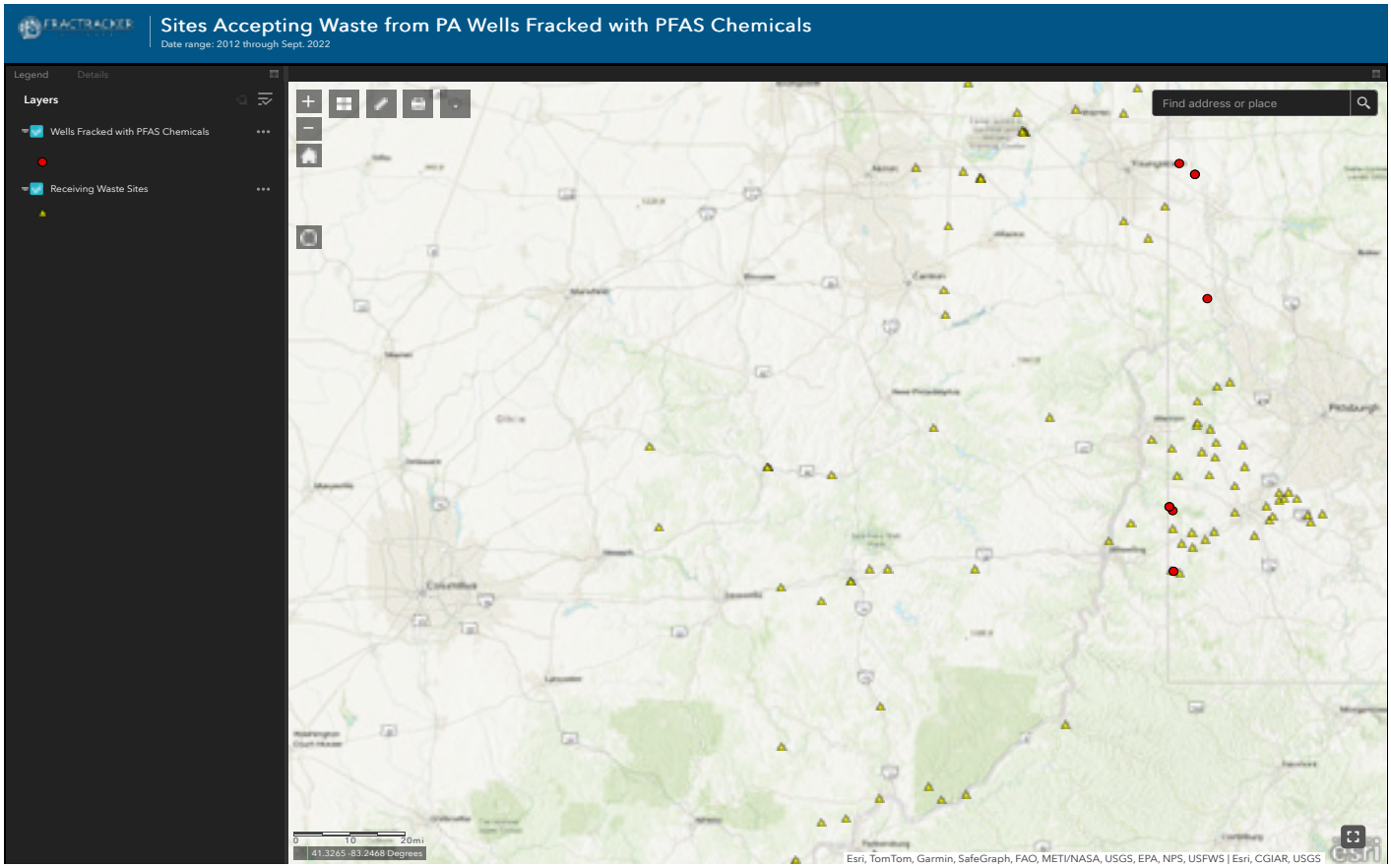
West Virginia disposal sites include the towns of:

- Colliers, where J.P. Mascaro & Sons Brooke County Landfill received more than 281 tons of drill cuttings combined from the Bernard McCulley Was 5H well[202] and Paul Schilinski Was 8H well,[203] both fracked in Washington County, PA.

- New Martinsville, where Wetzel County Landfill received more than 70 tons of fracking fluid waste combined from the Fred Jones Was 6H well,[204] fracked in Washington County, PA. and the Roberts Bea 6H well,[205] fracked in Beaver County, PA.

- Parkersburg, where the Northwestern Landfill operated by Waste Management received more than 70 tons of drill cuttings from the Paul Schilinski Was 8H well,[206] fracked in Washington County, PA.

Figure 5: Sites Accepting Waste from PA Wells Fracked with PFAS Chemicals



This map, developed by FracTracker Alliance for Environmental Health News, shows destinations for liquid and solid waste from eight Pennsylvania oil and gas wells where companies reported using PTFE/Teflon for fracking between 2012 and 2022. Reprinted with permission. An interactive map of these sites is available here: https://www.ehn.org/fracking-pennsylvania-pfas-2658837888.html.

- St. Mary's, where the Eureka Station Crosstex Energy centralized treatment plant for recycling received more than 150,000 gallons of produced fluids and other oil and gas wastes from the Bernard McCulley Was 5H well,[207] Fred Jones Was 6H well,[208] and the Paul Schilinski Was 8H well,[209] all fracked in Washington County, PA.

- Wheeling, where Short Creek Landfill operated by American Disposal Services received almost 3,500 tons of drill cuttings from the Bernard McCulley Was 5H well,[210] Fred Jones Was 6H well,[211] and Paul Schilinski Was 8H well,[212] all fracked in Washington County, PA.

One or more well pads in West Virginia received for reuse, likely in a production well, a combined total of more than 4.5 million gallons of produced fluids and other oil and gas wastes from the Bernard McCulley Was 5H well,[213] Fred Jones Was 6H well,[214] and the Paul Schilinski Was 8H well,[215] all fracked in Washington County, PA.*

Considering the vast use in Pennsylvania's oil and gas wells of undisclosed chemicals (identified by PSR in 2023[216]), there is a potential that the waste from any oil or gas well in Pennsylvania contains PFAS and that communities near oil and gas waste disposal sites in West Virginia that accept

* The volume of drill cuttings or fluid disposed of in West Virginia from Pennsylvania's unconventional gas wells injected with PFAS are as of March 2023.

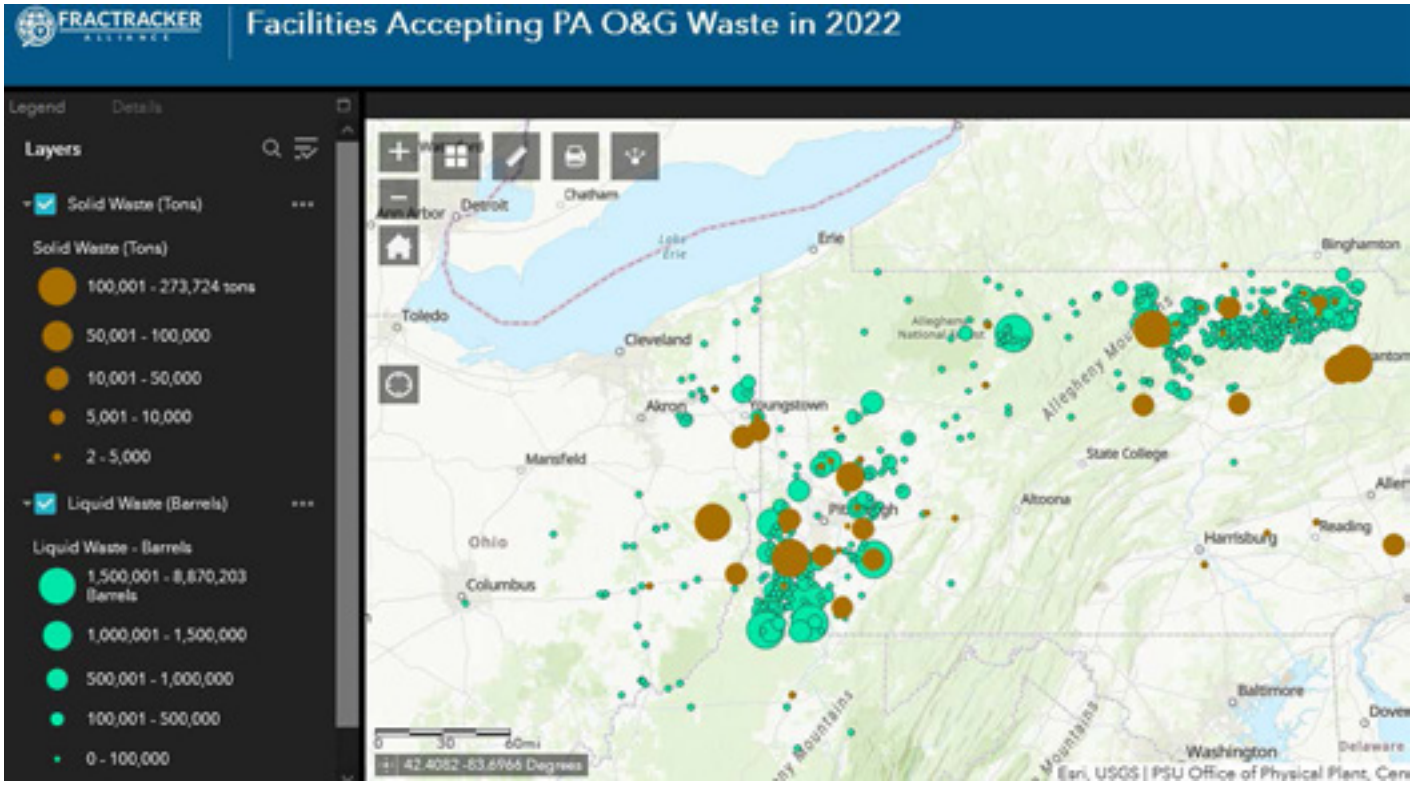
this waste could be at risk of contamination.[217] Figure 6 is a map from FracTracker Alliance showing the locations of the facilities in West Virginia that received oil and gas waste from Pennsylvania in 2022. Users can click on a link below the map to view an interactive version that enables users to zoom in on their communities.

Robert Delaney, a retired geologist and Superfund specialist previously with for the Michigan Department of Environmental Quality (now called the Michigan Department of Environment, Great Lakes, and Energy), spoke to Environmental Health News about the shipments of waste from Pennsylvania gas wells that had been fracked with PTFE. He said that "If there were PFAS in any of those waste products, it's likely that it would have gotten into the environment in some of those locations."[218] Delaney spent 36 years working in natural resource protection for the state of Michigan and first warned state officials about the looming problem with PFAS in 2012, though unrelated to oil and gas extraction.[219] Delaney told Environmental Health News,

> The odds are that just as there were spills at the well pads, there have been spills and leaks at these disposal sites. All these places that accepted the waste didn't know that they were dealing with PFAS. And the things you do to treat other chemicals doesn't work on them… these chemicals never go away.[220]

When Environmental Health News first asked the Pennsylvania Department of Environmental Protection (PADEP) to comment on the use of PFAS in oil and gas operations in Pennsylvania, the Department responded that "absent a spill or release on the surface or below surface, there is no reason to conclude that wellsite fluids (whether

Figure 6. Facilities Accepting Pennsylvania Oil and Gas Waste in 2022



This map, developed by FracTracker Alliance for Environmental Health News, showing destinations for liquid and solid waste from eight Pennsylvania oil and gas wells where companies reported using PTFE/Teflon for fracking between 2012 and 2022. Reprinted with permission. An interactive map of these sites is available here: https://www.ehn.org/fracking-pennsylvania-pfas-2658837888.html.

including PFAS compounds or not) would have reached nearby soils or drinking water."[221] EHN then found evidence that there were two spills at one of the wells in 2017 and 2020, and informed the PADEP.[222] In response, PADEP spokesperson James Thrasher told the publication,

> Given the time period between the use of the PFAS chemicals and the releases, the small amount of the spills, that the spills were contained to the gravel of the well pad, and that they were remediated quickly, DEP does not have current plans to sample for PFAS at this location.[223]

In his comments to EHN, Thrasher suggested that the produced water was unlikely to contain chemicals that were used in fracking.[224] Delaney, however, suggested to EHN that Pennsylvania officials should at least test for PTFE near the well sites where the chemical was used and consider testing at the locations where waste from these wells was disposed of.[225] Given that PFAS have earned the moniker "forever chemicals" due to their persistence in the environment, Delaney's advice may also apply to disposal sites in West Virginia.

c. Abandoned Wells Put Drinking Water at Risk

Due to the state's long history of oil and gas drilling, dating back to 1859,[226] West Virginia is riddled with thousands of abandoned oil and gas wells that could serve as pollution pathways for PFAS or other toxics associated with oil and gas extraction or waste disposal.[227] Researchers have known for decades that oil and gas wells which have ceased operating but have not been properly sealed off from the surrounding underground rock formations can be conduits for oil and gas-related water pollution.[228] Fluids associated with oil and gas wells can migrate up these abandoned wells and contaminate groundwater near the earth's surface[229] or, potentially, surface water.[230] Such fluids could include fracking fluid injected into adjacent oil and gas production wells,[231] or oil and gas wastewater injected into adjacent disposal wells.[232]

Evidence of pollution risks associated with abandoned oil and gas wells dates at least to the 1980s and involves a fracking operation in West Virginia. In 1987, EPA concluded in a report to Congress on oil and gas wastes that fracking fluid from a gas production well had contaminated a water well in Jackson County owned by a man named James Parsons.[233] "When fracturing the Kaiser gas well on Mr. James Parson's property, fractures were created allowing migration of fracture fluid from the gas well to Mr. Parson's water well," the agency wrote. "This fracture fluid, along with natural gas was present in Mr. Parson's water, rendering it unusable."[234] While EPA did not discuss the precise pathway for contaminants from the gas production well to the water well, the nonprofit Environmental Working Group reported in a 2011 paper that there were four abandoned gas wells on Parson's property that could have served as vertical conduits for the fracking fluid.[235]

In a more contemporary case, in 2022, the Pittsburgh Post-Gazette reported that a man in New Freeport, PA recounted having witnessed "a geyser" of water erupting from the location of an abandoned well on his property. He learned that a Pennsylvania-based oil and gas company, EQT Corp., was simultaneously fracking a horizontal well more than a mile away. The next day, EQT notified the Pennsylvania Department of Environmental Protection (PADEP) about a well communication issue; the term refers to a situation in which one well interacts with another. The company, however, told the Post-Gazette that it did not know if its fracking had caused the geyser. Several neighbors were quoted as saying that they thought the apparent well communication also impacted their water; one said her son took a shower on the day of the incident and later broke out in hives.

If this was a case of well communication, it was not an isolated incident. Over the previous six years, oil and gas companies had reported to the PADEP 45 suspected cases of well communication. Most were discovered by operators of active shale gas wells adjacent to other active shale gas wells that were the apparent source of the communication. The operators noticed changes in pressure or other impacts in their own wells. In contrast, it is less likely that anyone would be monitoring abandoned wells to identify a communication

incident.[236] Thus, communication with abandoned wells may be more common than reports reflect. The result could be water or soil contamination entirely unknown to the public, whether from PFAS or other toxics.

Compounding these problems is that in West Virginia, horizontal gas wells can be located as close as 250 feet from a water well, and the center of a well pad can be as close as 625 feet from an occupied home. Vertical oil and gas wells can be as close as 200 feet from a water well or a home.[237] Given this potential for proximity, toxic fluids from a well – abandoned or in active production – could pollute well water or soil at a residence. And airborne pollutants can easily travel such a short distance. In 2021, a criminal grand jury convened by Pennsylvania's Attorney General recommended a setback or no-drilling zone of 2,500 feet (about a half-mile) from homes and 5,000 feet from schools and hospitals.[238] These distances would be somewhat protective but perhaps not protective enough: In 2012, a New York office of the U.S. Geological Survey warned that if the type of shale gas fracking practiced in West Virginia were allowed in New York, fracking could jeopardize water supplies within an area of up to five square miles.[239] Water protection would then require no-drilling setbacks closer to 2.23 miles, not 2,500 feet.

The risk of pollution through abandoned oil and gas wells is multiplied by the presence of injection disposal wells, where liquid wastes from oil and gas wells are injected underground as a means of disposal – a common practice in the oil and gas industry.[240] In 1983, the then-existent Congressional Office of Technology Assessment reported on the "insidious" problem of underground injection of oil and gas wastewater. The congressional office had noted that such wastewater is typically injected in exactly the places where prior drilling has created opportunities for the wastewater to migrate through abandoned or closed wells into groundwater.[241] In 1989, Congress' investigative arm, the General Accounting Office (now the Government Accountability Office) reported on almost two dozen incidents of drinking water contamination associated with wastewater disposal wells.[242] Many of these cases involved wastewater migrating up abandoned oil and gas wells.[243] It is not known how much injected wastewater might contain PFAS.

Migration into water supplies of oil and gas wastewater injected into disposal wells may be even more likely in West Virginia because disposal wells in the state are poorly regulated, according to a report published by the nonprofit Natural Resources Defense Council (NRDC) in 2019.[244] NRDC reviewed records for 19 injection wells specifically designated for the disposal of oil and gas wastewater[245] listed in 2015 in a database maintained by the WVDEP.[246] NRDC found multiple deficiencies, including that state regulators failed for 13 of the 19 injection wells to conduct mechanical integrity tests every five years as required by state law. Mechanical integrity tests are designed to detect leaks in the wells and the potential that wastewater could migrate upward into underground sources of drinking water through an adjacent vertical conduit such as a nearby abandoned well.[247]

These deficiencies are particularly worrisome in light of recent experiences in Ohio, where injection disposal wells are common. In January 2021, in Noble County, Ohio, more than 1.6 million gallons of what appeared to be fracking wastewater flowed for four days from an unplugged oil and gas well that had been idle since 2012.[248] A nearby tributary, Taylor Fork, was impacted by the spill, resulting in a fish kill. The cause of the fluid flow was unclear, but there were six active fracking wastewater injection wells in Noble County, including three within four miles of the leaking oil and gas well. Another example occurred in September 2020 in Washington County, Ohio, when fracking wastewater migrated at least five miles from a disposal well to gas-producing wells, causing state officials to worry about possible groundwater contamination.[249] In 2023, the Ohio Department of Environmental Protection suspended injections at six oil and gas wastewater injection wells after concluding that wastewater from the wells had migrated up nearby oil and gas production wells. These injection wells included two in Noble County in January,[250] one in Athens County in May,[251] and three in Athens County in June.[252] **In each case, the Department concluded among other things that if the wells continued to operate, "additional impacts may occur in the future**

and are likely to contaminate the land, surface waters, or subsurface waters…."[253]

d. Spreading Oil and Gas Wastewater on Roads

Another pathway through which PFAS used in oil and gas wells could jeopardize West Virginians' health is through the practice of spreading oil and gas wastewater on roads for deicing or dust suppression.[254] West Virginia allows the practice only for "the wintertime application of natural gas well brines in order to minimize the formation of bonded snow and ice to roadway surfaces by utilizing the melting capabilities of salt brine."[255] The state places further limitations on this use of brines, including that the brines can come only from vertical wells and that concentrations of 12 types of chemicals in the brines must be below certain levels.[256]

However, West Virgina's limitations on spreading oil and gas wastewater on roads are insufficient to protect the public. There are no limits on PFAS in the wastewater that can be spread on roads, and no guarantee that the wastewater from vertical wells would lack PFAS. Nor are there limits on radium, a radioactive and carcinogenic element that has been found in the type of brine used for road-spreading in the northeastern U.S. In 2018, scientists wrote in a peer-reviewed paper that

> analyses of O&G [oil and gas] wastewaters spread on roads in the northeastern, (sic) U.S. show that these wastewaters have salt, radioactivity, and organic contaminant concentrations often many times above drinking water standards….The potential toxicity of these wastewaters is a concern as lab experiments demonstrated that nearly all of the metals from these wastewaters leach from roads after rain events, likely reaching ground and surface water… Spreading O&G wastewater on roads can harm aquatic life and pose health risks to humans.[257]

There is no indication that the scientists tested for PFAS, but if there were PFAS in the wastewater used for road-spreading, it seems likely that PFAS, which is highly mobile in water, could likewise run off of roads and pose health and environmental risks.

e. Leachate from Landfills

West Virginians could also be impacted by PFAS when solid waste from oil and gas operations is taken to landfills, if the waste were tainted with "forever" chemicals from oil and gas wells. As noted above, waste from eight Pennsylvania unconventional gas wells known to have been injected with PFAS was taken to landfills in West Virginia. When rainwater percolates through the contents of the landfill and comes in contact with buried wastes, it leaches out their chemicals or constituents, creating a wastewater known as "leachate."[258] Should rainwater contact oil and gas waste tainted with PFAS and leach out the forever chemicals, that leachate could cause contamination if it escaped or was collected and disposed of improperly.

One possible example of improper disposal comes from Fayette County, Pennsylvania, where in 2019 local prosecutors asked the Pennsylvania Attorney General's office to investigate after leachate from a landfill that had accepted oil and gas drill cuttings was taken to a wastewater treatment plant. That wastewater was apparently responsible for the plant's discharge of treated water that exceeded state and federal pollution standards. The plant discharged into the Monongahela River, a major source of drinking water for Western Pennsylvania.[259] It is unknown whether PFAS was involved.

A case that did involve PFAS allegations that leachate from a landfill in Pennsylvania had contaminated a creek near York with PFAS. In 2023, Lower Susquehanna Riverkeeper Ted Evgeniadis sued Modern Landfill and its owner Republic Services, asking a federal judge to force the company to comply with the Clean Water Act and institute penalties for alleged violations.[260] Evgeniadis asserted in a written complaint that the landfill was discharging extremely high levels of PFAS into a local creek in violation of the law: discharges with levels of PFOS at 374.3 parts per trillion, levels of PFOA at

847 parts per trillion, "and 25 other PFAS compounds also measured at very high levels."[261] The source of the PFAS in the landfill was unspecified. PADEP records show that in April 2019, Modern Landfill received three tons of produced fluid from unconventional gas wells,[262] but it is unclear that this volume of fluid was accurate because records of oil and gas waste shipments and deliveries in Pennsylvania are often inconsistent.[263] Nor is it clear whether gas-related waste contributed to the high PFAS levels near the landfill. In 2015, at the direction of the West Virginia legislature, a team of researchers led by Marshall University studied the disposal in municipal landfills of drilling waste such as rock fragments unearthed during the drilling process. The researchers did not analyze similar disposal of fracking waste.[264] The authors found "little concern with regards to the leachate from drill cuttings that were placed in approved and permitted landfills, once that leachate was processed through a correctly operated treatment facility."[265] However, there is no indication that the researchers tested any landfill materials or leachate for PFAS.

f. Volatilizing, Flaring Could Pollute Air with PFAS

PFAS used in West Virginia's oil and gas wells could follow airborne exposure routes, according to toxicologist David Brown, former director of environmental epidemiology at the Connecticut Department of Health. Brown has investigated health effects associated with unconventional gas drilling for the Southwest Pennsylvania Environmental Health Project and has expressed concerns about PFAS. He told PSR that if PFAS were to enter drinking water, it could subsequently volatilize or become airborne inside homes. Brown added that PFAS could become airborne outdoors when gas is burned off during flaring or venting at the oil and gas wellhead.[266]

Bolstering Brown's concern, both the EPA and the Interstate Technology Regulatory Council say that PFAS can be spread through air, though neither source mentions pathways from oil and gas operations, perhaps because such pathways have only recently come to the public's attention. On a

Drill cuttings from shale gas development being dumped at the Wetzel County (W.Va.) Landfill, Nov. 10, 2014. Photo credit: Bill Hughes.

webpage devoted to "PFAS Analytical Methods Development and Sampling Research, EPA includes a heading entitled "Source (Air) Emissions" and states that

> There are diverse sources of emissions, including chemical manufacturers, commercial applications, and thermal treatment incineration processes. EPA is developing test methods for measuring PFAS source emissions.[267]

The Interstate Technology Regulatory Council (ITRC), a state-led environmental coalition that includes members from state, federal, tribal, and international agencies as well as representatives from academia, the private sector and the general public,[268] reported that "Under certain conditions, particularly within industrial stack emissions, or during fire suppression, incineration, or combustion, PFAS can be transported through the atmosphere."[269] The ITRC added that deposition of PFAS could result in pollution of soil, groundwater, or other media:

> Short-range atmospheric transport and deposition can result in PFAS contamination in terrestrial and aquatic systems near points of significant emissions, impacting soil, groundwater, and other media of concern (citation omitted). Evidence of releases has been observed in areas where hydrologic transport could not plausibly explain the presence of PFAS in groundwater, with the extent of contamination reaching several miles from sources and in distribution patterns independent of regional hydrology (citations omitted).[270]

Where PFAS are used in oil and gas wells, this information indicates that nearby residents should be concerned about airborne emissions.

The overlook at Grandview, W.Va. New River Gorge National Park and Preserve, July 30, 2023. Photo credit: daveynin.

CH. 7 OIL & GAS-RELATED CHEMICAL EXPOSURE AS AN ENVIRONMENTAL JUSTICE ISSUE

"Fenceline" communities – people living close to oil and gas operations – often bear a disproportionate risk of exposure to toxic chemicals. This may place them particularly at risk from PFAS where it is used in oil and gas extraction.

Although drilling and fracking take place in the majority of U.S. states, not everyone shares in the risks equally. Rather, oil and gas infrastructure and associated chemicals are frequently located in or adjacent to lower-income, underserved, and marginalized communities. Evidence suggests that this disproportionality is the case in West Virginia, which has the third-highest poverty rate of the 50 states, according to a review of Census data by the West Virginia Center on Budget & Policy.[271] Clark University researchers conducted an analysis published in 2015 in which they used sophisticated Geographic Information Systems (GIS) tools to examine whether vulnerable populations were disproportionately exposed to pollution from unconventional gas wells in West Virginia, Ohio, and Pennsylvania. The researchers found clusters of vulnerable populations concentrated near unconventional gas wells in all three states, with West Virginia's disproportionately affected populations characterized by higher percentages of poverty, elderly population, and lower education level.[272] Where a pattern of risks affects lower-income people and/or people of color disproportionately, oil and gas production methods should be viewed and addressed as an issue of Environmental Justice. So too should any oil and gas related exposure to PFAS. Extra steps should be taken to inform the affected communities, hear their concerns, and work with them to remediate the problems.

CH. 8 POLICY CAN HELP PROTECT WEST VIRGINIANS FROM PFAS IN FRACKING

a. Federal Protections from PFAS Pollution are Modest

Governments at all levels will have to do more to protect West Virginians from PFAS, in large part because EPA has taken only modest steps to do so, while Congress and the executive branch have exempted the oil and gas industry from major provisions of multiple federal environmental laws. For example, oil and gas waste is exempted from the hazardous waste rules that require cradle-to-grave tracking and safe handling of hazardous substances under the Resource Conservation and Recovery Act. These exemptions increase the burden on state governments to address any PFAS pollution associated with oil and gas extraction.[273]

EPA has taken some steps to protect the public from dangerous PFAS. In 2005, EPA reached a then-record $16.5 million settlement with chemical manufacturer Dupont after accusing the company of violating the federal Toxic Substances Control Act (TSCA) by failing to disclose information about PFOA's toxicity and presence in the environment.[274] In 2006, EPA invited Dupont, 3M and six other companies to join a "stewardship" program in which the companies promised to achieve a 95 percent reduction of emissions of PFOA and related chemicals by 2010, compared to a year 2000 baseline. The agreement also required the companies to eliminate such emissions and use of these chemicals by 2015.[275] In 2022, EPA said on its website that the companies reported that they had accomplished those goals, either by exiting the PFAS industry or by transitioning to alternative chemicals.[276] EPA reported in 2022 that the manufacture and use of at least one PFAS – PFOA – had been phased out in the U.S., and that no chemical company had reported making PFOS in the U.S. since 2002. EPA noted that existing stocks of PFOA might still be used, and imported products may contain some PFOA.[277] A 2020 scientific article reported that PFOA was still used in Asia.[278] EPA stated that limited ongoing uses of PFOS remain.[279] However, since the announcement of its PFAS stewardship program in 2006, EPA has allowed nearly unlimited use of closely related "replacement" chemicals in dozens of industries.[280] In response, in 2015 a group of more than 200 scientists raised health and environmental concerns that the new PFAS designed to replace PFOA and PFOS may not be safer for health or the environment.[281]

In October 2021, EPA announced a "strategic roadmap" for regulating PFAS. This plan encompassed a goal of setting federal drinking water standards for several PFAS chemicals by 2023, as well as commitments to "use all available regulatory and permitting authorities to limit emissions and discharges from industrial facilities" and "hold polluters accountable."[282] The plan does not, however, include an examination of PFAS use in the oil and gas industry. (Later that month, 15 members of the U.S. House of Representatives asked EPA to examine this topic.[283] The month before, PSR had asked EPA to collect data on PFAS use in oil and gas extraction, utilizing its authority under TSCA.[284])

As previously stated, in June 2022, EPA announced new health advisory levels for several types of PFAS and in March 2023, EPA announced a plan to regulate six types of PFAS in drinking water. Additionally, in August 2022, EPA proposed designating PFOA and PFOS as hazardous under Superfund.[285] And in April 2023, EPA asked for public comment on potentially designating seven additional PFAS as hazardous under Superfund.[286] This designation would enable affected parties to more easily hold oil and gas companies accountable for cleanup costs if PFOA and PFOS were found at oil and gas sites because under Superfund, liability does not require negligence, and any potentially responsible party (PRP) can be held liable for cleanup of an entire site when it is difficult to distinguish contributions to pollution among several parties. As EPA writes about Superfund, "[i]f a PRP sent some amount of the hazardous waste found at the site, that party is liable."[287]

In acting belatedly to regulate at least some types of PFAS in drinking water, EPA is following behind the leadership taken by several states. As of 2023, nine states, but not West Virginia, had developed enforceable standards for concentrations of several types of PFAS in drinking water.[288]

b. West Virginia's Disclosure Rules: In Need of Sweeping Reform

In West Virginia, multiple reforms are needed to protect the public from the use of PFAS in oil and gas operations. One needed reform is to change the state's chemical disclosure rules to lift the veil of secrecy that oil and gas companies have used to conceal the use of potentially dangerous chemicals, possibly including PFAS. One initial step should be to establish tighter limits on the use of trade secret provisions.

Oil and gas companies have argued that chemical trade secrets are necessary to protect their intellectual property from competitors. However, this interest does not have to mean a complete withholding of information on chemical identities from scientists, regulators, and the public. In 2015, California, a major oil-producing state,[289] began requiring full disclosure of chemicals used for well stimulation, including fracking. The policy did away with trade secret exemptions for the individual chemicals used in fracking products.[290] In June 2022, Colorado, a major producer of oil and gas,[291] followed in California's footsteps but extended the disclosure requirements to all chemicals used in oil and gas wells, not just fracking or stimulation chemicals.[292]

The methodology utilized in California and Colorado is consistent with a recommendation issued in 2014 by an advisory panel to the U.S. Department of Energy: that companies reveal the fracking chemicals injected into each well, providing that information in a list in which the chemicals are disassociated from the trade name of the commercial products they are part of.[293] This form of disclosure enables the public to know all the chemicals used in fracking without disclosing to rival chemical manufacturers the exact components of proprietary formulas.[294] In a similar way, food producers keep recipes secret while disclosing individual ingredients, enabling the public to know the contents of food products but making it difficult for rival producers to recreate valuable food brands.

California and other states have additional provisions in their oil and gas chemical disclosure rules that could be models for West Virginia. California has a process under which state regulators review secrecy requests from chemical companies to determine whether the information must be kept proprietary.[295] Health and safety data related to fracking fluids are not allowed to be hidden from public view under California law.[296] Colorado, in its June 2022 legislation, required chemical disclosure from chemical manufacturers.[297] This last reform would address many of the gaps seen in the Safety Data Sheets created by chemical manufacturers that West Virginia horizontal gas well operators are required to disclose as part of well site safety plans.

These reasonable and feasible reforms are valuable steps to protect the health of people who may be exposed to PFAS and other dangerous oil and gas chemicals, be they industry workers, residents living near well sites, or first responders called to the scene of an accident. They can improve health and potentially save lives.

Additional steps to reduce the harms caused by oil and gas extraction are outlined in the recommendations section of this report. They include a ban on the use of PFAS in oil and gas operations, an action that Colorado took in 2022.[298] Among the evidence supporting the feasibility of this measure is a peer-reviewed scientific analysis published in 2021 showing that many PFAS are immediately replaceable with less-persistent and less-toxic substances, including for use in the oil and gas industry.[299]

c. West Virginia's Hazardous Waste Rules Also in Need of Reform

West Virginia's state government has recognized the dangers of PFAS but, in doing so, has illuminated another gap in state rules that should be closed to protect the public from PFAS use in oil and gas operations: the exemption of oil and gas wastes from hazardous waste requirements. Subtitle C of the Resource Conservation and Recovery Act (RCRA) is our nation's law that requires safe management of hazardous waste from "cradle-to-grave."[300] Yet under both the federal RCRA[301] and West Virginia's implementation of the federal

law in the Hazardous Waste Management Act,[302] oil and gas wastes are exempt from hazardous waste requirements.

This exemption allows drilling companies to take solid oil and gas waste that might be hazardous to municipal landfills that do not accept materials designated as hazardous.[303] Similarly, the exemption allows oil and gas companies to inject their liquid waste underground for disposal into Class II wells designated for oil and gas waste. Class II wells have lower standards of environmental protection than Class I wells that are designated for hazardous waste. For example, operators of Class II wells can analyze an area as small as that within a quarter-mile radius of the well to ensure that there are no adjacent wells that could be conduits allowing the oil and gas waste to migrate to the surface.[304] For Class I hazardous waste injection wells, this area of review is at least two miles.[305]

West Virginia could act to regulate oil and gas waste as hazardous by following the example of New York State, which in 2020 enacted legislation to designate oil and gas waste as hazardous.[306] State Senator Rachel May, one of the bill's sponsors, said in a statement,

> Wastewater from fracking can contain carcinogenic compounds and naturally occurring radioactive materials. The regulatory loophole that allowed waste from fracking and crude oil processing to be treated as standard industrial waste means it enters local sewage treatment facilities, sometimes with radiation levels hundreds of times the safe limit, it then flows directly back into our waterways – the source of drinking water for thousands of New Yorkers.[307]

May issued her statement before it was widely known that PFAS was used in oil and gas operations, but considering the oil and gas industry's now-documented record of using PFAS, the statement could apply to oil and gas wastes in West Virginia or other states. Continuing to exempt oil and gas wastes from hazardous waste treatment means that where PFAS is present in these wastes, it could enter waterways and the public drinking water system, with potentially serious consequences for West Virginians.

CH. 9 RECOMMENDATIONS

In light of the findings shared in this report, PSR recommends the following:

• **Halt PFAS use in oil and gas extraction**. West Virginia and the U.S. Environmental Protection Agency (EPA) should prohibit PFAS from being used, manufactured or imported for oil and gas extraction. Many PFAS are replaceable with less-persistent and less-toxic alternatives. In taking this step, West Virginia would be following the lead of Colorado, a major oil- and gas-producing state that in June 2022 passed legislation banning the use of PFAS in oil and gas wells.

• **Expand public disclosure**. West Virginia should greatly expand its requirements for public disclosure of oil and gas chemicals. The state could again follow the example offered by Colorado by requiring disclosure of all individual chemicals used in oil and gas wells, without exceptions for trade secrets. This action can be taken while still protecting product formulas as trade secrets. West Virginia should also require chemical disclosure prior to permitting for all oil and gas wells, as do California and Wyoming, and should require disclosure on the part of chemical manufacturers, as does Colorado. This provision would be critical to enable the WVDEP to identify and address sources of PFAS using the PFAS Protection Act. Finally, West Virginia should expand the disclosure requirements in the PFAS Protection Act to cover oil and gas production and waste disposal facilities to the extent that they are not already covered.

• **Increase testing and tracking**. West Virginia and/or the U.S. EPA should determine where PFAS have been used in oil and gas operations in the state and where related wastes have been deposited. They should test nearby residents, water, soil, flora, and fauna for PFAS, both for the particular type(s) of PFAS used and for organic fluorine to detect the presence of other PFAS and/or their breakdown products. They should use testing equipment sensitive enough to detect PFAS at concentrations below proposed or adopted maximum contaminant levels and/or other relevant regulatory guidelines or recommended limits. Such testing and tracking should be made a part of the WVDEP's action plans under the PFAS Protection Act for water sources near oil and gas production or waste disposal sites.

• **Require funding and cleanup**. Oil and gas companies and the firms that manufacture oil and gas chemicals should be required to fund environmental testing for PFAS in their areas of operation and, should PFAS be found, be required to fund cleanup. If cleanup of water sources is impossible, companies responsible for the use of PFAS should pay for alternative sources of water for homes, schools, hospitals, agriculture and other uses for as long as needed.

• **Remove West Virginia's oil and gas hazardous waste exemption**. West Virginia exempts oil and gas industry wastes from state hazardous waste rules. West Virginia should follow New York's lead and remove its state-level hazardous waste exemption for the oil and gas industry.

• **Reform West Virginia's regulations for oil and gas production wells and underground injection disposal wells**. The state should prohibit production wells and underground wastewater disposal wells in buffer zones near underground sources of drinking water, homes, health care facilities and schools. The size of the zones should be determined by scientific evidence specific to West Virginia. The state should also require groundwater monitoring for contaminants near the wells, and for disposal wells, require full public disclosure of chemicals in the wastewater.

• **Transition to renewable energy and better regulation**. Given the use of highly toxic chemicals in oil and gas extraction, including but not limited to PFAS, as well as climate impacts of oil and gas extraction and use, West Virginia should transition away from fracking and move toward renewable energy and efficiency while providing economic support for displaced oil and gas workers. As long as drilling and fracking continue, the state should better regulate these practices so that West Virginians are not exposed to toxic substances and should empower local governments also to regulate the industry. **When doubt exists as to the existence or danger of contamination, the rule of thumb should be, "First, do no harm**.

APPENDIX

Data Sources for PFAS Used in West Virginia's Oil and Gas Wells

To identify where and in what quantities PFAS and trade secret fracking chemicals were used at horizontal gas wells in West Virginia, PSR analyzed well-by-well reports of fracking chemicals recorded in FracFocus, a database[308] maintained by the Groundwater Protection Council,[309] a nonprofit comprised of regulators from state agencies. The dates of these records extend from January 1, 2013 to September 29, 2022. PSR consulted the open-source version of FracFocus, Open-FF,[310] which is more accurate and informative than the original version of FracFocus.[311] To determine the weights of the fracking chemicals injected into horizontal gas wells, we used the methodology detailed in endnote 122.

Under West Virginia law, well operators must disclose the fracking chemicals used in horizontal gas wells to the FracFocus database.[312] Disclosure must occur within 90 days after completing the permitted work on a well.[313] Based on West Virginia's rules[314] and disclosure forms available on FracFocus' website, operators must list, among other things, each individual chemical injected into the well and each chemical's CAS number, if available.[315] There are, however, significant exceptions to disclosure requirements under West Virginia's rules, including an exception for chemicals designated a trade secret[316] that are discussed in Chapter 4 and Chapter 8.

ENDNOTES

[1] U.S. Environmental Protection Agency. Technical Fact Sheet: Drinking Water Health Advisories for Four PFAS (PFOA, PFOS, GenX chemicals, and PFBS). June 2022, at 4. Accessed Oct. 4, 2023, at https://www.epa.gov/system/files/documents/2022-06/technical-factsheet-four-PFAS.pdf.

[2] U.S. Environmental Protection Agency. Our Current Understanding of the Human Health and Environmental Risks of PFAS. Accessed Oct. 4, 2023, at https://www.epa.gov/pfas/our-current-understanding-human-health-and-environmental-risks-pfas.

[3] Toxic Synthetic "Forever Chemicals" are in Our Water and on Our Plates. NOVA (PBS) (Nov. 2, 2020). Accessed Oct. 4, 2023, at https://www.pbs.org/wgbh/nova/article/pfas-synthetic-chemicals-water-toxic/.

[4] U.S. Environmental Protection Agency. Research on Per- and Polyfluoroalkyl Substances (PFAS) (last updated Nov. 10, 2021). Accessed Oct. 4, 2023, at https://www.epa.gov/chemical-research/research-and-polyfluoroalkyl-substances-pfas. David Andrews and Bill Walker. Environmental Working Group. Poisoned Legacy (April 2015), at 6. Accessed Oct. 4, 2023, at https://www.ewg.org/research/poisoned-legacy. Andrew B. Lindstrom et al. Polyfluorinated Compounds: Past, Present, and Future. Environmental Science & Technology (2011), 45, 7954-7961, 7954. Accessed Oct. 4, 2023, at https://pubs.acs.org/doi/pdf/10.1021/es2011622.

[5] U.S. Environmental Protection Agency. What are PFCs and How Do They Relate to Per- and Polyfluoroalkyl Substances (PFASs)? (Jan. 19, 2017). Accessed Oct. 4, 2023, at https://19january2017snapshot.epa.gov/pfas/what-are-pfcs-and-how-do-they-relate-and-polyfluoroalkyl-substances-pfass_.html. EPA noted that the acronym, PFCs, can also refer to perfluorocarbons that are distinct from PFAS or perfluorinated chemicals. Perfluorocarbons are not toxic, but they are a powerful and long-lasting greenhouse gas. Andrew B. Lindstrom et al. Polyfluorinated Compounds: Past, Present, and Future. Environmental Science & Technology (2011), 45, 7954-7961, 7954. Accessed Oct. 4, 2023, at https://pubs.acs.org/doi/pdf/10.1021/es2011622.

[6] David Andrews and Bill Walker. Environmental Working Group. Poisoned Legacy (April 2015), at 6. Accessed Oct. 5, 2023, at https://www.ewg.org/research/poisoned-legacy. Nathaniel Rich. The Lawyer Who Became Dupont's Worst Nightmare. New York Times Magazine (Jan. 6, 2016). Accessed Oct. 5, 2023, at https://www.nytimes.com/2016/01/10/magazine/the-lawyer-who-became-duponts-worst-nightmare.html?searchResultPosition=1. Andrew B. Lindstrom et al. Polyfluorinated Compounds: Past, Present, and Future. Environmental Science & Technology (2011), 45, 7954-7961, 7954, 7956. Accessed Oct. 5, 2023, at https://pubs.acs.org/doi/pdf/10.1021/es2011622.

[7] David Andrews and Bill Walker. Environmental Working Group. Poisoned Legacy (April 2015), at 6. Accessed Oct. 5, 2023, at https://www.ewg.org/research/poisoned-legacy. Andrew B. Lindstrom et al. Polyfluorinated Compounds: Past, Present, and Future. Environmental Science & Technology (2011), 45, 7954-7961, 7954. Accessed Oct. 5, 2023, at https://pubs.acs.org/doi/pdf/10.1021/es2011622.

[8] U.S. Environmental Protection Agency. PFAS Strategic Roadmap: EPA's Commitments to Action 2021-2024 (Oct. 2021), at 23. Accessed Oct. 5, 2023, at https://www.epa.gov/system/files/documents/2021-10/pfas-roadmap_final-508.pdf.

[9] David Andrews and Bill Walker. Environmental Working Group. Poisoned Legacy (April 2015), at 6-8. Accessed Oct. 5, 2023, at https://www.ewg.org/research/poisoned-legacy. Nathaniel Rich. The Lawyer Who Became Dupont's Worst Nightmare. New York Times Magazine (Jan. 6, 2016). Accessed Oct. 5, 2023, at https://www.nytimes.com/2016/01/10/magazine/the-lawyer-who-became-duponts-worst-nightmare.html?searchResultPosition=1.

[10] David Andrews and Bill Walker. Environmental Working Group. Poisoned Legacy (April 2015), at 8, 23. Accessed Oct. 5, 2023, at https://www.ewg.org/research/poisoned-legacy. Nathaniel Rich. The Lawyer Who Became Dupont's Worst Nightmare. New York Times Magazine (Jan. 6, 2016). Accessed Oct. 5, 2023, at https://www.nytimes.com/2016/01/10/magazine/the-lawyer-who-became-duponts-worst-nightmare.html?searchResultPosition=1.

[11] C8 Science Panel. C8 Probably Link Reports. Accessed Dec. 14, 2023, at http://www.c8sciencepanel.org/prob_link.html.

[12] Cleveland Clinic. Thyroid Disease. Accessed Oct. 5, 2023, at https://my.clevelandclinic.org/health/diseases/8541-thyroid-disease.

[13] Graham J. Burton et al. Preeclampsia: Pathophysiology and Clinical Implications. National Library of Medicine. PubMed.gov (July 15, 2019). Accessed Oct. 5, 2023, at https://pubmed.ncbi.nlm.nih.gov/31307997/.

[14] Mahesh Gajendran et al. A Comprehensive Review and Update on Ulcerative Colitis (March 2, 2019). National Library of Medicine. PubMed.gov. Accessed Oct. 5, 2023, at https://pubmed.ncbi.nlm.nih.gov/30837080/.

[15] U.S. Environmental Protection Agency. Our Current Understanding of the Human Health and Environmental Risks of PFAS. Accessed Oct. 5, 2023, at https://www.epa.gov/pfas/our-current-understanding-human-health-and-environmental-risks-pfas.

[16] Agency for Toxic Substances and Disease Registry. What are the health effects of PFAS? Accessed Oct. 5, 2023, at https://www.atsdr.cdc.gov/pfas/health-effects/index.html.

[17] Andrew B. Lindstrom et al. Polyfluorinated Compounds: Past, Present, and Future. Environmental Science & Technology (2011), 45, 7954-7961, 7956. Accessed Oct. 5, 2023, at https://pubs.acs.org/doi/pdf/10.1021/es2011622. Shantal Riley. Toxic Synthetic "Forever Chemicals" are in Our Water and on Our Plates. NOVA (PBS) (Nov. 2, 2020). Accessed Oct. 5, 2023, at https://www.pbs.org/wgbh/nova/article/pfas-synthetic-chemicals-water-toxic/. Oklahoma State University. Professor's Startup Turns Research into Real-World Solutions. News and Information (Oct. 3, 2018). Accessed Oct. 5, 2023, at https://news.okstate.edu/articles/arts-sciences/2018/professors-startup-turns-research-into-real-world-solutions.html.

[18] U.S. Environmental Protection Agency. EPA's Per- and Polyfluoroalkyl Action Plan (Feb. 2019) at 13. Accessed Oct. 5, 2023, at https://www.epa.gov/sites/default/files/2019-02/documents/pfas_action_plan_021319_508compliant_1.pdf.

[19] U.S. Environmental Protection Agency. Technical Fact Sheet: Drinking Water Health Advisories for Four PFAS (PFOA, PFOS, GenX chemicals, and PFBS). June 2022, at 2. Accessed Oct. 5, 2023, at https://www.epa.gov/system/files/documents/2022-06/technical-factsheet-four-PFAS.pdf.

[20] U.S. Environmental Protection Agency. Technical Fact Sheet: Drinking Water Health Advisories for Four PFAS (PFOA, PFOS, GenX chemicals, and PFBS). June 2022, at 2. Accessed Nov. 7, 2022, at https://www.epa.gov/system/files/documents/2022-06/technical-factsheet-four-PFAS.pdf.

[21] U.S. Environmental Protection Agency. Technical Fact Sheet: Drinking Water Health Advisories for Four PFAS (PFOA, PFOS, GenX chemicals, and PFBS). June 2022, at 4. Accessed Oct. 4, 2023, at https://www.epa.gov/system/files/documents/2022-06/technical-factsheet-four-PFAS.pdf.

[22] U.S. Environmental Protection Agency. Technical Fact Sheet: Drinking Water Health Advisories for Four PFAS (PFOA, PFOS, GenX chemicals, and PFBS). June 2022, at 4. Accessed Oct. 5, 2023, at https://www.epa.gov/system/files/documents/2022-06/technical-factsheet-four-PFAS.pdf.

[23] U.S. Environmental Protection Agency. Technical Fact Sheet: Drinking Water Health Advisories for Four PFAS (PFOA, PFOS, GenX chemicals, and PFBS). June 2022, at 4. Accessed Oct. 5, 2023, at https://www.epa.gov/system/files/documents/2022-06/technical-factsheet-four-PFAS.pdf.

[24] U.S. Environmental Protection Agency. Technical Fact Sheet: Drinking Water Health Advisories for Four PFAS (PFOA, PFOS, GenX chemicals, and PFBS). June 2022, at 2. Accessed Oct. 5, 2023, at https://www.epa.gov/system/files/documents/2022-06/technical-factsheet-four-PFAS.pdf.

[25] U.S. Environmental Protection Agency. Technical Fact Sheet: Drinking Water Health Advisories for Four PFAS (PFOA, PFOS, GenX chemicals, and PFBS). June 2022, at 2-3. Accessed Oct. 5, 2023, at https://www.epa.gov/system/files/documents/2022-06/technicalfactsheet-four-PFAS.pdf.

[26] 88 Fed. Reg. 18638, 18666 (Mar. 29, 2023). Accessed Oct. 5, 2023, at https://www.federalregister.gov/documents/2023/03/29/2023-05471/pfas-national-primary-drinkingwater-regulation-rulemaking#addresses.

[27] 88 Fed. Reg. 18638 (Mar. 29, 2023). Accessed Oct. 5, 2023, at https://www.federalregister.gov/documents/2023/03/29/2023-05471/pfas-national-primary-drinkingwater-regulation-rulemaking#addresses.

[28] 88 Fed. Reg. 18638, 18639 (Mar. 29, 2023). Accessed Dec. 14, 2023, at https://www.federalregister.gov/documents/2023/03/29/2023-05471/pfas-national-primary-drinkingwater-regulation-rulemaking#addresses.

[29] 88 Fed. Reg. 18638, 18639-18640, 18684 (Mar. 29, 2023). Accessed Aug. 7, 2023, at https://www.federalregister.gov/documents/2023/03/29/2023-05471/pfas-national-primary-drinkingwater-regulation-rulemaking#addresses.

[30] U.S. Environmental Protection Agency. EPA's Proposal to Limit PFAS in Drinking Water (March 2023). Fact Sheet. Accessed Oct. 5, 2023, at https://www.epa.gov/system/files/documents/2023-04/Fact%20Sheet_PFAS_NPWDR_Final_4.4.23.pdf.

[31] U.S. Environmental Protection Agency. EPA's PFAS Strategic Roadmap: Second Annual Progress Report (December 2023), at 6. Accessed Jan. 12, 2023, at https://www.epa.gov/system/files/documents/2023-12/epas-pfas-strategic-roadmap-dec-2023508v2.pdf.

[32] Commonwealth of Pennsylvania. Environmental Quality Board. Pa. Bulletin Doc. No. 23-46 (Jan. 14, 2023), at 12. Accessed Oct. 5, 2023, at https://www.pacodeandbulletin.gov/Display/pabull?file=/secure/pabulletin/data/vol53/53-2/46.html.

[33] PSR calculated the amount of PFOA that could contaminate the 10 billion gallons of water distributed annually by West Virginian American Water to customers in Charleston using the following data: EPA's proposed maximum contaminant level for PFOA in drinking water is 4 parts per trillion. U.S. Environmental Protection Agency. 88 FR 18638 (Mar. 29, 2023). Accessed Dec. 14, 2023, at https://www.federalregister.gov/documents/2023/03/29/2023-05471/pfas-national-primary-drinking-water-regulation-rulemaking#addresses. Parts per trillion refers to milligrams per one million liters of water. U.S. Environmental Protection Agency. Environmental Science and Technology Briefs for Citizens. Center for Hazardous Substance Research. Understanding Units of Measurement. Accessed Oct. 5, 2023, at https://cfpub.epa.gov/ncer_abstracts/index.cfm/fuseaction/display.files/fileid/14285. One measuring cup contains approximately 237 milliliters. Exploratorium. Cooking Equivalents and Measures. Accessed Oct. 5, 2023, at https://www.exploratorium.edu/food/measurements. The density of PFOA is 1.8 grams per milliliter. National Institutes of Health. National Library of Medicine. National Center for Biotechnology Information. PubChem. Perfluorooctanoic Acid. Density. Accessed Oct. 5, 2023, at https://pubchem.ncbi.nlm.nih.gov/compound/Perfluorooctanoic-acid. Therefore, the mass of one measuring cup of PFOA is 426.6 grams or 426,600 milligrams. This mass of PFOA is 106,650 times greater than 4 milligrams (EPA's maximum contaminant level per million liters). In order to dilute the mass of the PFOA in an equivalent volume of water, we multiplied 106,650 by 1,000,000. The result is 106,650,000,000 liters of water. There are 3.785 liters of water per gallon. U.S. Environmental Protection Agency. EPA. ExpoBox Unit Conversion Table. Accessed Oct. 5, 2023, at https://www.epa.gov/expobox/epa-expobox-unit-conversion-table. Therefore, 106,650,000,000,000 liters of water is equal to a bit more than 28 billion gallons of water – the amount of water that could be contaminated to EPA's maximum contaminant advisory level by one cup of PFOA.

[34] This volume, 28 billion gallons, is almost three times the amount of water (10 billion gallons) delivered each year by West Virginia American Water to customers in Kanawha, Boone, Putnam, Lincoln, Logan and Cabell counties. West Virginia American Water. 2022 Annual Water Quality Report, at 5. Accessed Oct. 5, 2023, at https://www.epicwaterfilters.com/blogs/news/charleston-wv-water-quality-report-copy.

[35] Electronic mail communication with Linda Aller (Jan. 9, 2024).

[36] Electronic mail communication with Linda Birnbaum (Mar. 10, 2023).

[37] Electronic mail communication with Zacariah Hildenbrand (Mar. 14, 2023).

[38] Electronic mail communication with Wilma Subra (Mar. 14, 2023).

[39] U.S. Environmental Protection Agency. Hydraulic fracturing for oil and gas: impacts from the hydraulic fracturing water cycle on drinking water resources in the United States. Washington, DC: Office of Research and Development; 2016, at 3-18 through 3-22, 5-7, 5-8, 5-11, 5-16, 6-67. EPA Report # 600/R-16/236F. Accessed Oct. 6, 2023, at https://www.epa.gov/hfstudy. Genevieve A. Kahrilas et al. Biocides in Hydraulic Fracturing Fluids: A Critical Review of Their Usage, Mobility, Degradation, and Toxicity. Environ. Sci. Technol.201549116-32 (Nov. 26, 2014). Accessed Oct. 6, 2023, at https://pubs.acs.org/doi/10.1021/es503724k.

[40] Concerned Health Professionals of New York and Physicians for Social Responsibility. Compendium of Scientific, Medical, and Media Findings Demonstrating Risks and Harms of Fracking (Unconventional Gas and Oil Extraction), Eighth Edition (2022). Accessed Oct. 6, 2023, at https://psr.org/resources/fracking-compendium-8/.

[41] U.S. Environmental Protection Agency. Hydraulic fracturing for oil and gas: impacts from the hydraulic fracturing water cycle on drinking water resources in the United States. Washington, DC: Office of Research and Development; 2016, at 9-1. Accessed Oct. 6, 2023, at https://www.epa.gov/hfstudy.

[42] See, e.g., U.S. Environmental Protection Agency. Focus report for chemical with EPA case number P-06-0676. Washington, DC: New Chemicals Program; 2006 (on file with PSR).

[43] Colorado General Assembly. HB22-1348. Senate Amended 3rd Reading (May 11, 2022). Accessed Oct. 6, 2023, at https://leg.colorado.gov/sites/default/files/documents/2022A/bills/2022a_1348_rer.pdf.

[44] Ohio Department of Natural Resources, Division of Oil and Gas Resources Management, Oil and Gas Well Locator, Form 8(A) for well API Number 34-111-24285. Accessed Oct. 6, 2023, at https://gis.ohiodnr.gov/MapViewer/?config=oilgaswells.

[45] National Institute for Occupational Safety and Health (NIOSH). Xylene. Accessed Dec. 12, 2023, at https://www.cdc.gov/niosh/topics/xylene/default.html#:~:text=Xylene%20(C8H10,harmed%20from%20exposure%20to%20xylene.

[46] U.S. Environmental Protection Agency. Hydraulic fracturing for oil and gas: impacts from the hydraulic fracturing water cycle on drinking water resources in the United States. Washington, DC: Office of Research and Development; 2016, at ES-3, 4-8, 6-39. Accessed Oct. 4, 2023, at https://www.epa.gov/hfstudy.

[47] U.S. Environmental Protection Agency. Hydraulic fracturing for oil and gas: impacts from the hydraulic fracturing water cycle on drinking water resources in the United States. Washington, DC: Office of Research and Development; 2016, at 3-14 through 3-17. EPA Report# 600/R-16/236F. Accessed Oct. 12, 2023, at https://www.epa.gov/hfstudy.

[48] U.S. Environmental Protection Agency. Hydraulic fracturing for oil and gas: impacts from the hydraulic fracturing water cycle on drinking water resources in the United States. Washington, DC: Office of Research and Development; 2016, at 10-14. EPA Report# 600/R-16/236F. Accessed Oct. 12, 2023, at https://www.epa.gov/hfstudy.

[49] U.S. Environmental Protection Agency. Hydraulic fracturing for oil and gas: impacts from the hydraulic fracturing water cycle on drinking water resources in the United States. Washington, DC: Office of Research and Development; 2016, at 3-14. EPA Report# 600/R-16/236F. Accessed Oct. 12, 2023, at https://www.epa.gov/hfstudy.

[50] Juliane Glüge et al. An Overview of the Uses of Per- and Polyfluoroalkyl Substances (PFAS) – Electronic Supplementary Information 1. Environmental Science: Processes and Impacts (Oct. 30, 2020) at 50-51. Accessed online Dec. 28, 2023, at https://www.rsc.org/suppdata/d0/em/d0em00291g/d0em00291g1.pdf.

[51] U.S. Environmental Protection Agency. Hydraulic fracturing for oil and gas: impacts from the hydraulic fracturing water cycle on drinking water resources in the United States. Washington, DC: Office of Research and Development; 2016, at 3-14, 3-15, 10-14. EPA Report# 600/R-16/236F. Accessed Oct. 12, 2023, at https://www.epa.gov/hfstudy.

[52] U.S. Environmental Protection Agency. Hydraulic fracturing for oil and gas: impacts from the hydraulic fracturing water cycle on drinking water resources in the United States. Washington, DC: Office of Research and Development; 2016, at 8-25. Accessed Oct. 4, 2023, at https://www.epa.gov/hfstudy.

[53] Alina Denham et al. Acute myocardial infarction associated with unconventional natural gas development: A natural experiment. Volume 195, 110872, April 2021. Accessed June 20, 2023, at https://www.sciencedirect.com/science/article/abs/pii/S0013935121001663?via%3Dihub.

[54] Alina Denham et al. Acute myocardial infarction associated with unconventional natural gas development: A natural experiment. Volume 195, 110872, April 2021. Accessed June 20, 2023, at https://www.sciencedirect.com/science/article/abs/pii/S0013935121001663?via%3Dihub.

[55] Tara P. McAlexander et al. Unconventional Natural Gas Development and Hospitalization for Heart Failure in Pennsylvania. Journal of the American College of Cardiology. Vol. 76, No. 24, 2020. Accessed June 20, 2023, at https://www.sciencedirect.com/science/article/pii/S0735109720375392?via%3Dihub.

[56] U.S. Centers for Disease Control and Prevention. Heart Attack Symptoms, Risk, and Recovery (July 12, 2022). Accessed June 20, 2023, at https://www.cdc.gov/heartdisease/heart_attack.htm.

[57] U.S. Centers for Disease Control. Infant Mortality. Accessed Sept. 8, 2022, at https://www.cdc.gov/reproductivehealth/maternalinfanthealth/infantmortality.htm.

[58] U.S. Environmental Protection Agency. Master List of PFAS Substances. Polytetrafluoroethylene. CAS number 9002-84-0. Accessed Oct. 4, 2023, at https://comptox.epa.gov/dashboard/chemical/details/DTXSID7047724?list=PFASMASTER.

[59] Public Employees for Environmental Responsibility. Revealed: EPA Data on PFAS Sites (Oct. 17, 2021). Accessed Oct. 4, 2023, at https://www.peer.org/blog-revealed-epa-data-on-potential-pfas-sites/.

[60] U.S. Environmental Protection Agency. Hydraulic fracturing for oil and gas: impacts from the hydraulic fracturing water cycle on drinking water resources in the United States. Washington, DC: Office of Research and Development; 2016, at 5-5 to 5-7. Accessed Oct. 4, 2023, at https://www.epa.gov/hfstudy.

[61] U.S. Environmental Protection Agency. Hydraulic fracturing for oil and gas: impacts from the hydraulic fracturing water cycle on drinking water resources in the United States. Washington, DC: Office of Research and Development; 2016, at ES-6, ES-31, 3-4, 3-6, 3-16. Accessed Oct. 7, 2023, at https://www.epa.gov/hfstudy.

[62] U.S. Department of Energy. Energy Information Administration. Natural Gas Gross Withdrawals and Production. Dry Production. Annual-Million Cubic Feet. Accessed Nov. 21, 2023, at https://www.eia.gov/dnav/ng/ng_prod_sum_a_EPG0_FPD_mmcf_a.htm.

[63] Helen G. Siegel et al. Investigation of Sources of Fluorinated Compounds in Private Water Supplies in an Oil and Gas-Producing Region of Northern West Virginia. Environmental Science & Technology, 57, 17452-17464, 17452-17453, 17456 (2023). Accessed Dec. 22, 2023, at https://pubs.acs.org/doi/abs/10.1021/acs.est.3c05192.

[64] Helen G. Siegel et al. Investigation of Sources of Fluorinated Compounds in Private Water Supplies in an Oil and Gas-Producing Region of Northern West Virginia. Environmental Science & Technology, 57, 17452-17464, 17459-17460 (2023). Accessed Dec. 22, 2023, at https://pubs.acs.org/doi/abs/10.1021/acs.est.3c05192.

[65] U.S. Environmental Protection Agency. Hydraulic fracturing for oil and gas: impacts from the hydraulic fracturing water cycle on drinking water resources in the United States. Washington, DC: Office of Research and Development; 2016, at 3-7. EPA Report # 600/R-16/236F. Accessed Oct. 6, 2023, at https://www.epa.gov/hfstudy.

[66] U.S. Environmental Protection Agency. Hydraulic fracturing for oil and gas: impacts from the hydraulic fracturing water cycle on drinking water resources in the United States. Washington, DC: Office of Research and Development; 2016, at 3-3, 3-4, 3-7. EPA Report # 600/R-16/236F. Accessed Oct. 6, 2023, at https://www.epa.gov/hfstudy.

[67] Helen G. Siegel et al. Investigation of Sources of Fluorinated Compounds in Private Water Supplies in an Oil and Gas-Producing Region of Northern West Virginia. Environmental Science & Technology, 57, 17452-17464, 17460 (2023). Accessed Dec. 22, 2023, at https://pubs.acs.org/doi/abs/10.1021/acs.est.3c05192.

[68] Helen G. Siegel et al. Investigation of Sources of Fluorinated Compounds in Private Water Supplies in an Oil and Gas-Producing Region of Northern West Virginia. Environmental Science & Technology, 57, 17452-17464, 17460 (2023). Accessed Dec. 22, 2023, at https://pubs.acs.org/doi/abs/10.1021/acs.est.3c05192.

[69] Helen G. Siegel et al. Investigation of Sources of Fluorinated Compounds in Private Water Supplies in an Oil and Gas-Producing Region of Northern West Virginia. Environmental Science & Technology, 57, 17452-17464, 17460-17461 (2023). Accessed Dec. 22, 2023, at https://pubs.acs.org/doi/abs/10.1021/acs.est.3c05192.

[70] Mitchell A. McAdoo et al. U.S. Geological Survey Report 2022-5067, at 22. Occurrence of Per- and Polyfluoroalkyl Substances and Inorganic Analytes in Groundwater and Surface Water Used as Sources for Public Water Supply in West Virginia. Accessed Oct. 5, 2023, at https://pubs.usgs.gov/sir/2022/5067/sir20225067.pdf. West Virginia Rivers. PFAS Information Packet Appendix (2023). Accessed February 22, 2024, at https://fdfad2.a2cdn1.secureserver.net/wp-content/uploads/2023/01/PFAS-Info-Packet-Attachment.pdf

[71] Mitchell A. McAdoo et al. U.S. Geological Survey Report 2022-5067, at 18, 20, 21. Occurrence of Per- and Polyfluoroalkyl Substances and Inorganic Analytes in Groundwater and Surface Water Used as Sources for Public Water Supply in West Virginia. Accessed Oct. 5, 2023, at https://pubs.usgs.gov/sir/2022/5067/sir20225067.pdf.

[72] Mitchell A. McAdoo et al. U.S. Geological Survey Report 2022-5067, at 21. Occurrence of Per- and Polyfluoroalkyl Substances and Inorganic Analytes in Groundwater and Surface Water Used as Sources for Public Water Supply in West Virginia. Accessed Oct. 5, 2023, at https://pubs.usgs.gov/sir/2022/5067/sir20225067.pdf.

[73] Mitchell A. McAdoo et al. U.S. Geological Survey Report 2022-5067, at 22. Occurrence of Per- and Polyfluoroalkyl Substances and Inorganic Analytes in Groundwater and Surface Water Used as Sources for Public Water Supply in West Virginia. Accessed Oct. 5, 2023, at https://pubs.usgs.gov/sir/2022/5067/sir20225067.pdf.

[74] Mitchell A. McAdoo et al. U.S. Geological Survey Report 2022-5067, at 22. Occurrence of Per- and Polyfluoroalkyl Substances and Inorganic Analytes in Groundwater and Surface Water Used as Sources for Public Water Supply in West Virginia. Accessed Oct. 5, 2023, at https://pubs.usgs.gov/sir/2022/5067/sir20225067.pdf.

[75] U.S. Geological Survey. National Water Information System: Web Interface. Water Use Data for West Virginia, Year: 2015; Area Type: State Total; Category: Public Supply and Domestic. Accessed Dec. 15, 2023, at https://waterdata.usgs.gov/wv/nwis/water_use/.

[76] Mitchell A. McAdoo et al. U.S. Geological Survey Report 2022-5067, at 23. Occurrence of Per- and Polyfluoroalkyl Substances and Inorganic Analytes in Groundwater and Surface Water Used as Sources for Public Water Supply in West Virginia. Accessed Oct. 5, 2023, at https://pubs.usgs.gov/sir/2022/5067/sir20225067.pdf

[77] Sara E. Breitmeyer et. al. U.S. Geological Survey. Per- and polyfluorinated alkyl substances (PFAS) in Pennsylvania surface waters: A statewide assessment, associated sources, and land-use relations. Science of the Total Environment 888 (2023) 164161, at 8. Accessed Oct. 2, 2023, at https://www.sciencedirect.com/science/article/pii/S0048969723027821.

[78] Sara E. Breitmeyer et. al. U.S. Geological Survey. Per- and polyfluorinated alkyl substances (PFAS) in Pennsylvania surface waters: A statewide assessment, associated sources, and land-use relations. Science of the Total Environment 888 (2023) 164161, at 8. Accessed Oct. 2, 2023, at https://www.sciencedirect.com/science/article/pii/S0048969723027821.

[79] David E. Hess. PA Environment Digest Blog (May 10, 2023). Accessed Aug. 7, 2023, at https://paenvironmentdaily.blogspot.com/2023/05/dep-widespread-presence-of-pfas-forever.html.

[80] Pennsylvania Department of Environmental Protection. Water Supply Request for Investigation 366639, Negative Determination – 58 Pa. C.S § 3218, Deemston Borough, Washington County (April 20, 2023), at 2-4. Accessed Aug. 7, 2023, at https://ehb.courtapps.com/efile/documentViewer.php?documentID=60106. The DEP did not specify how many wells were on the well pad, but at least two sources have reported that the number was two. See Kristina Marusic. Fractured: Distrustful of frackers, abandoned by regulators. Environmental Health News (Mar. 1, 2021). Accessed Sept. 25, 2023, at https://www.ehn.org/fractured-fracking-regulationneglect-2650594611.html. Susan Phillips. Special report: How the U.S. government hid fracking's risks to drinking water. StateImpact (Nov. 22, 2017). Accessed Sept. 25, 2023, at https://stateimpact.npr.org/pennsylvania/2017/11/22/special-report-how-the-u-sgovernment-hid-frackings-risks-to-drinking-water/.

[81] Pennsylvania Department of Environmental Protection. Water Supply Request for Investigation 366639, Negative Determination – 58 Pa. C.S § 3218, Deemston Borough, Washington County (April 20, 2023), at 2-4. Accessed Aug. 7, 2023, at https://ehb.courtapps.com/efile/documentViewer.php?documentID=60106 (speculating that PFAS may have been introduced into fracking wells through the use of water for fracking that already contained PFAS). 58 Pa.C.S. § 3222.1(c) (providing that unconventional gas well operators do not have to disclose chemicals that were not intentionally added to the fracking fluid; therefore, the operators would not have to disclose the presence of PFAS that was already in water that the operators imported to a well site for use in fracking). Pa. Rules Title 25 § 78.122 (providing that conventional well operators must disclose "chemical additives" used for fracking; it is apparent that these substances do not include chemicals that might be contained in water used for fracking).

[82] Britt E. Erickson. Wastewater from fracking: Growing disposal challenge or untapped resource? Chemical & Engineering News, published by West Virginia Water Research Institute (Nov. 17, 2019). Accessed Dec. 29, 2023, at https://wvwri.wvu.edu/news/2019/11/19/wastewater-from-fracking-growing-disposal-challenge-or-untapped-resource.

[83] Safer States et al. PFAS polymers pose serious health and environmental threats. Accessed Oct. 8, 2023, at https://www.nrdc.org/sites/default/files/pfas-polymer-fs.pdf.

[84] Rainer Lohmann et al. Are Fluoropolymers Really of Low Concern for Human and Environmental Health and Separate from Other PFAS? Environmental Science & Technology 2020, 54, 12820-12828, 12821-2. Accessed Oct. 8, 2023, at https://pubs.acs.org/doi/10.1021/acs.est.0c03244.

[85] Safer States et al. PFAS polymers pose serious health and environmental threats. Accessed Oct. 8, 2023, at https://www.nrdc.org/sites/default/files/pfas-polymer-fs.pdf.

[86] Rainer Lohmann et al. Are Fluoropolymers Really of Low Concern for Human and Environmental Health and Separate from Other PFAS? Environmental Science & Technology 2020, 54, 12820-12828, 12821-12822. Accessed Oct. 8, 2023, at https://pubs.acs.org/doi/10.1021/acs.est.0c03244.

[87] Rainer Lohmann et al. Are Fluoropolymers Really of Low Concern for Human and Environmental Health and Separate from Other PFAS? Environmental Science & Technology 2020, 54, 12820-12828, 12823. Accessed Oct. 8, 2023, at https://pubs.acs.org/doi/10.1021/acs.est.0c03244.

[88] Rainer Lohmann et al. Are Fluoropolymers Really of Low Concern for Human and Environmental Health and Separate from Other PFAS? Environmental Science & Technology 2020, 54, 12820-12828, 12823. Accessed Oct. 8, 2023, at https://pubs.acs.org/doi/10.1021/acs.est.0c03244.

[89] David A. Ellis et al. Thermolysis of Øuoropolymers as a Potential Source of Halogenated Organic Acids in the Environment. Nature. Letters to Nature, Vol. 412 (July 19, 2001). Accessed Oct. 8, 2023, at https://pubmed.ncbi.nlm.nih.gov/11460160/.

[90] Rainer Lohmann et al. Are Fluoropolymers Really of Low Concern for Human and Environmental Health and Separate from Other PFAS? Environmental Science & Technology 2020, 54, 12820-12828, 12823-12824. Accessed Oct. 9, 2023, at https://pubs.acs.org/doi/10.1021/acs.est.0c03244.

[91] Schlumberger. The Defining Series: HPHT Wells (Mar. 10, 2016). Accessed Oct. 9, 2023 at https://www.slb.com/resource-library/oilfield-review/defining-series/defining-hpht. Schlumberger. Oilfield Review (Autumn 2008), at 46, 48. Accessed Oct. 9, 2023, at https://www.slb.com/-/media/files/oilfield-review/high-pressure-high-temperature.

[92] Electronic mail communication with Ian Cousins, professor, Department of Environmental Science, Stockholm University (Oct. 15, 2021).

[93] Electronic mail communication between West Virginia Department of Environmental Protection and Dusty Horwitt (Dec. 15, 2023) (on file with PSR).

[94] Safer States et al. PFAS polymers pose serious health and environmental threats. Accessed Dec. 26, 2023, at https://www.nrdc.org/sites/default/files/pfas-polymer-fs.pdf (citing Rainer Lohmann et al. Are Fluoropolymers Really of Low Concern for Human and Environmental Health and Separate from Other PFAS? Environmental Science & Technology 2020, 54, 12820-12828, 12821-12822. Accessed Dec. 26, 2023, at https://pubs.acs.org/doi/10.1021/acs.est.0c03244.

[95] Safer States et al. PFAS polymers pose serious health and environmental threats. Accessed Dec. 26, 2023, at https://www.nrdc.org/sites/default/files/pfas-polymer-fs.pdf (citing Konstantinos Prevedouros et al. Sources, Fate and Transport of Perfluorocarboxylates. Environmental Science & Technology 40, 1, 32-44 (2006). Accessed Dec. 26, 2023, at https://pubs.acs.org/doi/epdf/10.1021/es0512475.

[96] Government of Canada. Health science summary: Long-chain perfluorocarboxylic acids (PFCAs), their salts and related compounds. Accessed Dec. 26, 2023, at https://www.canada.ca/en/health-canada/services/chemical-substances/chemicals-management-plan/initiatives/health-science-summary-long-chain-perfluorocarboxylic-acids-salts-related-compounds.html.

[97] Safer States et al. PFAS polymers pose serious health and environmental threats. Accessed Sept. 5, 2022, at https://www.nrdc.org/sites/default/files/pfas-polymer-fs.pdf.

[98] U.S. Securities and Exchange Commission. Exxon Mobil Corp. Form 10-K (filed Feb. 22, 2023). Accessed Oct. 9, 2023, at https://www.sec.gov/ix?doc=/Archives/edgar/data/34088/000003408823000020/xom-20221231.htm.

[99] Fortune. ExxonMobil. Accessed Oct. 8, 2023, at https://fortune.com/company/exxon-mobil/.

[100] U.S. Securities and Exchange Commission. Antero Resources Corp. Form 10-K (filed Feb. 15, 2023). Accessed Oct. 9, 2023, at https://www.sec.gov/ix?doc=/Archives/edgar/data/1433270/000155837023001378/ar-20221231x10k.htm.

[101] University of West Virginia. Training the next generation: Antero's $4M gift to WVU aids energy education. WVU Today (Aug. 21, 2023). Accessed Oct. 9, 2023, at https://wvutoday.wvu.edu/stories/2023/08/31/training-the-next-generation-antero-s-4m-gift-to-wvu-aids-energy-education.

[102] U.S. Energy Information Administration. What are Natural Gas Liquids and How are They Used? (April 20, 2012). Accessed Oct. 9, 2023, at https://www.eia.gov/todayinenergy/detail.php?id=5930.

[103] American Chemical Society. CAS Registry. Accessed Oct. 4, 2023, at https://bit.ly/3nnGpv4.

[104] FracFocus. Chemical Names & CAS Registry Numbers. Accessed Oct. 4, 2023, at https://fracfocus.org/explore/chemical-names-and-cas-registry-numbers.

[105] See, e.g., FracFocus. Find a Well. Well with API Number 47-017-06699 fracked by Antero Resources Corp. between March 25, 2017 and April 6, 2017 in Doddridge County. Accessed Oct. 9, 2023, at https://fracfocus.org/wells/47017066990000.

[106] U.S. Environmental Protection Agency. Hydraulic fracturing for oil and gas: impacts from the hydraulic fracturing water cycle on drinking water resources in the United States. Washington, DC: Office of Research and Development; 2016, at 5-5, 5-6, 5-8. Accessed Oct. 9, 2023, at https://www.epa.gov/hfstudy.

[107] W. Va. Code § 22-6A-7(e)(5)(providing that "if the drilling, fracturing, or stimulating of the horizontal well requires the use of water obtained by withdrawals from waters of this state in amounts that exceed 210,000 gallons during any 30-day period, the application for a well work permit shall include a water management plan, which may be submitted on an individual well basis or on a watershed basis, and which shall include the following information…A listing of the anticipated additives that may be used in water utilized for fracturing or stimulating the well. Upon well completion, a listing of the additives that were actually used in the fracturing or stimulating of the well shall be submitted as part of the completion log or report required by §22-6A-5(a)(14) of this code….") and W. Va. Code R. § 35-8-10.1.a (providing that "As part of the well completion report (Form WR-35), the operator or its service provider shall list all the additives used in the hydraulic fracturing or stimulation process…"). W. Va. Code R. § 35-8-10.1.b (providing that "The operator or service provider shall fulfill the additive reporting requirement of subdivision 10.1.a above by submitting the information to the Office [of Oil and Gas within the Department of Environmental Protection] and the FracFocus Chemical Disclosure Registry). W. Va. Code § 22-6A-4(6) defines a "horizontal well" as "any well site, other than a coalbed methane well, drilled using a horizontal drilling method, and which disturbs three acres or more of surface, excluding pipelines, gathering lines and roads, or utilizes more than two hundred ten thousand gallons of water in any thirty day period." W. Va. Code § 22-6A-4(5) states that "'horizontal drilling' means a method of drilling a well for the production of natural gas that is intended to maximize the length of wellbore that is exposed to the formation and in which the wellbore is initially vertical but is eventually curved to become horizontal, or nearly horizontal, to parallel a particular geologic formation…." Therefore, under West Virginia law, horizontal wells are considered to be gas wells only.

[108] W. Va. Code § 22-6A-4.

[109] U.S. Environmental Protection Agency. Hydraulic fracturing for oil and gas: impacts from the hydraulic fracturing water cycle on drinking water resources in the United States. Washington, DC: Office of Research and Development; 2016, at ES-22, ES-40, 3-24, 6-3. Accessed Oct. 8, 2023, at https://www.epa.gov/hfstudy.

[110] 2011 W. Va. Acts H.B. 401 (passed Dec. 14, 2011; in effect from passage).

[111] W. Va. Code § 22-6A-4(6).

[112] W. Va. Code § 22-6A-7(e)(5).

[113] W. Va. Code § 22-6A-7(e)(5), W. Va. Code R. § 35-8-10.1.a., and W. Va. Code R. § 35-8-10.1.b.

[114] W. Va. Code R. § 35-8-10.1.a, and W. Va. Code R. § 35-8-10.1.b.

[115] W. Va. Code § 22-6A-7(e)(5), W. Va. Code R. § 35-8-10.1.a., and W. Va. Code R. § 35-8-10.1.b.

[116] Groundwater Protection Council. Overview. Accessed Oct. 8, 2023, at https://www.gwpc.org/about-us/overview/.

[117] FracFocus. About. Accessed Oct. 8, 2023, at https://fracfocus.org/about-us.

[118] W. Va. Code § 22-6A-7(e)(5).

[119] U.S. Environmental Protection Agency. Hydraulic fracturing for oil and gas: impacts from the hydraulic fracturing water cycle on drinking water resources in the United States. Washington, DC: Office of Research and Development; 2016, at 3-18. EPA Report# 600/R-16/236F. Accessed Oct. 12, 2023, at https://www.epa.gov/hfstudy.

[120] W. Va. Code R. § 35-8-10.1.a.

[121] Gary Allison (2021) Open-FF: Transforming the FracFocus Disclosure Data into a Usable Resource [Source Code]. Accessed Oct. 26, 2022, at https://doi.org/10.24433/CO.1058811.v15. PSR accessed Open-FF data set downloaded from FracFocus on Sept. 29, 2022.

[122] PSR calculated the amounts of trade secret chemicals used in each well in West Virginia and the combined weight of these chemicals primarily by using disclosures by well operators for each well listed in FracFocus. We then aggregated the amounts for each well to calculate county-by-county and state-wide totals. To illustrate the methodology, we will use as an example the figures from XTO Energy/ExxonMobil's well number 35-019-26303 fractured in Carter County, Oklahoma in 2019. We estimated the total mass of the hydraulic fracking fluid used in each well in pounds by multiplying the gallons of water listed as being used as the base fluid for the fracking fluid (223,650 in this case) by 8.33, the number of pounds in a gallon of water as listed in a table of the weights of various solvents published by the U.S. Environmental Protection Agency. See U.S. Environmental Protection Agency. Conversion from Gallons to Pounds of Common Solvents. Accessed Jan. 12, 2022, at https://www.epa.gov/p2/pollution-prevention-tools-and-calculators. That quantity of water in the XTO Energy/ExxonMobil example weighs approximately 1,863,005 pounds. We then calculated the total mass of the fracking fluid by multiplying the mass of the water in pounds by 100 and dividing that product by the listed maximum percent concentration of water in the fracking fluid (78.31797). FracFocus lists only maximum concentrations of components of the fracking fluid; there is no minimum-maximum range. The estimated total maximum mass of the fracking fluid in the example is 2,378,770 pounds. Next, we multiplied the listed maximum concentration in percent by mass of the potential PFAS chemical in the fracking fluid (0.00074) by the total estimated mass of the fluid. The result was an estimated maximum of 17.6 pounds of potential PFAS used to fracture the well. PSR included in our analysis of trade secret chemicals those chemicals in Open-FF whose specific identities were explicitly labeled "proprietary," "trade secret," or "confidential business information" in place of a CAS number. PSR did not include as trade secrets additional unidentified chemicals for which the CAS number in Open-FF is blank. The total weight figures reflect the sum of all records for which we have enough information to calculate a chemical's weight. Because many fracking chemical disclosures lack sufficient data to perform this calculation, the total weight figures may represent an undercount. On the other hand, FracFocus' use of maximum concentration figures may produce an overcount. PSR's weight figures are based on the best available data.

[123] PSR determined that a chemical was a surfactant if the chemical's ingredient name or purpose was listed in FracFocus as a surfactant.

[124] U.S. Environmental Protection Agency. Hydraulic fracturing for oil and gas: impacts from the hydraulic fracturing water cycle on drinking water resources in the United States. Washington, DC: Office of Research and Development; 2016, at 5-19. Accessed Oct. 4, 2023, at https://www.epa.gov/hfstudy.

[125] U.S. Environmental Protection Agency. Hydraulic fracturing for oil and gas: impacts from the hydraulic fracturing water cycle on drinking water resources in the United States. Washington, DC: Office of Research and Development; 2016, at 5-11 (describing for what purposes 2-butoxyethanol can be used in fracking fluid), 5-19 (naming 2-butoxyethanol as a surfactant). Accessed Oct. 7, 2023, at https://www.epa.gov/hfstudy.

[126] Robert C. Buck et al. Perfluoroalkyl and Polyfluoroalkyl Substances in the Environment: Terminology, Classification, and Origins. Integrated Environmental Assessment and Management — Volume 7, Number 4—pp. 513–541, 517. Accessed Oct. 4, 2023, at https://www.ncbi.nlm.nih.gov/pmc/articles/PMC3214619/pdf/ieam0007-513.pdf.

[127] Robert C. Buck et al. Perfluoroalkyl and Polyfluoroalkyl Substances in the Environment: Terminology Classification, and Origins. Integrated Environmental Assessment and Management (2011) Volume 7, Number 4—pp. 513–541, 522. Accessed Oct. 4, 2023, at https://www.ncbi.nlm.nih.gov/pmc/articles/PMC3214619/pdf/ieam0007-0513.pdf.

[128] U.S. Environmental Protection Agency. Master List of PFAS Substances. 2-(Perfluorooctyl)ethanol. CAS number 678-39-7. Accessed Oct. 4, 2023, at https://comptox.epa.gov/dashboard/chemical/details/DTXSID7029904?list=PFASMASTER.

[129] Nicholas J. Herkert. Characterization of Per- and Polyfluorinated Alkyl Substances Present in Commercial Anti-fog Products and Their In Vitro Adipogenic Activity. Environmental Science & Technology (2022), 56, 1162-1173. Accessed Oct. 4, 2023, at https://pubs.acs.org/doi/pdf/10.1021/acs.est.1c06990.

[130] Robert C. Buck et al. Perfluoroalkyl and Polyfluoroalkyl Substances in the Environment: Terminology, Classification, and Origins. Integrated Environmental (Oct. 2011); 7(4): 513–541. Accessed Oct. 4, 2023, at https://www.ncbi.nlm.nih.gov/pmc/articles/PMC3214619/.

[131] FracFocus. Find a Well. Well with API Number 47-051-02327 fracked between April 10, 2022 and June 3, 2022 in Marshall County. Accessed Oct. 8, 2023, at https://fracfocus.org/wells/47051023270000.

[132] FracFocus. Find a Well. Well with API Number 47-073-02558 fracked between April 22, 2018 and May 7, 2018 in Pleasants County. Accessed Oct. 8, 2023, at https://fracfocus.org/wells/47073025580000.

[133] U.S. Department of Energy. Energy Information Administration. Natural Gas Gross Withdrawals and Production. Dry Production. Annual-Million Cubic Feet. Accessed Nov. 21, 2023, at https://www.eia.gov/dnav/ng/ng_prod_sum_a_EPG0_FPD_mmcf_a.htm.

[134] P.R. Lockhart. Mountain State Spotlight explains: Why West Virginia's reliance on volatile severance taxes is problematic. Mountain State Spotlight (April 10, 2023). Accessed Oct. 4, 2023, at https://mountainstatespotlight.org/2023/04/10/wv-severance-tax-budget-explained/.

[135] Britt E. Erickson. Wastewater from fracking: Growing disposal challenge or untapped resource? Chemical & Engineering News (Nov. 17, 2019). Accessed Oct. 4, 2023, at https://cen.acs.org/environment/water/Wastewater-fracking-Growing-disposal-challenge/97/i45.

[136] United States House of Representatives Committee on Energy and Commerce, Minority Staff. Chemicals Used in Hydraulic Fracturing (April 2011), at 2 (on file with PSR).

[137] W. Va. Code R. § 35-8-2(2.3)(stating that "'chief' means Chief of the Office of Oil and Gas as designated by the Secretary of the Department of Environmental Protection") and W. Va. Code R. § 35-8-10.1(d)(providing that in the event of an investigation into a chemical declared confidential, a well operator shall provide the confidential chemical's identity and potentially other confidential information about the substance upon request to the chief or the chief's designee, and the state officials must keep the information confidential).

[138] W. Va. Code R. § 35-8-2(2.13)(stating that "'Health care professional' means a physician, physician assistant, nurse practitioner, registered nurse, or emergency medical technician licensed by the State of West Virginia.") and W. Va. Code R. § 35-8-10.1(e)(providing that upon request by a health professional to address a medical emergency or for diagnostic or treatment purposes, well operators must provide trade secret chemical identities and potentially other confidential information about trade secret chemicals, and the health professionals must keep this information confidential.)

[139] 15 USC § 2613(d).

[140] 29 CFR § 1910.1200(i); 2023.

[141] Dusty Horwitt. Environmental Issues Concerning Hydraulic Fracturing, Vol. 1. Chapter 4: Hydraulic Fracturing Chemical Disclosure: Can the Public Know What's Going Into Oil and Natural Gas Wells? (Elsevier: 2017) at 91, 95 (on file with PSR).

[142] W. Va. Code § 22-6A-7(a), (b)(13) and W. Va. Code R. § 35-8-1(5.7a).

[143] 29 CFR § 1910.1200.

[144] West Virginia Department of Environmental Protection. opentext ApplicationXtender. PERMITSOOG. NEW QUERY. API# 4701706699*. Accessed Dec. 27, 2023, at https://documents.dep.wv.gov/AppXtender/DataSources/DEPAX16/account/login?ret=L2RhdGFzb3VyY2VzL0RFUEFYMTYvcXVlcnkvY3JlYXRlLzM5.

[145] West Virginia Department of Environmental Protection. opentext ApplicationXtender. PERMITSOOG. NEW QUERY. API# 4707302558*. Accessed Dec. 27, 2023, at https://documents.dep.wv.gov/AppXtender/DataSources/DEPAX16/account/login?ret=L2RhdGFzb3VyY2VzL0RFUEFYMTYvcXVlcnkvY3JlYXRlLzM5.

[146] Kate Konschnik et al. Legal Fractures in Chemical Disclosure Laws: why the voluntary chemical disclosure registry FracFocus fails as a regulatory compliance tool. Harvard Law School, Environmental Law Program Policy Initiative; 2013, at 5. Accessed Dec. 11, 2022, at https://blogs.harvard.edu/environmentallawprogram/files/2013/04/4-23-2013-LEGAL-FRACTURES.pdf. See also, 29 CFR § 1910.1200(b)(2); 2023.

[147] Kate Konschnik et al. Legal Fractures in Chemical Disclosure Laws: why the voluntary chemical disclosure registry FracFocus fails as a regulatory compliance tool. Harvard Law School, Environmental Law Program Policy Initiative; 2013, at 5. Accessed Dec. 11, 2022, at https://blogs.harvard.edu/environmentallawprogram/files/2013/04/4-23-2013-LEGAL-FRACTURES.pdf. See also, 29 CFR § 1910.1200(Appendix A; A.0.2.1); 2023.

[148] Kate Konschnik et al. Legal Fractures in Chemical Disclosure Laws: why the voluntary chemical disclosure registry FracFocus fails as a regulatory compliance tool. Harvard Law School, Environmental Law Program Policy Initiative; 2013, at 5. Accessed Dec. 11, 2022, at https://blogs.harvard.edu/environmentallawprogram/files/2013/04/4-23-2013-LEGAL-FRACTURES.pdf. pdf. 29 CFR § 1910.1200; 2023.

[149] 29 CFR § 1910.1200(i); 2023.

[150] Petitioners' pleading filed in Robinson Twp. v. Commonwealth, Docket No. 284 MD 2012 (June 9, 2014), at 13 FN5 (on file with PSR).

[151] Kiskadden v. Department of Environmental Protection v. Range Resources – Appalachia, LLC. Docket No. 2011-149-R. Permittee Range Resources – Appalachia, LLC's Amended Responses and Objections to Appellant's Request for Production of Documents and Request for Admission. Filed with Commonwealth of Pennsylvania Environmental Hearing Board (April 24, 2013) (on file with PSR).

[152] Kiskadden v. Department of Environmental Protection v. Range Resources – Appalachia, LLC. Docket No. 2011-149-R. Permittee Range Resources – Appalachia, LLC's Amended Responses and Objections to Appellant's Request for Production of Documents and Request for Admission. Filed with Commonwealth of Pennsylvania Environmental Hearing Board (April 24, 2013) (on file with PSR).

[153] Kiskadden v. Department of Environmental Protection v. Range Resources – Appalachia, LLC. Docket No. 2011-149-R. Permittee Range Resources – Appalachia, LLC's Amended Responses and Objections to Appellant's Request for Production of Documents and Request for Admission. Filed with Commonwealth of Pennsylvania Environmental Hearing Board (April 24, 2013) (on file with PSR).

[154] W. Va. Code R. § 35-8-10.1.a-b.

[155] United States House of Representatives Committee on Energy and Commerce, Minority Staff. Chemicals Used in Hydraulic Fracturing (April 2011), at 2 (on file with PSR).

[156] United States House of Representatives Committee on Energy and Commerce, Minority Staff. Chemicals Used in Hydraulic Fracturing(April 2011), at 2 (on file with PSR).

[157] Halliburton Energy Services, Inc. Request for Trade Secret or Confidential Commercial Information Exemption #15-06-001. See http://wogcc.state.wy.us/post2014tradesecrets/haliburton/15-06-001_HALLIBURTON.pdf; 2015.

[158] Baker Hughes Oilfield Operations, Inc. Request for trade secret or confidential commercial information exemption #15-06-001. See http://bit.ly/2u47Aha; 2015.

[159] U.S. Environmental Protection Agency. Hydraulic fracturing for oil and gas: impacts from the hydraulic fracturing water cycle on drinking water resources in the United States. Washington, DC: Office of Research and Development; 2016, at 3-3. Accessed June 14, 2023, at https://www.epa.gov/hfstudy.

[160] U.S. Environmental Protection Agency. Hydraulic fracturing for oil and gas: impacts from the hydraulic fracturing water cycle on drinking water resources in the United States. Washington, DC: Office of Research and Development; 2016, at 3-14, 3-16. Accessed June 14, 2023, at https://www.epa.gov/hfstudy (reporting that drilling fluids, sometimes called drilling mud, are typically pumped into wells during drilling whether the wells are vertical, horizontal, or otherwise deviated). See also Juliane Glüge et al. An Overview of the Uses of Per- and Polyfluoroalkyl Substances (PFAS) – Electronic Supplementary Information 1. Environmental Science: Processes and Impacts (Oct. 30, 2020) at 50-51. Accessed online Dec. 28, 2023, at https://www.rsc.org/suppdata/d0/em/d0em00291g/d0em00291g1.pdf (reporting that PFAS have at least been proposed for use in drilling fluids).

[161] Electronic mail communication between West Virginia Department of Environmental Protection, Office of Oil and Gas and PSR Consultant Dusty Horwitt (Nov. 22, 2023) (on file with PSR).

[162] Electronic mail communication between West Virginia Department of Environmental Protection, Office of Oil and Gas and PSR Consultant Dusty Horwitt (Nov. 22, 2023) (on file with PSR).

[163] Earl Ray Tomblin, Governor of West Virginia, Exec. Order No. 4-11 (July 12, 2011) (providing that for a horizontal gas well in the Marcellus Shale formation that requires withdrawals of water in West Virginia in amounts exceeding 210,000 gallons during any month, the operator of the well must file with the state a water management plan that includes a list of the "anticipated additives that may be used in water used for fracturing or stimulating a well"; and "upon well completion, a list of the additives that were actually used in the fracturing or stimulating of the well shall be submitted as part of the completion report.") (on file with PSR). Natalie E. Tennant, Secretary of State of West Virginia, Notice of an Emergency Rule (Aug. 22, 2011) (providing that all applications for a work permit for horizontal oil or gas well sites that will disturb three or more acres of surface must include a well site safety plan). The West Virginia

State Legislature later in 2011 enacted slightly modified legislation encompassing the executive order and emergency rule. See 2011 W. Va. Acts H.B. 401 (passed Dec. 14, 2011; in effect from passage). West Virginia also enacted regulations implementing the legislation. See W. Va. Code R. § 35-8-5 and 35-8-10.

[164] West Virginia Geological and Economic Survey. Oil and Gas Well Data System Description. Accessed Dec. 28, 2023, at https://www.wvgs.wvnet.edu/www/services/servogdt.htm.

[165] Sara E. Breitmeyer et. al. U.S. Geological Survey. Per- and polyfluorinated alkyl substances (PFAS) in Pennsylvania surface waters: A statewide assessment, associated sources, and land-use relations. Science of the Total Environment 888 (2023) 164161, at 4. Accessed Oct. 2, 2023, at https://www.sciencedirect.com/science/article/pii/S0048969723027821.

[166] Peter M. Murphy and Tracy Hewat. Fluorosurfactants in Enhanced Oil Recovery. The Open Petroleum Engineering Journal, 1. 58-61, 58 (2008). Accessed Sept. 7, 2022, at https://citeseerx.ist.psu.edu/viewdoc/download?doi=10.1.1.858.5125&rep=rep1&type=pdf.

[167] Peter M. Murphy and Tracy Hewat. Fluorosurfactants in Enhanced Oil Recovery. The Open Petroleum Engineering Journal, 1. 58-61, 58 (2008). Accessed Sept. 7, 2022, at https://citeseerx.ist.psu.edu/viewdoc/download?doi=10.1.1.858.5125&rep=rep1&type=pdf.

[168] Juliane Glüge et al. An Overview of the Uses of Per- and Polyfluoroalkyl Substances (PFAS) – Electronic Supplementary Information 1. Environmental Science: Processes and Impacts (Oct. 30, 2020) at 50-51, 53. Accessed online Sept. 7, 2022, at https://pubs.rsc.org/en/content/articlelanding/2020/em/d0em00291g#!divAbstract.

[169] Boston University. Institute for Global Sustainability. Visualizing Energy. Four million wells and counting: the history of oil and gas drilling in the U.S. Accessed Jan. 13, 2024, at https://visualizingenergy.org/four-million-wells-and-counting-the-history-of-oil-and-gas-drilling-in-the-u-s/.

[170] U.S. Environmental Protection Agency. Hydraulic fracturing for oil and gas: impacts from the hydraulic fracturing water cycle on drinking water resources in the United States. Washington, DC: Office of Research and Development; 2016, at 3-4. Accessed June 14, 2023, at https://www.epa.gov/hfstudy.

[171] Hussain et al. Fluorinated surfactants: A review on recent progress on synthesis and oilfield applications. Advances in Colloid and Interface Science, Vol. 303 (May 2022), at 102634. Accessed Oct. 2, 2023, at https://www.sciencedirect.com/science/article/abs/pii/S0001868622000367.

[172] Hussain et al. Fluorinated surfactants: A review on recent progress on synthesis and oilfield applications. Advances in Colloid and Interface Science, Vol. 303 (May 2022) 102634, at 1. Accessed Oct. 2, 2023, at https://www.sciencedirect.com/science/article/abs/pii/S0001868622000367.

[173] Hussain et al. Fluorinated surfactants: A review on recent progress on synthesis and oilfield applications. Advances in Colloid and Interface Science, Vol. 303 (May 2022) 102634, at 16. Accessed Oct. 2, 2023, at https://www.sciencedirect.com/science/article/abs/pii/S0001868622000367.

[174] U.S. Environmental Protection Agency. Hydraulic fracturing for oil and gas: impacts from the hydraulic fracturing water cycle on drinking water resources in the United States. Washington, DC: Office of Research and Development; 2016, at 7-10. Accessed June 14, 2023, at https://www.epa.gov/hfstudy.

[175] Timothy Vance. West Virginia Department of Commerce Geological & Economic Survey. 2020 Marcellus Shale and Utica-Point Pleasant Production Summary (Jan. 27, 2022). Accessed November 15, 2023 at https://www.wvgs.wvnet.edu/www/datastat/Marcellus/reports/WVGES2020MarcellusandUticaPtPleasantProductionSummary.pdf.

[176] U.S. Environmental Protection Agency. Hydraulic fracturing for oil and gas: impacts from the hydraulic fracturing water cycle on drinking water resources in the United States. Washington, DC: Office of Research and Development; 2016, at 7-6. Accessed June 14, 2023, at https://www.epa.gov/hfstudy.

[177] U.S. Environmental Protection Agency. Hydraulic fracturing for oil and gas: impacts from the hydraulic fracturing water cycle on drinking water resources in the United States. Washington, DC: Office of Research and Development; 2016, at 7-10. Accessed June 14, 2023, at https://www.epa.gov/hfstudy.

[178] U.S. Environmental Protection Agency. Hydraulic fracturing for oil and gas: impacts from the hydraulic fracturing water cycle on drinking water resources in the United States. Washington, DC: Office of Research and Development; 2016, at 7-10. Accessed June 14, 2023, at https://www.epa.gov/hfstudy.

[179] Britt E. Erickson. Wastewater from fracking: Growing disposal challenge or untapped resource? Chemical & Engineering News (Nov. 17, 2019). Accessed Nov. 15, 2023, at https://cen.acs.org/environment/water/Wastewater-fracking-Growing-disposal-challenge/97/i45.

[180] U.S. Environmental Protection Agency. Hydraulic fracturing for oil and gas: impacts from the hydraulic fracturing water cycle on drinking water resources in the United States. Washington, DC: Office of Research and Development; 2016, at 7-3. Accessed June 14, 2023, at https://www.epa.gov/hfstudy

[181] U.S. Environmental Protection Agency. Hydraulic fracturing for oil and gas: impacts from the hydraulic fracturing water cycle on drinking water resources in the United States. Washington, DC: Office of Research and Development; 2016, at 7-9. Accessed June 14, 2023, at https://www.epa.gov/hfstudy.

[182] U.S. Environmental Protection Agency. Hydraulic fracturing for oil and gas: impacts from the hydraulic fracturing water cycle on drinking water resources in the United States. Washington, DC: Office of Research and Development; 2016, at 3-23, 8-3. Accessed June 14, 2023, at https://www.epa.gov/hfstudy.

[183] Justin Nobel. In West Virginia, Plan to Clean up Radioactive Fracking Waste Ends in Monster Lawsuit. DeSmog (Sept. 19, 2023). Accessed Jan. 21, 2023, at https://www.desmog.com/2023/09/19/radioactive-fracking-waste-west-virginia-veolia-antero-clearwater/.

[184] U.S. Environmental Protection Agency. Hydraulic fracturing for oil and gas: impacts from the hydraulic fracturing water cycle on drinking water resources in the United States. Washington, DC: Office of Research and Development; 2016, at 8-34. Accessed June 14, 2023, at https://www.epa.gov/hfstudy.

[185] Denise M. Akob et al. Wastewater Disposal from Unconventional Oil and Gas Development Degrades Stream Quality at a West Virginia Injection Facility. Environmental Science & Technology (2016), 5517-5525. Accessed November 16, 2023, at https://pubs.acs.org/doi/10.1021/acs.est.6b00428.

[186] U.S. Environmental Protection Agency. Hydraulic fracturing for oil and gas: impacts from the hydraulic fracturing water cycle on drinking water resources in the United States. Washington, DC: Office of Research and Development; 2016, at 8-4. Accessed June 14, 2023, at https://www.epa.gov/hfstudy.

[187] Denise M. Akob et al. Wastewater Disposal from Unconventional Oil and Gas Development Degrades Stream Quality at a West Virginia Injection Facility. Environmental Science & Technology (2016), 5517-5525. Accessed November 16, 2023, at https://pubs.acs.org/doi/10.1021/acs.est.6b00428.

[188] Denise M. Akob et al. Wastewater Disposal from Unconventional Oil and Gas Development Degrades Stream Quality at a West Virginia Injection Facility. Environmental Science & Technology (2016), 5517-5525. Accessed November 16, 2023, at https://pubs.acs.org/doi/10.1021/acs.est.6b00428.

[189] Christopher D. Kassotis et al. Endocrine disrupting activities of surface water associated with a West Virginia oil and gas industry wastewater disposal site. Science of the Total Environment (2016), 1:557-558:901-10. Accessed Nov. 16, 2023, at https://pubmed.ncbi.nlm.nih.gov/27073166/.

[190] The Endocrine Society. Endocrine Society supports EPA rule regulating "forever chemicals" in drinking water (Mar. 14, 2023). Accessed Nov. 19, 2023, at https://www.endocrine.org/news-and-advocacy/news-room/2023/endocrine-society-supports-epa-rule-regulating-forever-chemicals-in-drinking-water.

[191] U.S. Environmental Protection Agency. Overview of Endocrine Disruption. Accessed Nov. 19, 2023, at https://www.epa.gov/endocrine-disruption/overview-endocrine-disruption.

[192] U.S. Environmental Protection Agency. Overview of Endocrine Disruption. Accessed Nov. 19, 2023, at https://www.epa.gov/endocrine-disruption/overview-endocrine-disruption.

[193] Christopher D. Kassotis et al. Endocrine disrupting activities of surface water associated with a West Virginia oil and gas industry wastewater disposal site. Science of the Total Environment (2016), 1:557-558:901-10. Accessed Nov. 16, 2023, at https://pubmed.ncbi.nlm.nih.gov/27073166/.

[194] Jennifer S. Harkness. Iodide, Bromide, and Ammonium in Hydraulic Fracturing and Oil and Gas Wastewaters: Environmental Implications. Environmental Science & Technology, 2015, 49, 3, 1955–1963. Accessed November 19, 2023, at https://pubs.acs.org/doi/epdf/10.1021/es504654n.

[195] Penn State Marcellus Center for Outreach and Research. Cross-Section of Typical Horizontal Marcellus Well (2023). Accessed June 19, 2023, at https://marcellus.psu.edu/resources/maps-graphics-and-videos/.

[196] West Virginia Department of Commerce. Geological and Economic Survey. 2019 Marcellus Shale and Utica-Point Pleasant Production Summary. Accessed Dec. 28, 2023, at https://www.wvgs.wvnet.edu/www/datastat/Marcellus/reports/WVGES2019MarcellusandUticaPtPleasantProductionSummary.pdf. The West Virginia Department of Environmental Protection has said that vertical depths of horizontal gas wells range from 5,000 to 12,000 feet and horizontal legs range from 3,000 to 24,000 feet. Electronic mail communication between West Virginia Department of Environmental Protection, Office of Oil and Gas and PSR Consultant Dusty Horwitt (Jan. 23, 2024) (on file with PSR)

[197] George Kazamias and Antonis A. Zorpas. Drill cuttings waste management from oil & gas exploitation industries through end-of-waste criteria in the framework of circular economy strategy. Journal of Cleaner Production, Vol. 322 (Nov. 1, 2021). Accessed June 19, 2023, at https://www.sciencedirect.com/science/article/abs/pii/S095965262103287X.

[198] Juliane Glüge et al. An Overview of the Uses of Per- and Polyfluoroalkyl Substances (PFAS) – Electronic Supplementary Information 1. Environmental Science: Processes and Impacts (Oct. 30, 2020) at 50-51. Accessed online Dec. 28, 2023, at https://www.rsc.org/suppdata/d0/em/d0em00291g/d0em00291g1.pdf.

[199] Kristina Marusic. Revealed: Nearly 100 potential PFAS-polluted sites in Pennsylvania, Ohio and West Virginia from fracking waste. Environmental Health News (Dec. 7, 2022). Accessed June 13, 2023, at https://www.ehn.org/fracking-pennsylvania-pfas-2658837888.html.

[200] Kristina Marusic. Revealed: Nearly 100 potential PFAS-polluted sites in Pennsylvania, Ohio and West Virginia from fracking waste. Environmental Health News (Dec. 7, 2022). Accessed June 13, 2023, at https://www.ehn.org/fracking-pennsylvania-pfas-2658837888.html.

[201] Kristina Marusic. Revealed: Nearly 100 potential PFAS-polluted sites in Pennsylvania, Ohio and West Virginia from fracking waste. Environmental Health News (Dec. 7, 2022). Accessed June 13, 2023, at https://www.ehn.org/fracking-pennsylvania-pfas-2658837888.html.

[202] Pennsylvania Department of Environmental Protection. Oil and Gas Well Waste Report. Searches for well with permit number 125-27055. Accessed Nov. 20, 2023, at https://greenport.pa.gov/ReportExtracts/OG/OilGasWellWasteReport.

[203] Pennsylvania Department of Environmental Protection. Oil and Gas Well Waste Report. Searches for well with permit number 125-24946. Accessed Nov. 20, 2023, at https://greenport.pa.gov/ReportExtracts/OG/OilGasWellWasteReport.

[204] Pennsylvania Department of Environmental Protection. Oil and Gas Well Waste Report. Searches for well with permit number 125-27155. Accessed Nov. 20, 2023, at https://greenport.pa.gov/ReportExtracts/OG/OilGasWellWasteReport.

[205] Pennsylvania Department of Environmental Protection. Oil and Gas Well Waste Report. Searches for well with permit number . Accessed Nov. 20, 2023, at https://greenport.pa.gov/ReportExtracts/OG/OilGasWellWasteReport.

[206] Pennsylvania Department of Environmental Protection. Oil and Gas Well Waste Report. Searches for well with permit number 125-24946. Accessed Nov. 20, 2023, at https://greenport.pa.gov/ReportExtracts/OG/OilGasWellWasteReport.

[207] Pennsylvania Department of Environmental Protection. Oil and Gas Well Waste Report. Searches for well with permit number 125-27055. Accessed Nov. 20, 2023, at https://greenport.pa.gov/ReportExtracts/OG/OilGasWellWasteReport.

[208] Pennsylvania Department of Environmental Protection. Oil and Gas Well Waste Report. Searches for well with permit number 125-27155. Accessed Nov. 20, 2023, at https://greenport.pa.gov/ReportExtracts/OG/OilGasWellWasteReport.

[209] Pennsylvania Department of Environmental Protection. Oil and Gas Well Waste Report. Searches for well with permit number 125-24946. Accessed Nov. 20, 2023, at https://greenport.pa.gov/ReportExtracts/OG/OilGasWellWasteReport.

[210] Pennsylvania Department of Environmental Protection. Oil and Gas Well Waste Report. Searches for well with permit number 125-27055. Accessed Nov. 20, 2023, at https://greenport.pa.gov/ReportExtracts/OG/OilGasWellWasteReport.

[211] Pennsylvania Department of Environmental Protection. Oil and Gas Well Waste Report. Searches for well with permit number 125-27155. Accessed Nov. 20, 2023, at https://greenport.pa.gov/ReportExtracts/OG/OilGasWellWasteReport.

[212] Pennsylvania Department of Environmental Protection. Oil and Gas Well Waste Report. Searches for well with permit number 125-24946. Accessed Nov. 20, 2023, at https://greenport.pa.gov/ReportExtracts/OG/OilGasWellWasteReport.

[213] Pennsylvania Department of Environmental Protection. Oil and Gas Well Waste Report. Searches for well with permit number 125-27055. Accessed Nov. 20, 2023, at https://greenport.pa.gov/ReportExtracts/OG/OilGasWellWasteReport.

[214] Pennsylvania Department of Environmental Protection. Oil and Gas Well Waste Report. Searches for well with permit number 125-27155. Accessed Nov. 20, 2023, at https://greenport.pa.gov/ReportExtracts/OG/OilGasWellWasteReport.

[215] Pennsylvania Department of Environmental Protection. Oil and Gas Well Waste Report. Searches for well with permit number 125-24946. Accessed Nov. 20, 2023, at https://greenport.pa.gov/ReportExtracts/OG/OilGasWellWasteReport.

[216] Dusty Horwitt and Barbara Gottlieb. Fracking with "Forever" Chemicals in Pennsylvania. Physicians for Social Responsibility (Oct. 2023). Accessed Nov. 20, 2023, at https://psr.org/wp-content/uploads/2023/10/fracking-with-forever-chemicals-in-pennsylvania.pdf.

[217] Dusty Horwitt and Barbara Gottlieb. Fracking with "Forever" Chemicals in Pennsylvania. Physicians for Social Responsibility (Oct. 2023), at 8-18. Accessed Nov. 20, 2023, at https://psr.org/wp-content/uploads/2023/10/fracking-with-forever-chemicals-in-pennsylvania.pdf.

[218] Kristina Marusic. Revealed: Nearly 100 potential PFAS-polluted sites in Pennsylvania, Ohio and West Virginia from fracking waste. Environmental Health News (Dec. 7, 2022). Accessed June 13, 2023, at https://www.ehn.org/fracking-pennsylvania-pfas-2658837888.html.

[219] Garrett Ellison. Major Warning about Michigan PFAS Crisis Came 6 Years Ago. Mlive (July 10, 2018). Accessed Nov. 15, 2020 at https://www.mlive.com/news/2018/07/meq_pfas_delaney_2012_report.html.

[220] Kristina Marusic. Revealed: Nearly 100 potential PFAS-polluted sites in Pennsylvania, Ohio and West Virginia from fracking waste. Environmental Health News (Dec. 7, 2022). Accessed June 13, 2023, at https://www.ehn.org/fracking-pennsylvania-pfas-2658837888.html.

[221] Kristina Marusic. Revealed: Nearly 100 potential PFAS-polluted sites in Pennsylvania, Ohio and West Virginia from fracking waste. Environmental Health News (Dec. 7, 2022). Accessed June 13, 2023, at https://www.ehn.org/fracking-pennsylvania-pfas-2658837888.html.

[222] Electronic mail communication from Jamar Thrasher, Pennsylvania Department of Environmental Protection, to Kristina Marusic, Environmental Health News (Oct. 31, 2022) (on file with PSR).

[223] Kristina Marusic. Revealed: Nearly 100 potential PFAS-polluted sites in Pennsylvania, Ohio and West Virginia from fracking waste. Environmental Health News (Dec. 7, 2022). Accessed June 13, 2023, at https://www.ehn.org/fracking-pennsylvania-pfas-2658837888.html.

[224] Kristina Marusic. Revealed: Nearly 100 potential PFAS-polluted sites in Pennsylvania, Ohio and West Virginia from fracking waste. Environmental Health News (Dec. 7, 2022). Accessed June 13, 2023, at https://www.ehn.org/fracking-pennsylvania-pfas-2658837888.html. Electronic mail communication from Jamar Thrasher, Pennsylvania Department of Environmental Protection, to Kristina Marusic, Environmental Health News (Oct. 31, 2022) (on file with PSR).

[225] Kristina Marusic. Revealed: Nearly 100 potential PFAS-polluted sites in Pennsylvania, Ohio and West Virginia from fracking waste. Environmental Health News (Dec. 7, 2022). Accessed June 13, 2023, at https://www.ehn.org/fracking-pennsylvania-pfas-2658837888.html.

[226] West Virginia Geological and Economic Survey. History of WV Mineral Industries - Oil and Gas. Accessed Dec. 28, 2023, at https://www.wvgs.wvnet.edu/www/geology/geoldvog.htm.

[227] Sarah Elbeshbishi. Millions in federal funding to help West Virginia tackle orphaned and abandoned oil wells doesn't go far enough. Mountain State Spotlight. Accessed Dec. 28, 2023, at https://mountainstatespotlight.org/2023/10/20/orphaned-abandoned-oil-wells-state-problem/.

[228] Texas Department of Agriculture. Agricultural Land and Water Contamination from Injection Wells, Disposal Pits, and Abandoned Wells used in Oil and Gas Production (1985), at 5 (on file with PSR).

[229] U.S. General Accounting Office. Safeguards Are Not Preventing Contamination from Injected Oil and Gas Wastes (July 1989), at 19. Accessed Sept. 8, 2022, at https://www.gao.gov/assets/150/147952.pdf. U.S. Environmental Protection Agency. Report to Congress: Management of Wastes from the Exploration, Development, and Production of Crude Oil, Natural Gas, and Geothermal Energy, Vol. 1 of 3 (Dec. 1987), at III-47 through 48. Accessed Dec. 29, 2023, at https://archive.epa.gov/epawaste/nonhaz/industrial/special/web/pdf/530sw88003a.pdf.

[230] Beth Burger, "Thousands of Gallons of Fracking Waste Spilled from Noble County Well for Four Days," The Columbus Dispatch (Feb. 5, 2021) Accessed Sept. 8, 2022, at https://www.dispatch.com/story/news/2021/02/04/thousands-gallons-flthousands-of-gallouid-spilled-oil-and-gas-well-noble-co-damage-and-cause-unclear/4397912001/.

[231] Anya Litvak. A shale well met an abandoned well a mile away. How did it happen? Pittsburgh Post-Gazette (July 18, 2022). Accessed June 19, 2023, at https://www.post-gazette.com/business/powersource/2022/07/18/marcellus-shale-natural-gas-well-abandoned-well-communication-fracking-eqt-greene-county-pennsylvania-department-environmental-protection-frack-out/stories/202207180019.

[232] U.S. General Accounting Office. Safeguards Are Not Preventing Contamination from Injected Oil and Gas Wastes (July 1989), at 19. Accessed Sept. 8, 2022, at https://www.gao.gov/assets/150/147952.pdf.

[233] U.S. Environmental Protection Agency, Report to Congress: Management of Wastes from the Exploration, Development, and Production of Crude Oil, Natural Gas, and Geothermal Energy, Vol. 1 of 3 (Dec. 1987), at IV-22. Accessed Nov. 20, 2023, at https://archive.epa.gov/epawaste/nonhaz/industrial/special/web/pdf/530sw88003a.pdf.

[234] Ian Urbina. A Tainted Water Well, and Concern There May Be More. New York Times (Aug. 3, 2011). Accessed Nov. 20, 2023, at https://www.nytimes.com/2011/08/04/us/04natgas.html.

[235] Dusty Horwitt. Cracks in the Façade. Environmental Working Group (Aug. 3, 2011). Accessed Nov. 20, 2023, at https://www.nytimes.com/2011/08/04/us/04natgas.html.

[236] Anya Litvak. A shale well met an abandoned well a mile away. How did it happen? Pittsburgh Post-Gazette (July 18, 2022). Accessed June 19, 2023, at https://www.post-gazette.com/business/powersource/2022/07/18/marcellus-shale-natural-gas-well-abandoned-well-communication-fracking-eqt-greene-county-pennsylvania-department-environmental-protection-frack-out/stories/202207180019.

[237] W. Va. Code § 22-6A-12 (providing setback standards for horizontal gas wells). W. Va. Code § 22-6-21 (providing setback standards for vertical oil and gas wells).

[238] Office of the Attorney General, Commonwealth of Pennsylvania. Report 1 of the Forty-Third Statewide Investigating Grand Jury (June 25, 2020), at 94. Accessed Sept. 8, 2022, at https://www.attorneygeneral.gov/wp-content/uploads/2020/06/FINAL-frackingreport-w.responses-with-page-number-V2.pdf.

[239] U.S. Geological Survey. New York Water Science Center Comments on the Revised Draft Supplemental Generic Environmental Impact Statement (2012), at 6 (on file with PSR).

[240] Denise M. Akob et al. Wastewater Disposal from Unconventional Oil and Gas Development Degrades Stream Quality at a West Virginia Injection Facility. Environmental Science & Technology (2016), 5517-5525. Accessed November 16, 2023, at https://pubs.acs.org/doi/10.1021/acs.est.6b00428.

[241] Texas Department of Agriculture. Agricultural Land and Water Contamination from Injection Wells, Disposal Pits, and Abandoned Wells used in Oil and Gas Production (1985), at 11 (on file with PSR).

[242] U.S. General Accounting Office. Safeguards Are Not Preventing Contamination from Injected Oil and Gas Wastes (July 1989), at 3. Accessed Sept. 8, 2022, at https://www.gao.gov/assets/150/147952.pdf.

[243] U.S. General Accounting Office. Safeguards Are Not Preventing Contamination from Injected Oil and Gas Wastes (July 1989), at 3. Accessed Sept. 8, 2022, at https://www.gao.gov/assets/150/147952.pdf.

[244] Mordechai Treiger and George Monk West Virginia's Groundwater is not Adequately Protected from Underground Injection. Natural Resources Defense Council (2019). Accessed Nov. 20, 2023, at https://www.nrdc.org/sites/default/files/west-virginia-groundwater-underground-injection-report.pdf.

[245] Mordechai Treiger and George Monk West Virginia's Groundwater is not Adequately Protected from Underground Injection. Natural Resources Defense Council (2019), at 4-5. Accessed Nov. 20, 2023, at https://www.nrdc.org/sites/default/files/west-virginia-groundwater-underground-injection-report.pdf.

[246] Mordechai Treiger and George Monk West Virginia's Groundwater is not Adequately Protected from Underground Injection. Natural Resources Defense Council (2019), at 4-5, 6. Accessed Nov. 20, 2023, at https://www.nrdc.org/sites/default/files/west-virginia-groundwater-underground-injection-report.pdf.

[247] Mordechai Treiger and George Monk West Virginia's Groundwater is not Adequately Protected from Underground Injection. Natural Resources Defense Council (2019), at 8. Accessed Nov. 20, 2023, at https://www.nrdc.org/sites/default/files/west-virginia-groundwater-underground-injection-report.pdf.

[248] Beth Burger, "Thousands of Gallons of Fracking Waste Spilled from Noble County Well for Four Days," The Columbus Dispatch (Feb. 5, 2021) Accessed Sept. 8, 2022, at https://www.dispatch.com/story/news/2021/02/04/thousands-gallons-flthousands-of-gallouid-spilled-oil-and-gas-well-noble-co-damage-and-cause-unclear/4397912001/.

[249] Beth Burger. State Investigating Whether Injection Well Waste Affecting Drinking Water. Columbus Dispatch (Sept. 5, 2020). Accessed Sept. 8, 2022, at https://www.dispatch.com/story/news/local/2020/09/05/state-investigating-whether-injection-well-wasteaffecting-drinking-water/113667974/.

[250] Ohio Department of Natural Resources. Division of Oil and Gas Resources Management. Order by the Chief. ORDER NO. 2023-02 (January 9, 2023) (on file with PSR), at 4.

[251] Ohio Department of Natural Resources. Division of Oil and Gas Resources Management. Order by the Chief. ORDER NO. 2023-93 (May 1, 2023) (on file with PSR), at 3-4.

[252] Ohio Department of Natural Resources. Division of Oil and Gas Resources Management. Order by the Chief. ORDER NO. 2023-139 (June 26, 2023) (on file with PSR), at 6.

[253] Ohio Department of Natural Resources. Division of Oil and Gas Resources Management. Order by the Chief. ORDER NO. 2023-02 (January 9, 2023) (on file with PSR), at 4.

[254] T.L. Tasker et al. Environmental and Human Health Impacts of Spreading Oil and Gas Wastewater on Roads. Environmental Science & Technology (2018), 52, 7081. Accessed Nov. 20, 2023, at https://par.nsf.gov/servlets/purl/10093932.

[255] Memorandum of Agreement between the West Virginia Department of Environmental Protection and the West Virginia Division of Highways. Subject: WVDOH/WVDEP Salt Brine from Gas Wells Agreement (Dec. 22, 2011) (on file with PSR).

[256] Memorandum of Agreement between the West Virginia Department of Environmental Protection and the West Virginia Division of Highways. Subject: WVDOH/WVDEP Salt Brine from Gas Wells Agreement (Dec. 22, 2011) (on file with PSR).257 T.L. Tasker et al. Environmental and Human Health Impacts of Spreading Oil and Gas Wastewater on Roads. Environmental Science & Technology (2018), 52, 7081, 7089. Accessed Nov. 20, 2023, at https://par.nsf.gov/servlets/purl/10093932.

[257] T.L. Tasker et al. Environmental and Human Health Impacts of Spreading Oil and Gas Wastewater on Roads. Environmental Science & Technology (2018), 52, 7081, 7089. Accessed Nov. 20, 2023, at https://par.nsf.gov/servlets/purl/10093932.

[258] U.S. Environmental Protection Agency. Municipal Solid Waste Landfills (April 4, 2023). Accessed June 20, 2023, at https://www.epa.gov/landfills/municipal-solid-waste-landfills.

[259] Reid Frazier. AG Investigating Wastewater Case from Landfill that Accepts Fracking Waste. Allegheny Front (May 24, 2019). Accessed Sept. 8, 2022, at https://www.alleghenyfront.org/ag-investigating-wastewater-case-from-landfill-that-accepts-fracking-waste/.

[260] Mike Argento. Lawsuit filed alleging 'dangerous' levels of 'forever chemicals' in York County creek. York Daily Record (Jan. 11, 2023). Accessed June 20, 2023, at https://www.ydr.com/story/news/2023/01/11/modern-landfill-sued-over-levels-of-forever-chemicals-in-local-creek/69799773007/.

[261] Lower Susquehanna Riverkeeper Association v. Republic Services of Pennsylvania LLC. Case 1:23-cv-00044-JPW. Filed Jan. 11, 2023. Accessed June 20, 2023, at https://www.aboutlawsuits.com/wp-content/uploads/2023-01-11-Complaint-1.pdf.

[262] Lauren Badertscher et al. Elevated sediment radionuclide concentrations downstream of facilities treating leachate from landfills accepting oil and gas waste. Ecological Indicators 154, 110616 (2023), at 4 (on file with PSR). The lead author sent a DEP record stating that in April 2019, Modern Landfill in York, Pa. received three tons of produced fluid from unconventional gas wells. Electronic mail from Duquesne University Professor John Stolz to Dusty Horwitt sharing electronic mail record from Lauren Badertscher (July 6, 2023) (on file with PSR).

[263] Lauren Badertscher et al. Elevated sediment radionuclide concentrations downstream of facilities treating leachate from landfills accepting oil and gas waste. Ecological Indicators 154, 110616 (2023), at 6 (on file with PSR).

[264] Marshall University Center for Environmental, Geotechnical and Applied Sciences. Examination of Leachate, Drill Cuttings and Related Environmental, Economic and Technical Aspects Associated with Solid Waste Facilities in West Virginia. Cover letter (June 30, 2015). Accessed Nov. 21, 2023, at https://dep.wv.gov/pio/Documents/E05_FY_2015_2933.pdf.

[265] Marshall University Center for Environmental, Geotechnical and Applied Sciences. Examination of Leachate, Drill Cuttings and Related Environmental, Economic and Technical Aspects Associated with Solid Waste Facilities in West Virginia. Cover letter (June 30, 2015), at 2. Accessed Nov. 21, 2023, at https://dep.wv.gov/pio/Documents/E05_FY_2015_2933.pdf.

[266] Dusty Horwitt. Fracking with Forever Chemicals. Physicians for Social Responsibility (July 2021), at 15. Accessed Sept. 8, 2022, at https://www.psr.org/wp-content/uploads/2021/07/fracking-withforever-chemicals.pdf. Telephone interview with David Brown (January 26, 2023).

[267] U.S. Environmental Protection Agency. PFAS Analytical Methods Development and Sampling Research (Feb. 16, 2023). Accessed June 20, 2023, at https://www.epa.gov/water-research/pfas-analytical-methods-development-and-sampling-research.

[268] Interstate Technology Regulatory Council. Who We Are (2023). Accessed June 20, 2023, at https://itrcweb.org/about/about.

[269] Interstate Technology Regulatory Council. PFAS — Per- and Polyfluoroalkyl Substances. 5 Environmental Fate and Transport Processes. Section 5.2.4 Partitioning to Air (June 2022). Accessed June 20, 2023, at https://pfas-1.itrcweb.org/5-environmental-fate-and-transport-processes/.

[270] Interstate Technology Regulatory Council. PFAS — Per- and Polyfluoroalkyl Substances. 5 Environmental Fate and Transport Processes. Section 5.3.2 PFAS Transport Via Air (June 2022). Accessed June 20, 2023, at https://pfas-1.itrcweb.org/5-environmental-fate-and-transport-processes/.

[271] West Virginia Center on Budget & Policy. A Deeper Look at West Virginia's 2022 Poverty Data. Accessed Dec. 29, 2023, at https://wvpolicy.org/child-poverty-increased-in-west-virginia/.

[272] Yelena Ogneva-Himmelberger and Liyao Huang. Spatial distribution of unconventional gas wells and human populations in the Marcellus Shale in the United States: Vulnerability analysis. Applied Geography (June 2015), Vol. 60, 165-174. Accessed Nov. 21, 2023, at https://www.sciencedirect.com/science/article/abs/pii/S0143622815000776.

[273] Ian Urbina. Pressure Limits Efforts to Police Drilling for Gas. New York Times (Mar. 3, 2011). Accessed Dec. 29, 2023, at https://www.nytimes.com/2011/03/04/us/04gas.html?ref=us. Related sidebar, Lax Rules for the Natural Gas Industry, accessed Sept. 8, 2022, at https://archive.nytimes.com/www.nytimes.com/interactive/2011/03/03/us/20110303-natural-gas-timeline.html.

[274] Michael Janofsky. Dupont to Pay $16.5 Million for Unreported Risks. New York Times (Dec. 15, 2005). Accessed Dec. 29, 2023, at https://www.nytimes.com/2005/12/15/politics/dupont-to-pay-165-million-for-unreported-risks.html. The Lawyer Who Became Dupont's Worst Nightmare. New York Times Magazine (Jan. 6, 2016). Accessed Dec. 29, 2023, at https://www.nytimes.com/2016/01/10/magazine/the-lawyer-who-became-duponts-worst-nightmare.html?searchResultPosition=1 (reporting that Dupont's settlement payment amounted to less than two percent of Dupont's profits from PFOA that year and the company was not required to admit liability).

[275] U.S. Environmental Protection Agency. Fact Sheet: 2010/2015 PFOA Stewardship Program. Accessed Dec. 29, 2023, at https://www.epa.gov/assessing-and-managing-chemicals-under-tsca/fact-sheet-20102015-pfoa-stewardship-program. U.S. Environmental Protection Agency. 2010/15 PFOA Stewardship Program. Guidance on Reporting Emissions and Product Content (October 2006). Accessed Dec. 29, 2023, at https://www.epa.gov/sites/default/files/2015-10/documents/pfoaguidance.pdf. Nathaniel Rich. The Lawyer Who Became DuPont's Worst Nightmare. New York Times Magazine (Jan. 6, 2016). Accessed Dec. 29, 2023, at https://www.nytimes.com/2016/01/10/magazine/the-lawyer-who-became-duponts-worst-nightmare.html?searchResultPosition=1.

[276] U.S. Environmental Protection Agency. Fact Sheet: 2010/2015 PFOA Stewardship Program. Accessed Dec. 29, 2023, at https://www.epa.gov/assessing-and-managing-chemicals-under-tsca/fact-sheet-20102015-pfoa-stewardship-program.

[277] U.S. Environmental Protection Agency. Fact Sheet: 2010/2015 PFOA Stewardship Program. Accessed Dec. 29, 2023, at https://www.epa.gov/assessing-and-managing-chemicals-under-tsca/fact-sheet-20102015-pfoa-stewardship-program.

[278] Rainer Lohmann et al. Are Fluoropolymers Really of Low Concern for Human and Environmental Health and Separate from Other PFAS? Environmental Science & Technology 2020, 54, 12820-12828, 12821-12822. Accessed Dec. 29, 2023, at https://pubs.acs.org/doi/10.1021/acs.est.0c03244.

[279] U.S. Environmental Protection Agency. Fact Sheet: 2010/2015 PFOA Stewardship Program. Accessed Dec. 29, 2023, at https://www.epa.gov/assessing-and-managing-chemicals-under-tsca/fact-sheet-20102015-pfoa-stewardship-program.

[280] Earthjustice. EPA's Secret Chemical Problem, Unveiled. Accessed Dec. 29, 2023, at https://earthjustice.org/sites/default/files/files/20200317_comms_pc_tsca_english_final.pdf. Sharon Lerner. EPA Continues to Approve Toxic PFAS Chemicals Despite Widespread Contamination. The Intercept (Oct. 25, 2018). Accessed Dec. 29, 2023, at https://theintercept.com/2018/10/25/epa-pfoa-pfas-pfos-chemicals/.

[281] Arlene Blum et al. The Madrid Statement on Poly- and Perfluoroalkyl Substances (PFASs). Environmental Health Perspectives (May 1, 2015), Vol. 123, No. 5. Accessed Dec. 29, 2023, at https://ehp.niehs.nih.gov/doi/10.1289/ehp.1509934.

[282] U.S. Environmental Protection Agency. PFAS Strategic Roadmap: EPA's Commitments to Action 2021-2024 (Oct. 2021), at 7. Accessed Dec. 29, 2023, at https://www.epa.gov/system/files/documents/2021-10/pfas-roadmap_final-508.pdf.

[283] Letter from U.S. Rep. Jared Huffman et al. to U.S. Environmental Protection Agency Administrator Michael S. Regan (Oct. 27, 2021). Accessed Dec. 29, 2023, at https://huffman.house.gov/media-center/press-releases/huffman-calls-on-epa-to-protect-public-from-chemical-hazards-created-by-hydraulic-fracturing.

[284] Physicians for Social Responsibility. Comments submitted to the U.S. Environmental Protection Agency in reference to Docket Identification (ID) Number EPA-HQ-OPPT-2020-0549 (Sept. 27, 2021).

[285] U.S. Environmental Protection Agency. EPA Proposes Designating Certain PFAS Chemicals as Hazardous Substances Under Superfund to Protect People's Health (Aug. 26, 2022). Accessed Dec. 29, 2023, at https://www.epa.gov/newsreleases/epa-proposes-designating-certain-pfas-chemicals-hazardous-substances-under-superfund.

[286] U.S. Environmental Protection Agency. Advance Notice of Proposed Rulemaking. 88 Fed. Reg. 22399 (April 13, 2023). Accessed Dec. 29, 2023, at https://www.govinfo.gov/content/pkg/FR-2023-04-13/pdf/2023-07535.pdf.

[287] U.S. Environmental Protection Agency. Superfund Liability (July 25, 2022). Accessed Dec. 29, 2023, at https://www.epa.gov/enforcement/superfund-liability.

[288] Interstate Technology Regulatory Council. Fact Sheets: PFAS Water and Soil Regulatory and Guidance Values Table Excel File. Water Table. Accessed Dec. 29, 2023, at https://pfas-1.itrcweb.org/.

[289] U.S. Department of Energy. Energy Information Administration. Petroleum & other Liquids. Crude Oil Production. Annual – Thousand Barrels. Accessed Dec. 29, 2023, at https://www.eia.gov/dnav/pet/pet_crd_crpdn_adc_mbbl_a.htm.

[290] Cal. Public Resources. § 3160 (j)(2)(A) (providing that "Notwithstanding any other law or regulation, none of the following information shall be protected as a trade secret…The identities of the chemical constituents of additives [in well stimulation treatment fluids], including CAS identification numbers."

[291] U.S. Department of Energy. Secretary of Energy Advisory Board Task Force Report on FracFocus 2.0 (Mar. 28, 2014). Accessed Dec. 29, 2023, at https://www.energy.gov/sites/default/files/2014/04/f14/20140328_SEAB_TF_FracFocus2_Report_Final.pdf. U.S. Department of Energy. Secretary of Energy Advisory Board Task Force Report on FracFocus 2.0 (Mar. 28, 2014). Accessed Dec. 29, 2023, at https://www.energy.gov/sites/default/files/2014/04/f14/20140328_SEAB_TF_FracFocus2_Report_Final.pdf.

[292] Colorado General Assembly. HB22-1348. Senate Amended 3rd Reading (May 11, 2022). Accessed Dec. 29, 2023, at https://leg.colorado.gov/sites/default/files/documents/2022A/bills/2022a_1348_rer.pdf.

[293] U.S. Department of Energy. Secretary of Energy Advisory Board Task Force Report on FracFocus 2.0 (Mar. 28, 2014). Accessed Dec. 29, 2023, at https://www.energy.gov/sites/default/files/2014/04/f14/20140328_SEAB_TF_FracFocus2_Report_Final.pdf.

[294] U.S. Department of Energy. Secretary of Energy Advisory Board Task Force Report on FracFocus 2.0 (Mar. 28, 2014). Accessed Dec. 29, 2023, at https://www.energy.gov/sites/default/files/2014/04/f14/20140328_SEAB_TF_FracFocus2_Report_Final.pdf.

[295] Cal. Public Resources. § 3160(j)(5-7).

[296] Cal. Public Resources § 3160(j)(2).

[297] Colorado House Bill 22-1348(2)(f) (enacted June 8, 2022). Accessed Dec. 29, 2023, at https://leg.colorado.gov/sites/default/files/2022a_1348_signed.pdf.

[298] Colorado House Bill 22-1348(2)(A)(II) (enacted June 8, 2022) (requiring that well operators, service providers, and vendors must declare that additives, base fluids, and fracking fluids used in oil and gas wells contain no intentionally added PFAS) and House Bill 22-1345 (enacted June 3, 2022) (prohibiting the sale, distribution for sale, or distribution for use of any drilling fluids, fracking fluids, or proppants containing intentionally added PFAS). Accessed Dec. 29, 2023, at https://leg.colorado.gov/sites/default/files/2022a_1348_signed.pdf.

[299] Julianne Glüge et al. Information Requirements under the Essential-Use Concept: PFAS Case Studies. Environmental Science & Technology (Oct. 5, 2021). Accessed Dec. 29, 2023, at https://pubs.acs.org/doi/10.1021/acs.est.1c03732.

[300] U.S. Environmental Protection Agency. Resource Conservation and Recovery Act (RCRA) Overview. Accessed Jan. 20, 2023, at https://www.epa.gov/rcra/resource-conservation-and-recovery-act-rcra-overview.

[301] U.S. Environmental Protection Agency. Regulatory Determination for Oil and Gas and Geothermal Exploration, Development and Production Wastes. 53 FR 25447 (July 6, 1988). Accessed Jan. 20, 2023, at https://archive.epa.gov/epawaste/nonhaz/industrial/special/web/pdf/og88wp.pdf.

[302] W. Va. Code § 22-18-23.

[303] Wetzel County Landfill. Accessed Nov. 21, 2023, at https://jpmascaro.com/our-facilities/wetzel-county-landfill.aspx (the landfill accepts oil and gas waste and states that it does not accept hazardous waste).

[304] 40 C.F.R. § 144.3, 144.6.

[305] U.S. Environmental Protection Agency. Requirements for all Class I Wells and Class I Hazardous Waste Wells. Accessed Dec. 29, 2023, at https://www.epa.gov/sites/default/files/2015-10/documents/page_uic-class1_summary_class1_reqs_508c.pdf.

[306] New York State Senate. S. 3392 (signed by governor Aug. 3, 2020). Accessed Dec. 29, 2023, at https://www.nysenate.gov/legislation/bills/2019/s3392.

[307] New York State Senator Rachel May. Legislature Closes Decade Long Loophole on Treatment of Hazardous Fracking Waste. News Release (July 22, 2020). Accessed Dec. 29, 2023, at https://www.nysenate.gov/newsroom/press-releases/2020/rachel-may/legislature-closes-decade-long-loophole-treatment-hazardous.

[308] FracFocus. About FracFocus. Accessed Dec. 29, 2023, at https://www.fracfocus.org/learn/about-fracfocus.

[309] Groundwater Protection Council. Overview. Accessed Dec. 29, 2023, at https://www.gwpc.org/about-us/overview/.

[310] Gary Allison (2021) Open-FF: Transforming the FracFocus Disclosure Data into a Usable Resource [Source Code]. Accessed Dec. 29, 2023, at https://doi.org/10.24433/CO.1058811.v15. PSR accessed Open-FF data set downloaded from FracFocus on Sept. 29, 2022.

[311] Gary Allison (2021) Open-FF: Transforming the FracFocus Disclosure Data into a Usable Resource [Source Code]. Accessed Dec. 29, 2023, at https://doi.org/10.24433/CO.1058811.v15.

[312] W. Va. Code R. § 35-8-10.1.a-b.

[313] W. Va. Code R. § 35-8-10.2.a.

[314] W. Va. Code R. § 35-8-10.1.a.

[315] See, e.g., FracFocus. Find a Well. Well with API Number 47-017-06699 fracked by Antero Resources Corp. between March 25 and April 6, 2017 in Doddridge County. Accessed Nov. 21, 2023, at https://fracfocusdata.org/DisclosureSearch/Search.aspx.

[316] W. Va. Code R. § 35-8-10.1.a.

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