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FRACKING WITH "FOREVER CHEMICALS" IN COLORADO

Evidence Shows Oil and Gas Companies Have Used PFAS in Colorado Wells; 'Trade Secret' Laws Limit Public's Ability to Know Full Extent of Use

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Cover photo by Patricia Nelson. It shows a well pad near Bella Romero Elementary School, Greeley, Colorado. Taken June 6, 2018.

Maps by Matt Kelso, FracTracker Alliance.

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Erratum: This report was corrected on pages i and 1 to state that the oil and gas wells in Colorado definitively known to have been injected with PFAS are located in 10 counties, with most of that use occurring in Weld County.

EXECUTIVE SUMMARY

Previously unpublicized information unearthed by Physicians for Social Responsibility (PSR) shows that a class of extremely toxic chemicals known as PFAS has been used in Colorado's oil and gas wells since at least 2008. However, gaps in Colorado's disclosure rules prevent the public from knowing how widely PFAS – or other toxic chemicals – have been used in oil and gas drilling and extraction. These findings raise concerns that Coloradans may unknowingly be exposed to highly hazardous substances.

PSR analyzed industry data recorded in FracFocus, the official repository for Colorado's oil and gas chemical disclosure, and found that PFAS have been used in Colorado wells, both for hydraulic fracturing ("fracking") and for a separate extraction technique called enhanced oil recovery. The affected wells are located in 10 Colorado counties, with most of that use occurring in Weld County.

However, the number of definitively identified cases of PFAS use may significantly underrepresent the extent of PFAS use in the state. That is in large part because Colorado law allows oil and gas companies to withhold fracking chemical identities from the public and regulators by claiming them as a "trade secret." Between 2011 and 2021, companies claimed trade secret privileges in more than 12,000 wells across 31 Colorado counties. Furthermore, oil and gas companies in the state are not required to publicly disclose chemicals used in other stages or methods of oil and gas extraction, including the drilling that precedes fracking.

By shielding from public view the chemicals injected into oil and gas wells, these disclosure gaps raise the potential that Coloradans may be exposed to PFAS and other toxic chemicals from hundreds or even thousands of wells.

PFAS have been linked to cancer, birth defects, pre-eclampsia, and other serious health effects. Toxic in minuscule concentrations, they are extremely mobile in groundwater and do not break down in the environment – hence their nickname, "forever chemicals."

Among our key findings are:

PFAS have been used in oil and gas extraction in Colorado. Records in FracFocus document that over the past decade, oil and gas companies used a PFAS known as polytetrafluoroethylene (PTFE), commonly known as Teflon, for hydraulic fracturing in Colorado oil and gas wells. Separately, in 2008, a peer-reviewed oil and gas industry journal showed that a type of PFAS called fluorosurfactants had been used in Colorado.

Trade secrets make it extremely difficult to determine how extensively PFAS (and other highly toxic chemicals) have been used in Colorado. The peer-reviewed journal referenced above said in 2008 that fluorosurfactants have been used for oil and gas extraction "for four decades." Separately, in 2020, a scientific paper indicated that PFAS mixtures known as fluorosurfactants have been used in oil and gas extraction globally since 1956. In a report PSR published in 2021, we found that between 2012 and 2020, oil and gas companies had used PFAS, most of them fluorosurfactants, for fracking in six states. Yet, in examining records for the slightly longer period 2011 to 2021, we found no reports of the use of fluorosurfactants in Colorado. This improbable absence may reflect oil and gas companies' extensive use of trade secret confidentiality claims. Of the 12,000 Colorado wells for which oil and gas firms withheld chemical identities as trade secrets over the past decade, more than 3,200 had been injected with chemicals identified as "surfactants." Some of these may be fluorosurfactants.

PFAS pollution at oil and gas wells in Colorado is possible wherever these substances have been used. Over the past decade, oil and gas companies have reported thousands of spills of chemicals and other fluids at oil and gas wells in Colorado, creating risks for groundwater and surface water pollution. Where PFAS chemicals are used, these spills may contain PFAS. Air emissions from flaring constitute another potential route of PFAS pollution from well sites. Coloradans should be allowed to know where they may be exposed to PFAS.

In light of these findings, PSR recommends the following:

- **Halt PFAS use in oil and gas extraction.** Colorado and EPA should prohibit PFAS from being used, manufactured, or imported for oil and gas extraction. Many PFAS are immediately replaceable with less persistent and less toxic substances, including in the oil and gas industry.

- **Expand public disclosure.** Colorado should greatly expand its requirements for public disclosure of oil and gas chemicals. The state could readily follow the example offered by California, a major oil producer that prohibits the use of trade secret claims for fracking chemicals. Colorado should also require disclosure of other chemicals used in oil and gas drilling and extraction, with no minimums placed on the weight or quantity of the chemicals to be disclosed. The state should also require disclosure from chemical manufacturers.

- **Increase testing and tracking.** Colorado and/or the Environmental Protection Agency should determine where PFAS have been used in oil and gas operations in the state and where related wastes have been deposited and should test nearby water, soil, flora, and fauna for PFAS.

- **Require funding and cleanup.** Oil and gas and chemical firms should be required to fund environmental testing and evaluation where these are needed, and should PFAS be found, also be required to fund cleanup. If water cleanup is impossible, the companies responsible for the use of PFAS should pay for alternative sources of water for drinking and agriculture, as needed.

- **Limit or ban drilling and fracking.** Given the use of highly toxic chemicals including PFAS in oil and gas extraction, Colorado and local governments should prohibit drilling, fracking, and disposal of related wastes in areas relatively unimpacted by oil and gas pollution and should increase protections in already-impacted regions. When doubt exists as to the existence or danger of contamination, the rule of thumb should be, "First, do no harm."

PFAS: A MANMADE THREAT TO HEALTH

Physicians for Social Responsibility (PSR) has identified evidence from industry sources that a highly dangerous class of chemicals, known as per- and polyfluoroalkyl substances (PFAS), as well as chemicals that could degrade into PFAS, known as PFAS precursors,* have been used in Colorado oil and gas wells** for hydraulic fracturing ("fracking") and enhanced oil recovery. The wells definitively known to have been injected with PFAS are located in 10 Colorado counties, with most of that use occurring in Weld County. However, the wells PSR was able to identify may significantly underrepresent the extent of PFAS use in the state.

PFAS are a class of thousands of manmade chemicals known for having properties that are valuable in multiple contexts, including being slippery, oil- and water-repellant, and able to serve as dispersants or foaming agents.[1] PFAS have been called "perfluorinated chemicals" and "polyfluorinated compounds," or PFCs, though the term currently preferred by EPA is PFAS.[2]

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.[3] Other PFAS chemicals have been used in food packaging, fire-fighting foam, and in 3M's widely used fabric protector, Scotchgard.[4]

EPA and other regulators have identified PFAS as a serious threat to health and the environment.[5] And as early as the 1960s and 1970s, researchers inside Dupont and 3M became aware that the PFAS they were manufacturing or using were associated with health problems including cancers and birth defects, had accumulated in virtually every human being, and persisted in the environment.[6] Many of these facts, kept internal by the companies, came to light after attorney Rob Bilott filed lawsuits in 1999 and 2001 accusing Dupont of causing pollution in and around Parkersburg, West Virginia with PFOA, a type of PFAS used in making Teflon.[7] 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 kidney cancer, testicular cancer, thyroid disease (over- or under-production of hormones by the thyroid gland), 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), and ulcerative colitis (a disease causing inflammation and ulcers in the large intestine or colon).[8]

*Throughout this report, when we refer to PFAS, the term includes PFAS and PFAS precursors.

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

PFAS: PERSISTENT IN THE ENVIRONMENT

PFAS are not only highly toxic; they also demonstrate extreme persistence in the environment. PFAS' nickname "forever chemicals" reflects their chemistry, in which hydrocarbon chains of carbon and hydrogen atoms are mixed with hydrofluoric acid. The fluorine atoms in the acid replace the hydrogen atoms in the hydrocarbon chains, forming a bond between fluorine and carbon that is among the strongest in chemistry and rarely if ever exists in nature. The result: chemicals that are extremely resistant to breaking down in the environment.[9]

The U.S. Environmental Protection Agency (EPA) reports that there are currently about 650 types of PFAS in commerce.[10] Weak chemical disclosure laws make it difficult for the Agency to identify which PFAS chemicals are used, and where, in the U.S. Yet evidence has mounted over the years of PFAS's risks and of cases of PFAS pollution from a variety of sources, including in Colorado. In 2019, the Denver Post reported that

> Colorado officials estimated more than 100,000 residents have relied on public drinking water systems where elevated PFAS levels have been detected in source wells — more people than in any other state.[11]

In fact, in 2020, PFAS were detected in every single surface water sample analyzed by the state's Department of Public Health and the Environment.[12]

Concern over PFAS pollution has led ten states, though not Colorado, to develop guidelines for concentrations in drinking water of several types of PFAS.[13] One of these states is Michigan, which set standards in 2020 for limiting PFAS in drinking water and for removing PFAS from groundwater. The standards applied to PFOA and six other forms of PFAS. Michigan's maximum allowable level is no more than eight parts per trillion for PFOA.[14] By extrapolation, these standards suggest that one measuring cup of PFOA could contaminate almost eight billion gallons of water – six times the 1.3 billion gallons of water used each day by New York City, or the amount of water needed to fill almost 12,000 Olympic-sized swimming pools at about 660,000 gallons per pool.[15] The extreme potency of PFOA, as with other PFAS, indicates why health experts are concerned about even minute quantities of these chemicals.

The use of PFAS in oil and gas production in Colorado has only recently been exposed.[16] The lack of full disclosure of chemicals used in oil and gas operations in Colorado raises the potential that PFAS may have been used more extensively than records indicate, both geographically and in additional methods or stages of oil and gas operations, such as drilling, that precede enhanced oil recovery and fracking.

COLORADO'S DISCLOSURE LAWS SHIELD DANGEROUS CHEMICALS

For years, scientists, advocates and regulators in Colorado and other states have raised concerns about the hundreds of industrial chemicals used in fracking of oil and gas wells including potential threats to water resources and health. The Fort Collins Coloradoan reported in 2014 that "fracking has become a polarizing issue in Colorado, in part due to the number of chemical ingredients that oil companies have kept secret from the public."[17] PSR's findings indicate these risks persist in alarming ways, despite rules enacted in 2012 that require public disclosure of fracking chemicals in Colorado.[18]

Colorado rules require that well operators disclose their fracking chemicals to FracFocus, a database maintained by the Groundwater Protection Council, a nonprofit comprised of regulators from state agencies, and the Interstate Oil and Gas Compact Commission, which represents governors of oil and gas-producing states as well as some oil-producing countries and the U.S. Department of the Interior.[19] Operators must disclose both the name of chemical products used in fracking, and each individual component chemical used in each product. They must also disclose each chemical's Chemical Abstracts Service (CAS) number, if available.[20] CAS numbers are unique numeric identifiers assigned to each chemical by the American Chemical Society. They are the most accurate way to identify chemicals, as a chemical can have multiple names or trade names but only one CAS number.[21]

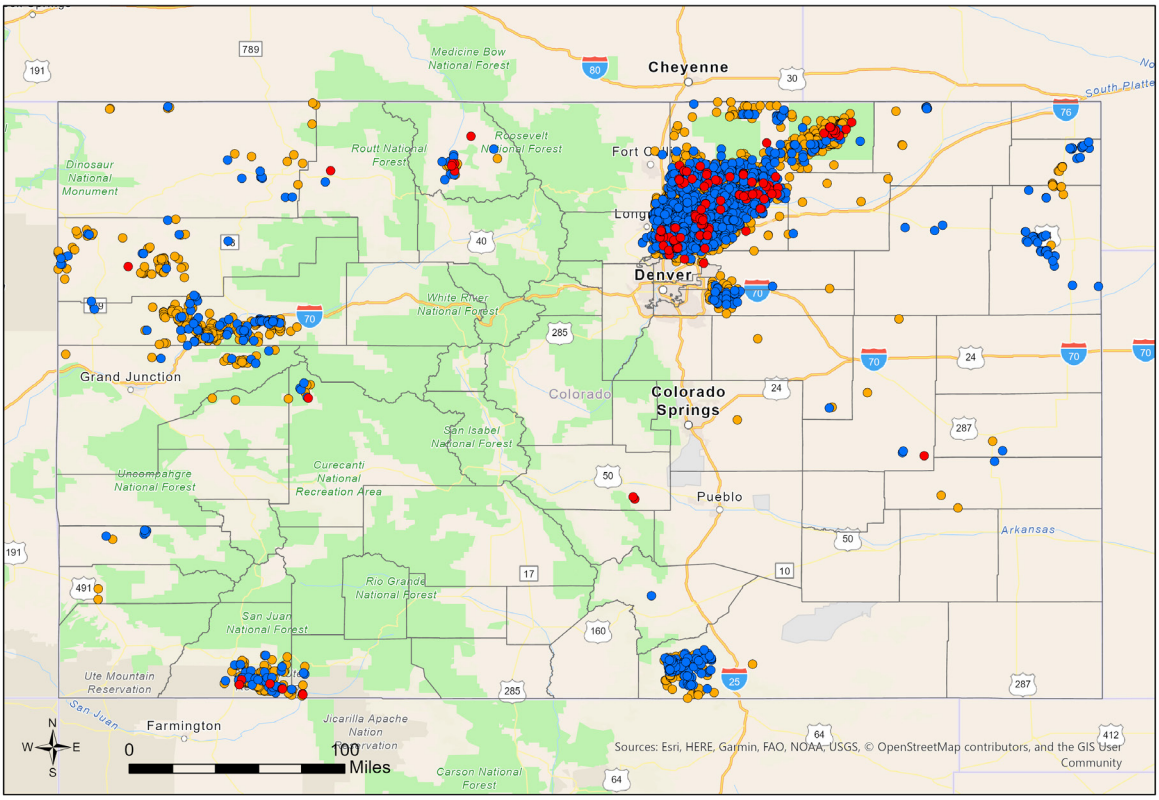
This system sounds effective on the face of it; however, an important exception allows companies to avoid full and meaningful disclosure: The law allows chemical manufacturers, well operators and other companies in the chemical supply chain to withhold exact fracking fluid ingredient information if they deem it a "trade secret."***[22] In place of a specific chemical identity, they must publicly disclose a chemical family or similar descriptor in place of the specific identity.[23] Regrettably, the use of a descriptor can hide from public view the true identity of dangerous chemicals. This legal loophole effectively undermines the public health benefits of disclosure by preventing health professionals, state regulators and the public from knowing where PFAS – or other toxic chemicals – have been used in oil and gas wells.

> "PSR's findings indicate these risks persist in alarming ways, despite rules enacted in 2012 that require public disclosure of fracking chemicals in Colorado."

In addition to allowing trade secret exemptions for fracking chemicals, Colorado does not require public disclosure of chemicals used in drilling, enhanced oil recovery, or other extraction techniques that are distinct from fracking per se. This regulatory gap increases the potential that Coloradans could unknowingly be exposed to PFAS and other chemicals used during the drilling phase and in other phases and methods of oil and gas extraction.[24] EPA has indicated that any chemicals used during the first stage of the drilling process would be highly likely to leach into groundwater since during this stage, drilling passes directly through groundwater zones[25] before any casing or cement is placed in the well to seal it off from surrounding aquifers. The resulting potential for groundwater contamination makes public disclosure of chemicals used in drilling especially important.

***Trade secret information is also called "proprietary" or "confidential business information" (CBI).

Colorado Oil & Gas Wells Fracked with PTFE and Trade Secret Chemicals, 2011-2021



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FRACTRACKER ALLIANCE

This map shows the disclosed use of PTFE/Teflon for use in fracking in Colorado. Wider use of PTFE and other PFAS in the state may be obscured by trade secrets in more than 12,000 wells. An interactive version of this map is available at https://www.psr.org/resources/colorado-pfas-map/.

FracFocus Data Reveal Use of PTFE, a PFAS Fluoropolymer, in Colorado

PSR's analysis of oil and gas industry data recorded in FracFocus show that companies have used polytetrafluoroethylene (PTFE), a class of PFAS known as a fluoropolymer, in Colorado oil and gas wells. Oil and gas companies reported using PTFE for fracking in 282 wells in the state, primarily in Weld County between 2012 and 2019. (See maps and tables above and on following pages. An interactive version of the statewide map is available at https://www.psr.org/resources/colorado-pfas-map/.) It is unclear for what purpose the PTFE was used; however, PTFE, which is marketed as Teflon, is known for its slipperiness, and fracking chemicals are sometimes used as friction reducers.[26]

PSR discovered the use of PTFE through use of the open-source version of FracFocus, Open-FF,[27] that is more accurate and informative than the original version of FracFocus.[28]

Fluoropolymers including PTFE are a type of plastic.[29] Scientists' and environmentalists' major concerns about PTFE and other fluoropolymers are not related so much to these substances themselves but rather are based on the associated impacts of their production, use, and disposal[30]: Highly toxic PFAS are used as production aids in the production of PTFE and other fluoropolymers. As was noted in a 2020 scientific paper, these other PFAS have included fluorosurfactants such as PFOA, which has been phased out as a manufacturing aid in the U.S. but is still used in Asia, and GenX, which is similarly harmful and has replaced PFOA in fluoropolymer production.[31] Fluoropolymers like PTFE can

contain these more toxic PFAS fragments as impurities, and release the compounds if they break down under heat or pressure.[32] 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.[33]

In addition, the authors noted that the persistence in the environment of PTFE and other fluoropolymers could pose problems during disposal. "Landfilling of fluoropolymers leads to contamination of leachates with PFAS and can contribute to release of plastics and microplastics," they wrote.[34] One of the authors added in an email to PSR that if PTFE were used in high-temperature oil and gas wells, it 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."[35]

In 2021, a coalition of environmental groups including the Center for Environmental Health, Clean Water Action, Ecology Center, Environmental Working Group, Natural Resources Defense Council, Safer States, and the Sierra Club shared similar concerns, based on multiple scientific articles, regarding the risks of fluoropolymers such as PTFE. The groups also noted that fluoropolymers are manufactured with chemicals that have an outsized negative effect on climate change.[36] Disclosure gaps in Colorado law discussed below may prevent scientists and the public from knowing the extent of PTFE use in oil and gas operations.

Curiously Absent: Disclosure of PFAS Fluorosurfactants in Colorado

Our analysis of data posted in FracFocus also examined the direct use of fluorosurfactants, sometimes called fluorinated surfactants, in fracking in Colorado. As indicated above, these substances that are used to manufacture PTFE are of even greater concern than PTFE itself. Fluorosurfactants are part of a larger group of chemicals known as "surfactants" that, according to EPA,

> lower the surface tension of a liquid, the interaction at the surface between two liquids (called interfacial tension), or that between a liquid and a solid. Surfactants may act as detergents, soaps, wetting agents, degreasers, emulsifiers, foaming agents and dispersants.[37]

Surfactants are commonly used in fracking.[38] 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."[39] Fluorosurfactants encompass PFOA, PFOS, and hundreds of other less-studied replacement chemicals and mixtures.[40] Some are known to be extremely toxic to people,[41] could be harmful to animals[42] and are expected to persist in the environment.[43]

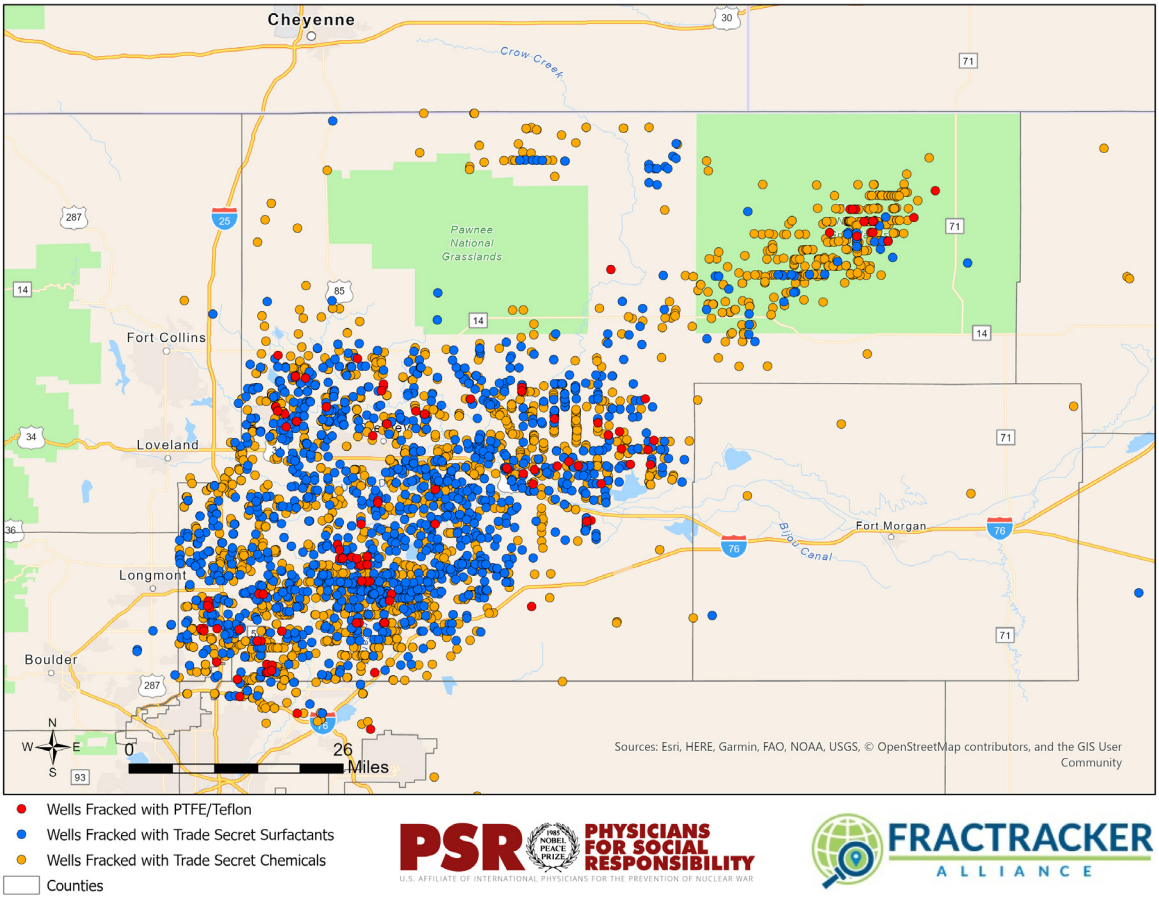
Evidence of fluorosurfactant use in Colorado is surprisingly spotty. In 2008, two authors, one of whom was identified as an employee at DuPont, wrote in the peer-reviewed Open Petroleum Engineering Journal that "cationic polymeric fluorosurfactants in methanol" were used for "enhanced oil recovery" in the state. (According to oilfield service company Schlumberger, enhanced oil recovery, or EOR, can involve injections of chemicals or carbon dioxide into underground formations as well as the use of steam to restore formation pressure and to improve displacement of oil or fluid flow in underground reservoirs.[44]) "This EOR technique using fluorosurfactants," the Open Petroleum Engineering Journal authors wrote,

> was employed at a well in Moffat County, Colorado from the Fort Union Sand Formation using methanol, 0.2 weight percent C10-12 alcohol ethoxylates, and 0.01 weight percent of a cationic polymeric fluorosurfactant. After treatment, the gas productivity increased from 100 million cubic feet (MCF) per day to 300 MCF per day.[45]

The authors suggested that the use of fluorosurfactants was relatively common in the oil and gas industry and that their use was about to surge. They referred to fluorosurfactants as an "emerging technology" and stated,

> 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.[46]

Weld County Oil & Gas Wells Fracked with PTFE and Trade Secret Chemicals, 2011-2021



Trade secret chemicals were widely used in Weld County. From 2011 to 2021, Weld County also showed the highest level among all Colorado counties of the use in fracking of the PFAS known as PTFE/Teflon.

The paper is consistent with a peer-reviewed article published in 2020 in Environmental Science: Processes and Impacts. In that article, the authors found evidence that since 1956, PFAS including fluorosurfactants had been used or proposed to be used globally in oil and gas extraction techniques including chemical-driven gas production, chemical flooding, fracking, and the drilling that precedes fracking and other oil and gas production techniques.[47] The paper on enhanced oil recovery and fluorosurfactants is also consistent with PSR's findings published in July 2021 which found that between 2012 and 2020, oil and gas companies used PFAS in fracking in more than 1,200 wells in six states. Most were fluorosurfactants.[48]

Yet despite evidence of widespread and longstanding use of fluorosurfactants in oil and gas extraction, PSR did not find further evidence of their use in Colorado beyond the single gas well in Moffat County, despite searching in Open-FF and other online sources. This surprising lack of evidence, as is discussed below, may be due to the significant gaps in reporting requirements for the oil and gas industry in Colorado, rather than to lack of use of fluorosurfactant chemicals.

Extensive Use of 'Trade Secret' Claims Veils Actual Use

The lack of evidence of additional use of PFAS in Colorado's oil and gas wells reflects, at least in part, extensive application of the trade secret provisions in Colorado's chemical disclosure rules. PSR's data analysis revealed that, between 2011 and 2021, Colorado well operators claimed at

least one fracking chemical as a trade secret in 12,623 oil and gas wells. Of these, 9,210 (73 percent) were in Weld County and 2,079 (16.5 percent) were in Garfield County. The trade secret chemicals used in Colorado over this 10-year period totaled almost 414 million pounds.[49] (See Table 1, next page.) If even a small fraction of this weight were PFAS, that fraction could pose significant health and environmental risks.

Non-disclosure provisions made it impossible to determine if any of these trade secret chemicals were PFAS. In an effort to do so, PSR examined whether any were listed as a surfactant, which could indicate that the chemicals were fluorosurfactants. We found thousands of cases of oil and gas companies using at least one trade secret chemical that was listed as a surfactant. These occurred in 3,221 wells, the majority of which (2,589) were in Weld County.[50] (See Table 1, next page.) Operators' names for these chemicals were vague, including "surfactant," "amphoteric surfactant," and "proprietary surfactant." These trade secret surfactants totaled almost 12 million pounds. (See examples from individual wells in Table 2.)

Companies using trade secret surfactants include prominent oil and gas producers. Among them are Anadarko Petroleum Corp., the co-owner along with BP of the Macondo well that spewed millions of gallons of oil into the Gulf of Mexico in 2010,[51] and Encana Corp., once one of Canada's largest oil companies until it moved its corporate headquarters to the U.S. in 2020 and changed its name to Ovintiv.[52] (See Table 3.)

Spills at Colorado Wells Raise Pollution Concerns

When PFAS are used at oil and gas well sites, there is a real risk that they could impact health and the environment, due to the thousands of spills and hundreds of cases of associated pollution that have been documented at oil and gas well sites in Colorado and other states.[53] According to an analysis by the Center for Western Priorities, state data from 2012-2020 showed that oil and gas producers in Colorado reported 4,928 spills – an average of more than 1.5 spills per day.[54] The type of fluids spilled included wastewater or "produced water" that flows out of oil and gas wells from underground formations during production; oil; condensate (a naturally occurring hydrocarbon); "other" fluids; drilling fluid, and flowback or the fracking fluid that flows out of the well after fracking.[55] At least some of these fluids could contain PFAS if PFAS were used in those wells, posing risks to groundwater or surface water.

The evidence on spills in Colorado is significant in light of EPA's findings in its 2016 national report on fracking and drinking water. The agency found that fracking-related pollution could follow a number of pathways, including:

- 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 (much of the fracking fluid can remain underground);
- 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.[56]

Where PFAS are used at oil and gas sites, they could enter water supplies through one or more of these pathways, thus placing drinking water and agricultural water sources at risk. In addition, in PSR's July 2021 report, toxicologist Dave Brown, former director of environmental epidemiology at the Connecticut Department of Health, noted that PFAS used in oil and gas wells could follow airborne exposure routes. He warned that if PFAS were to enter drinking water, it could subsequently volatilize or become airborne inside homes. Brown also added another potential pathway for airborne exposure: PFAS could become airborne when gas is burned off during flaring at the wellhead.[57]

PFAS Use Could Compound Health Harms from Other Oil and Gas Chemicals

PFAS is by no means the only chemical associated with oil and gas extraction that could cause harm to health. Deeper investigation of PFAS use in oil and gas operations is especially important because exposure to PFAS may be additional to, and could impact or intensify, health effects from those other chemicals.

TABLE No.1 – Disclosed Use of Trade Secret Chemicals and PFAS in Fracking in Colorado Oil and Gas Wells, 2011-2021

County Name	Number of wells with at least one trade secret chemical	Mass of all trade secret chemicals (lbs.)*	Number of wells with trade secret surfactants	Mass of trade secret surfactants (lbs.)*	Number of wells using PTFE	Mass of PTFE (lbs.)*
Adams	231	12,970,690	42	671,214	3	266
Arapahoe	87	4,557,047	28	93,502	0	0
Archuleta	7	7,691	2	88	2	No data available
Boulder	9	37,744	9	10,726	0	0
Broomfield	31	1,375,502	3	3,081	0	0
Cheyenne	2	1,218	1	1,106	0	0
Delta	3	183,751	0	0	0	0
Dolores	2	5,347	0	0	0	0
El Paso	1	60,818	0	0	0	0
Elbert	3	6,655	1	No data available	0	0
Fremont	2	No data available	0	0	2	No data available
Garfield	2,079	15,973,557	268	241,979	0	0
Gunnison	8	251,243	4	38,112	1	No data available
Huerfano	1	22,940	1	3,976	0	0
Jackson	53	3,494,710	29	56,624	6	765
Kiowa	3	5,926	1	1,429	0	0
La Plata	168	192,770	41	6,165	5	5
Larimer	98	4,254,325	6	15,408	0	0
Las Animas	163	65,941	83	27,255	0	0
Lincoln	5	33,562	2	15	1	No data available
Logan	9	2,219	6	771	0	0
Mesa	115	585,750	12	48,934	0	0
Moffat	24	591,243	10	12,342	0	0
Morgan	2	8,452	0	0	0	0
Phillips	23	6,598	15	6,328	0	0
Rio Blanco	226	934,129	21	8,989	2	No data available
Routt	2	7,760	1	211	1	21
San Miguel	10	23,590	9	3,136	0	0
Washington	3	645	3	645	0	0
Weld	9,210	368,255,921	2,589	10,693,593	259	7,840
Yuma	43	5,926	34	5,019	0	0
Total *	12,623	413,923,683	3,221	11,950,659	282	8,900

This table, based on FracFocus data, shows county-by-county the number of Colorado wells in which oil and gas companies injected at least one trade secret fracking chemical, and some of our specific findings. The total mass figures reflect the sum of all records for which we have enough information to calculate a chemical's mass. However, the total mass figures represent an undercount because many fracking chemical disclosures lack sufficient data to perform this calculation.

TABLE No.2 – Examples of Individual Oil and Gas Wells

Well Operator	Well Number	County	Year Fracking Completed	Chemical used in Well	CAS Number	Trade Name	Mass (lbs.)
Bayswater Exploration & Production, LLC	05123401900000	Weld	2021	surfactant	proprietary	Not reported	7,242
Bonanza Creek Energy, Inc.	05123450640000	Weld	2019	amphoteric surfactant	proprietary	Not reported	34,581
Anadarko Petroleum Corporation	05123426300000	Weld	2017	ethoxylated alcohol	proprietary	SFT-82	11,149
SandRidge Energy	05057065530000	Jackson	2016	PTFE	9002-84-0	Not reported	127
TEP Rocky Mountain, LLC	05045225960000	Garfield	2016	nonionic surfactant	proprietary	TFR-0102	107

This table shows a sample of specific wells injected with the types of fracking chemicals referenced in the larger table above: trade secret chemicals such as the "ethoxylated alcohol," trade secret surfactants such as the "amphoteric surfactant," and PTFE. We selected the examples to cover a range of years and to represent wells fracked in the two Colorado counties with the most oil and gas extraction: Garfield and Weld. Even the smallest mass shown, 107 pounds for a proprietary nonionic surfactant, would be a significant amount of PFAS if this proprietary chemical were PFAS.

TABLE No.3 – Oil and Gas Companies that Fracked the Most Wells in Colorado with Trade Secret Surfactants, 2011-2021

Well Operator	Number of wells with trade secret surfactants	Total mass (lbs.)*
Anadarko Petroleum Corporation	718	4,660,036
Noble Energy, Inc.	694	1,737,766
Encana Oil & Gas (USA) Inc.	266	1,220,224
Great Western Oil & Gas Company, LLC	208	305,944
PDC Energy	147	346,970
Bill Barrett Corp.	128	320,347
Bonanza Creek Energy, Inc.	124	512,514
Bayswater Exploration & Production, LLC	97	289,736
Synergy Resources Corporation	79	152,788
HighPoint Operating Corporation	66	36,938
TEP Rocky Mountain, LLC	65	8,726
Pioneer Natural Resources	58	23,661
Caerus Oil and Gas, LLC	54	50,706
Laramie Energy, LLC	39	No data available
SRC Energy	39	8,953

This table shows the fifteen oil and gas companies that fracked the most oil and gas wells in Colorado with trade secret surfactants between 2011 and 2021. Surfactants may be more likely to be PFAS than other trade secret chemicals because of the widespread use in oil and gas wells of PFAS known as fluorosurfactants.

In 2016, EPA published a study that 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 173 of these chemicals, that information was troubling. EPA found that

> health effects associated with chronic oral exposure to these chemicals include carcinogenicity [for benzene and radium], neurotoxicity, immune system effects, changes in body weight, changes in blood chemistry, liver and kidney toxicity, and reproductive and developmental toxicity.[58]

Chemicals used in the drilling stage that precedes fracking can also pose health risks, including developmental toxicity and the formation of tumors, according to EPA regulators.[59] A disclosure form filed with the state of Ohio, perhaps the only state to require disclosure of drilling chemicals, shows that Statoil, Norway's state oil company (since renamed Equinor), has used a neurotoxic chemical, xylene, in drilling.[60]

Frye Farms well pad in Windsor, CO. October 30, 2021. By permission of the photographer.

Chemicals used in oil and gas operations have been found to be associated with harms to human health. Peer-reviewed studies of people living near oil and gas operations in Colorado and other states have found that proximity to active well sites correlates with a variety of diseases and other health effects. A 2019 study in the journal Environment International examined 3,324 babies born in Colorado between 2005 and 2011 and found that, compared with control groups, congenital heart defects were 1.4 and 1.7 times more likely in babies born to mothers in areas of medium and high unconventional gas drilling, respectively.[61] A 2017 study in PLOS One of Coloradans between birth and 24 years old diagnosed with cancer between 2000 and 2013 found that those between the ages of five and 24 were more than four times more likely to live in areas of heavy oil and gas drilling, compared to controls.[62]

On a national scale, PSR and Concerned Health Professionals of New York have collaborated to compile and summarize the substantial and growing number of scientific studies that have found serious health effects associated with oil and gas drilling. In the seventh edition (2020), they wrote,

> Public health problems associated with drilling and fracking include poor birth outcomes, respiratory impacts, cancer, heart disease, and mental health problems. Poor birth outcomes have been linked to fracking activities in multiple studies in multiple locations using a variety of methodologies. Studies of mothers living near oil and gas extraction operations consistently find impairments to infant health, especially elevated risks for low birth weight and preterm birth. [63]

Low birthweight is a leading contributor to infant death in the United States.[64]

The Southwest Pennsylvania Environmental Health Project[65] and the Pennsylvania-based FracTracker Alliance[66] have also examined studies of health impacts of unconventional oil and gas development and reached similar conclusions.

In addition to the findings in peer-reviewed studies, residents living near oil and gas operations have anecdotally reported experiencing illnesses that they believe are related to chemical exposures. Many residents have also expressed frustration over the secrecy surrounding chemicals used by the oil and gas industry.[67] In 2020, Pennsylvania's Attorney

General issued a report based on a criminal grand jury investigation of oil and gas drilling pollution in the Keystone State. In that state, drilling for gas in shale formations has surged over the past 15 years,[68] vaulting Pennsylvania into the number two spot among gas-producing states (Texas is number one)[69] and bringing many more Pennsylvanians into contact with gas drilling and its impacts. Based on testimony from over 70 households, the attorney general found that

> Many of those living in close proximity to a well pad began to become chronically, and inexplicably, sick. Pets died; farm animals that lived outside started miscarrying, or giving birth to deformed offspring. But the worst was the children, who were most susceptible to the effects. Families went to their doctors for answers, but the doctors didn't know what to do. The unconventional oil and gas companies would not even identify the chemicals they were using, so that they could be studied; the companies said the compounds were "trade secrets" and "proprietary information." The absence of information created roadblocks to effective medical treatment. One family was told that doctors would discuss their hypotheses, but only if the information never left the room.[70]

Fracking and Chemical Exposure as an Environmental Justice Issue

"Fenceline" communities – people living very close to oil and gas operations – often bear a disproportionate risk of exposure to toxic chemicals and may be particularly at risk from PFAS used in oil and gas extraction. Although drilling and fracking take place in the majority of U.S. states, not everyone shares in that risk equally. Rather, oil and gas infrastructure and associated chemicals are frequently located in or adjacent to poor, underserved, and marginalized communities, Indigenous communities, and other communities of color. For example, a 2019 analysis conducted in Colorado, Oklahoma, Pennsylvania, and Texas found strong evidence that people of color disproportionately lived near fracking wells. [71] Where a pattern of risks affects people of color disproportionately, fracking should be viewed as an Environmental Justice issue.

One such issue may have occurred in 2018 in Greeley, Colorado, where an oil and gas company built a massive well pad housing 24 wells near Bella Romero Academy, an elementary school in a low-income community where 82 percent of students were Latino, after abandoning an earlier plan to drill the wells near a charter school where most students were white and middle-class. A company spokesperson denied that the wells were located near Bella Romero Academy because of the racial background of the school's students.[72,73] An analysis of state data showed that in 2019, airborne benzene levels near the school exceeded health-based limits 113 times, including spikes during four full school days.[74] Benzene is a known cause of leukemia.[75]

With Lax EPA Regulation, States Will Have to Address PFAS

Colorado and other state governments will likely have to take the lead in addressing PFAS pollution, whether from oil and gas operations or other sources. State action will be necessary because EPA has taken only modest steps to protect the public. In 2005, EPA reached a then-record $16.5 million settlement with 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.[76] 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 phase out emissions and use of these chemicals by 2015.[77] In 2021, EPA says 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.[78] 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.[79] 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.[80]

In October 2021, EPA announced a "strategic roadmap" for regulating PFAS that encompasses a goal to set 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."[81] The plan does not 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.[82] The month before, PSR asked EPA to collect data on PFAS use in oil and gas extraction, utilizing its authority under TSCA.[83])

EPA's record of lax regulation suggests that at least in the short term, state and local governments will have to play leading roles to protect the public from these dangerous chemicals. In addition, 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 under the Resource Conservation and Recovery Act. These exemptions also place the burden on state governments to address any PFAS pollution associated with oil and gas extraction.[84] State and local governments should draw on growing research about PFAS' risks to better regulate these dangerous chemicals. Among the recent published papers is a peer-reviewed analysis showing that many PFAS are immediately replaceable with less persistent and less toxic substances, including in the oil and gas industry.[85]

COLORADO DISCLOSURE RULES: IN NEED OF SWEEPING REFORM

To protect human health and the environment, multiple reforms are needed in Colorado's disclosure rules. Besides reforming the overly generous trade secret provisions, the state should address multiple exemptions that allow the oil and gas industry to maintain a veil of secrecy over its use of dangerous chemicals.

One such reform should involve requiring public disclosure of all chemicals used in oil and gas extraction, not just those used in fracking. Currently, Colorado requires well operators to compile inventories of at least some chemical products used in techniques other than fracking, but these provisions do not require public disclosure or provide a way for the public to access the information. Well operators are required to maintain Material Safety Data Sheets (MSDS), which originate with chemical manufacturers and indicate health and physical hazards (e.g. flammability) of a chemical product.[86] Between 2009 and 2020, Colorado required that companies maintain MSDS documents for chemical products "brought to a well site for use downhole during drilling, completion, and workover operations…."[87] (The term "workover operations" refers to the repair or stimulation of an existing production well for the purpose of restoring, prolonging or enhancing the production of gas or oil.[88]) These records had to be kept on file and available for inspection by the Colorado Oil and Gas Conservation Commission – but not by the public – for at least five years.[89]

Since 2009, Colorado has also required oil and gas companies to maintain an inventory of chemical products (including MSDS, since 2021 called Safety Data Sheets) used downhole at each well site.[90] The inventory applies to any chemical product in use or in storage at a well site in an amount greater than 500 pounds of cumulative maximum weight of the product present at the site during a quarterly reporting period.[91] The companies must maintain this list "in a readily retrievable format at the Operator's local field office"[92] and must keep it for five years after plugging and abandonment of the associated well or following closure of an associated oil and gas site.[93]

Access to these records is limited, as they are held by well operators, not the state. Therefore, they are not public records that would otherwise be subject to the Colorado Freedom of Information Act which defines "public records" in part as "all writings made, maintained, or kept by the state…."[94] The only explicit scenarios under the rules in which people other than oil and gas companies can access these records apply to government officials, emergency responders, and health professionals.[95] A physician, physician assistant, nurse practitioner, registered nurse, or emergency medical technician licensed by the State of Colorado has the right to these records for the purpose of diagnosis or treatment of someone who may have been exposed to a chemical used at an oil and gas site.[96] Emergency responders and other government officials may request the chemical information in defined circumstances including "as a result of a spill or release, a complaint from a potentially adversely Affected Person, or when necessary to protect and minimize adverse impacts to public health, safety, welfare, the environment, and wildlife resources."[97] The specific names of chemical products and/or constituents of these products listed in a chemical inventory or covered by an MSDS can be withheld as trade secrets.[98]

Another impediment to the public's right to know is that individual PFAS are not commonly listed on MSDS. This is the case even in products such as firefighting foam in which PFAS may be a major ingredient.[99] Therefore, even if the public could access records related to oil and gas chemicals used in Colorado, the records might not show that PFAS were being used at well sites when, in fact, they were. The omission of PFAS from MSDS may be related to MSDS rules that, according to Harvard researchers, require listing only of "hazardous" chemicals that have been studied for workplace exposure.[100] If PFAS have not been studied for such exposure, then manufacturers would not have to list them. The same researchers noted that federal regulations state that "there is no requirement to test the chemical to determine how to classify its hazards." Instead, chemical manufacturers can rely on existing scientific literature.[101] If the literature did

not establish hazards associated with particular PFAS, these substances would not have to be listed on an MSDS. Finally, if a chemical product containing PFAS were used at a well in quantities weighing less than 500 pounds, it would not have to be reported on the chemical inventory.[102] Colorado should amend its rules to require disclosure of all individual chemicals used in oil and gas extraction, with no exceptions for trade secrets and no minimums placed on the weight or quantity of the chemicals to be disclosed. The public needs a full accounting of chemicals used at well sites.

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 lack of information on chemical identities for scientists, regulators, and the general public.

California has produced more oil than Colorado over the past five years[103] and also began requiring full disclosure of fracking chemicals, without trade secret exemptions for individual chemical constituents, in 2015.[104] The methodology utilized in California is consistent with a recommendation issued in 2014 by an advisory panel to the U.S. Department of Energy.[105] The panel suggested that fracking chemicals injected into each well should be disclosed in a random-order list in which the chemicals are listed but disassociated from the trade name of the commercial products they are part of. This form of disclosure would enable the public to know all the chemicals used in fracking without disclosing to rival chemical manufacturers the exact components of any proprietary formulas.[106] California also has a process where state regulators review secrecy requests from chemical companies to determine whether the information must be kept proprietary.[107] Health and safety data related to fracking fluids are not allowed to be kept from the public.[108]

Colorado should also ensure that full chemical disclosure is required from all of the companies in the chemical supply chain, including especially the chemical manufacturers. Currently, Colorado rules require chemical disclosure only from companies further down the supply chain, such as well operators, service providers, and vendors.[109] Chemical manufacturers are implicitly exempted, despite being the only entity that always knows the contents of the chemicals they produce. Evidence suggests that chemical manufacturers do not always tell companies further down the supply chain the full contents of the chemical products they are using; rather, they provide these companies with vague descriptions, generic chemical family names, or MSDS with an incomplete list of chemicals.[110] In such cases, the end users may legitimately be unable to disclose all the identities of chemicals used at a particular well – including PFAS – whether under trade secret protection or not. They simply would not have the information. Requiring disclosure of oil and gas chemicals from chemical manufacturers would avoid this problem.

RECOMMENDATIONS

In light of these findings, PSR recommends the following:

- **Halt PFAS use in oil and gas extraction.** Colorado and EPA should prohibit PFAS from being used, manufactured, or imported for oil and gas extraction. Many PFAS are immediately replaceable with less persistent and less toxic substances, including in the oil and gas industry.

- **Expand public disclosure.** Colorado should greatly expand its requirements for public disclosure of oil and gas chemicals. The state could readily follow the example offered by California, a major oil producer that prohibits the use of trade secret claims for fracking chemicals. Colorado should also require disclosure of other chemicals used in oil and gas drilling and extraction, with no minimums placed on the weight or quantity of the chemicals to be disclosed. The state should also require disclosure from chemical manufacturers.

- **Increase testing and tracking.** Colorado and/or the Environmental Protection Agency should determine where PFAS have been used in oil and gas operations in the state, and where related wastes have been deposited and should test nearby water, soil, flora, and fauna for PFAS.

- **Require funding and cleanup.** Oil and gas and chemical firms should be required to fund environmental testing and evaluation where these are needed, and should PFAS be found, also be required to fund cleanup. If water cleanup is impossible, the companies responsible for the use of PFAS should pay for alternative sources of water for drinking and agriculture, as needed.

- **Limit or ban drilling and fracking.** Given the use of highly toxic chemicals including PFAS in oil and gas extraction, Colorado and local governments should prohibit drilling, fracking, and disposal of related wastes in areas relatively unimpacted by oil and gas pollution and should increase protections in already-impacted regions. When doubt exists as to the existence or danger of contamination, the rule of thumb should be, "First, do no harm."

ENDNOTES

[1] U.S. Environmental Protection Agency. Research on Per- and Polyfluoroalkyl Substances (PFAS) (last updated Nov. 10, 2021). Accessed Dec. 20, 2021 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 Jan. 12, 2022, 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 Jan. 12, 2022, at https://pubs.acs.org/doi/pdf/10.1021/es2011622.

[2] U.S. Environmental Protection Agency. What are PFCs and How Do They Relate to Per- and Polyfluoroalkyl Substances (PFASs)? (Jan. 19, 2017). Accessed Jan. 12, 2022, 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 Jan. 12, 2022, at https://pubs.acs.org/doi/pdf/10.1021/es2011622.

[3] David Andrews and Bill Walker. Environmental Working Group. Poisoned Legacy (April 2015), at 6. Accessed Jan. 12, 2022, 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 Jan. 12, 2022, 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 Jan. 12, 2022, at https://pubs.acs.org/doi/pdf/10.1021/es2011622.

[4] David Andrews and Bill Walker. Environmental Working Group. Poisoned Legacy (April 2015), at 6. Accessed Jan. 12, 2022, 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 Jan. 12, 2022, at https://pubs.acs.org/doi/pdf/10.1021/es2011622.

[5] U.S. Environmental Protection Agency. PFAS Strategic Roadmap: EPA's Commitments to Action 2021-2024 (Oct. 21), at 5. Accessed Jan. 12, 2022, at https://www.epa.gov/system/files/documents/2021-10/pfas-roadmap_final-508.pdf.

[6] David Andrews and Bill Walker. Environmental Working Group. Poisoned Legacy (April 2015), at 6-8. Accessed Jan. 12, 2022, 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 Jan. 12, 2022, at https://www.nytimes.com/2016/01/10/magazine/the-lawyer-who-became-duponts-worst-nightmare.html?searchResultPosition=1.

[7] David Andrews and Bill Walker. Environmental Working Group. Poisoned Legacy (April 2015), at 8, 23. Accessed Jan. 12, 2022, 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 Jan. 12, 2022, at https://www.nytimes.com/2016/01/10/magazine/the-lawyer-who-became-duponts-worst-nightmare.html?searchResultPosition=1.

[8] Nathaniel Rich. The Lawyer Who Became Dupont's Worst Nightmare. New York Times Magazine (Jan. 6, 2016). Accessed Jan. 12, 2022, at https://www.nytimes.com/2016/01/10/magazine/the-lawyer-who-became-duponts-worst-nightmare.html?searchResultPosition=1. Cleveland Clinic. Thyroid Disease. Accessed Jan. 12, 2022, at https://my.clevelandclinic.org/health/diseases/8541-thyroid-disease. Graham J. Burton et al. Pre-eclampsia: Pathophysiology and Clinical Implications. National Library of Medicine. PubMed.gov (July 15, 2019). Accessed Oct.18, 2020 at https://pubmed.ncbi.nlm.nih.gov/31307997/. Mahesh Gajendran et al. A Comprehensive Review and Update on Ulcerative Colitis (March 2, 2019). National Library of Medicine. PubMed.gov. Accessed Jan. 12, 2022, at https://pubmed.ncbi.nlm.nih.gov/30837080/.

[9] Andrew B. Lindstrom et al. Polyfluorinated Compounds: Past, Present, and Future. Environmental Science & Technology (2011), 45, 7954-7961, 7956. Accessed Jan. 12, 2022, 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 Jan. 12, 2022, 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 Jan. 12, 2022, at https://news.okstate.edu/articles/arts-sciences/2018/professors-startup-turns-research-into-real-world-solutions.html.

[10] U.S. Environmental Protection Agency. PFAS Strategic Roadmap: EPA's Commitments to Action 2021-2024 (Oct. 21), at 23. Accessed Jan. 12, 2022, at https://www.epa.gov/system/files/documents/2021-10/pfas-roadmap_final-508.pdf.

[11] Bruce Finley. Colorado ramps up response to toxic "forever chemicals" after discovery of hot spots across metro Denver. The Denver Post (Sept. 10, 2019). Accessed Jan. 12, 2022, at https://dpo.st/3nRyplL.

[12] Colorado Department of Health and the Environment. 2020 PFAS Sampling Project Results Surface Water Summary. Accessed Jan. 12, 2022, at https://bit.ly/3xMRnOJ.

[13] Gloria B. Post. Recent U.S. State and Federal Drinking Water Guidelines for Per- and Polyfluoroalkyl Substances. Environmental Toxicology and Chemistry (Aug. 26, 2020). Accessed Jan. 12, 2022, at https://setac.onlinelibrary.wiley.com/doi/10.1002/etc.4863.

[14] Michigan Department of Environment, Great Lakes, and Energy. Michigan Adopts Strict PFAS in Drinking Water Standards. News Release (July 22, 2020). Accessed Jan. 12, 2022, at https://www.michigan.gov/egle/0,9429,7-135--534660--,00.html. Keith Matheny. Michigan's Drinking Water Standards for These Chemicals Now Among Toughest in the Nation. Detroit Free Press (Aug. 3, 2020). Accessed Jan. 12, 2022, at https://www.freep.com/story/news/local/michigan/2020/08/03/tougher-pfas-standards-drinking-water-michigan/5574268002/.

[15] New York City. Environmental Protection. History of New York City Drinking Water (2021). Accessed Jan. 12, 2022, at https://www1.nyc.gov/site/dep/water/history-of-new-york-citys-drinking-water.page. Tim Buckland. Toxic GenX: Defining Parts Per Trillion. Wilmington (N.C.) Star News (August 18, 2017). Accessed Jan. 12, 2022, at https://www.starnewsonline.com/news/20170818/what-does-140-parts-per-trillion-look-like.

[16] Public Employees for Environmental Responsibility. Revealed: EPA Data on PFAS Sites (Oct. 17, 2021). Accessed Jan. 12, 2022, at https://www.peer.org/blog-revealed-epa-data-on-potential-pfas-sites/.

[17] Ryan Maye Handy. Company to Disclose 'Secret' Fracking Chemicals. The Coloradoan (April 25, 2014). Accessed Dec. 2, 2021, at https://www.coloradoan.com/story/news/0001/01/01/company-disclose-secret-fracking-chemicals/8174677/.

[18] 2 CCR 404-1. Series 200 § 205A (applying to hydraulic fracturing treatments occurring on or after April 1, 2012).

[19] 2 CCR 404-1. Series 100. Definitions. Chemical Disclosure Registry. Series 200 § 208 (c) (an updated rule taking effect on Jan. 15, 2021). Series 200 § 205A (applying to hydraulic fracturing treatments occurring on or after April 1, 2012).

[20] 2 CCR 404-1. Series 100. Definitions. Chemical Disclosure Registry. Series 200 § 208 (c) (an updated rule taking effect on Jan. 15, 2021). Series 200 § 205A (applying to hydraulic fracturing treatments occurring on or after April 1, 2012).

[21] FracFocus. Chemical Names & CAS Registry Numbers. Accessed Jan. 12, 2022, at https://www.fracfocus.org/index.php/explore/chemical-names-cas-registry-numbers. American Chemical Society. CAS Registry. Accessed Jan. 12, 2022, at https://bit.ly/3nnGpv4.

[22] 2 CCR 404-1. Series 200 § 208 (b) (rule taking effect on Jan. 15, 2021). State of Colorado Oil and Gas Conservation Commission. Form 41. Trade Secret Claim of Entitlement. Accessed Jan. 12, 2022, at https://cogcc.state.co.us/forms/PDF_Forms/Form41_05312012.pdf.

[23] 2 CCR 404-1. Series 200 § 208 (c) (an updated rule taking effect on Jan. 15, 2021). Series 200 § 205A(b)(2)(B) (applying to hydraulic fracturing treatments occurring on or after April 1, 2012). Colorado's Form 41, Trade Secret Claim of Entitlement, shows that well owners can withhold chemical identities as trade secrets not just from the public, but from regulators, too. Accessed Jan. 12, 2022, at https://cogcc.state.co.us/forms/PDF_Forms/Form41_05312012.pdf.

[24] 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 Jan. 12, 2022, at https://pubs.rsc.org/en/content/articlelanding/2020/em/d0em00291g#!divAbstract.

[25] 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. Accessed Oct. 16, 2020, at https://www.epa.gov/hfstudy.

[26] 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 Jan. 12, 2022, at https://www.epa.gov/hfstudy.

[27] Gary Allison (2021) Open-FF: Transforming the FracFocus Disclosure Data into a Usable Resource [Source Code]. Accessed Jan. 12, 2022, at https://doi.org/10.24433/CO.1058811.v10.

[28] Gary Allison (2021) Open-FF: Transforming the FracFocus Disclosure Data into a Usable Resource [Source Code]. Accessed Jan. 12, 2022, at https://doi.org/10.24433/CO.1058811.v10.

[29] Safer States et al. PFAS polymers pose serious health and environmental threats. Accessed Jan. 12, 2022, at https://www.nrdc.org/sites/default/files/pfas-polymer-fs.pdf.

[30] 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 Jan. 12, 2022, at https://pubs.acs.org/doi/10.1021/acs.est.0c03244. Safer States et al. PFAS polymers pose serious health and environmental threats. Accessed Jan. 12, 2022, at https://www.nrdc.org/sites/default/files/pfas-polymer-fs.pdf.

[31] 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, 12822. Accessed Jan. 12, 2022, at https://pubs.acs.org/doi/10.1021/acs.est.0c03244.

[32] 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 Jan. 12, 2022, at https://pubs.acs.org/doi/10.1021/acs.est.0c03244.

[33] 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 Jan. 12, 2022, at https://pubs.acs.org/doi/10.1021/acs.est.0c03244.

[34] 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 Jan. 12, 2022, at https://pubs.acs.org/doi/10.1021/acs.est.0c03244.

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

[36] Safer States et al. PFAS polymers pose serious health and environmental threats. Accessed Jan. 12, 2022, at https://www.nrdc.org/sites/default/files/pfas-polymer-fs.pdf.

[37] U.S. Environmental Protection Agency. Criteria for Biodegradability Claims on Products Registered under FIFRA. Accessed Mar. 30, 2021, at https://www.epa.gov/pesticide-labels/criteria-biodegradability-claims-products-registered-under-fifra.

[38] 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 Jan. 12, 2022, at https://www.epa.gov/hfstudy.

[39] 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 Jan. 12, 2022, at https://www.ncbi.nlm.nih.gov/pmc/articles/PMC3214619/pdf/ieam0007-0513.pdf.

[40] 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 Jan. 12, 2022, at https://www.ncbi.nlm.nih.gov/pmc/articles/PMC3214619/pdf/ieam0007-0513.pdf.

[41] Gloria B. Post. Recent U.S. State and Federal Drinking Water Guidelines for Per- and Polyfluoroalkyl Substances. Environmental Toxicology and Chemistry (Aug. 26, 2020). Accessed Jan. 12, 2022, at https://setac.onlinelibrary.wiley.com/doi/10.1002/etc.4863. The Lawyer Who Became Dupont's Worst Nightmare. New York Times Magazine (Jan. 6, 2016). Accessed Jan. 12, 2022, at https://www.nytimes.com/2016/01/10/magazine/the-lawyer-who-became-duponts-worst-nightmare.html?searchResultPosition=1.

[42] U.S. Environmental Protection Agency. PFAS Explained (last updated Oct. 18, 2021). Accessed Jan. 12, 2022 at https://www.epa.gov/pfas/pfas-explained.

[43] U.S. Environmental Protection Agency. PFAS Explained (last updated Oct. 18, 2021). Accessed Jan. 12, 2022 at https://www.epa.gov/pfas/pfas-explained.

[44] Schlumberger. Oilfield Glossary. EOR [Enhanced Oil Recovery]. Accessed Jan. 12, 2022, at https://glossary.oilfield.slb.com/en/terms/e/eor.

[45] Peter M. Murphy and Tracy Hewat. Fluorosurfactants in Enhanced Oil Recovery. The Open Petroleum Engineering Journal, 1. 58-61, 60 (2008). Accessed Jan. 12, 2022, at https://citeseerx.ist.psu.edu/viewdoc/download?doi=10.1.1.858.5125&rep=rep1&type=pdf.

[46] Peter M. Murphy and Tracy Hewat. Fluorosurfactants in Enhanced Oil Recovery. The Open Petroleum Engineering Journal, 1. 58-61, 58 (2008). Accessed Jan. 12, 2022, at https://citeseerx.ist.psu.edu/viewdoc/download?doi=10.1.1.858.5125&rep=rep1&type=pdf.

[47] 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 Jan. 12, 2022, at https://pubs.rsc.org/en/content/articlelanding/2020/em/d0em00291g#!divAbstract.

[48] Dusty Horwitt. Fracking with Forever Chemicals. Physicians for Social Responsibility (July 2021), at 4, 10. Accessed Jan. 12, 2022, at https://www.psr.org/wp-content/uploads/2021/07/fracking-with-forever-chemicals.pdf (additional data on file with PSR).

[49] PSR calculated the estimated maximum amounts of trade secret chemicals used in each well in Colorado primarily by using disclosures by well operators for each well listed in FracFocus. We then aggregated the maximum 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 fracturing fluid used in each well in pounds by multiplying the gallons of water listed as being used as the base fluid for the hydraulic fracturing 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 weights approximately 1,863,005 pounds. We then calculated the total mass of the fracturing fluid by multiplying the mass of the water in pounds by 100 and dividing that product by the listed maximum concentration in percent by mass of water in the fracturing fluid (78.31797). The estimated total maximum mass of the fracturing 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 fracturing 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.

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

[51] Jennifer Larino. Appeals court stands by ruling holding BP, Anadarko liable for oil spill penalties. New Orleans Times-Picayune (July 22, 2019). Accessed Jan. 12, 2022, at https://www.nola.com/news/business/article_40b1c0f0-2c8e-5b0e-99ca-ac1bfccd054a.html.

[52] Shariq Khan and Rod Nickel. Encana to Move to U.S., Change Name Amid Pipeline Crunch in Canada. Reuters (Oct. 31, 2019). Accessed Jan. 12, 2022, at https://www.reuters.com/article/us-encana-results-idUSKBN1XA1GK.

[53] Multiple sources have discussed spills at oil and gas sites and associated water contamination including the following: Bruce Finley. Drilling Spills Reaching Colorado Groundwater; State Mulls Test Rules. Denver Post. Accessed Jan. 12, 2022 at https://www.denverpost.com/2012/12/08/drilling-spills-reaching-colorado-groundwater-state-mulls-test-rules/. 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). Seventh Edition (Dec. 2020), at 86-141. Accessed Jan. 12, 2022, https://www.psr.org/wp-content/uploads/2020/12/fracking-science-compendium-7.pdf.

[54] Center for Western Priorities. 2020 Western Oil and Gas Spills Tracker. Accessed Jan. 12, 2022, at https://westernpriorities.org/2021/03/01/western-oil-and-gas-spills-tracker-2020-update/. Center for Western Priorities. Toxic Release: Colorado Oil and Gas Spills 2012 (April 15, 2013), at 4. Accessed Jan. 12, 2022, at https://westernpriorities.org/wp-content/uploads/2013/04/Colorado-Oil-Gas-Spills-2012-copy.pdf.

[55] Center for Western Priorities. 2020 Colorado Oil and Gas Spills Tracker. Accessed Jan. 12, 2022, at https://westernpriorities.org/2020-colorado-oil-and-gas-spills-tracker/.

[56] 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 Jan. 12, 2022, at https://www.epa.gov/hfstudy.

[57] Dusty Horwitt. Fracking with Forever Chemicals. Physicians for Social Responsibility (July 2021), at 15. Accessed Jan. 12, 2022, at https://www.psr.org/wp-content/uploads/2021/07/fracking-with-forever-chemicals.pdf.

[58] 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 Jan. 12, 2022, at https://www.epa.gov/hfstudy.

[59] 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).

[60] 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 Jan. 12, 2022, at https://gis.ohiodnr.gov/MapViewer/?config=oilgaswells.

[61] Lisa M. McKenzie et al. Congenital heart defects and intensity of oil and gas well site activities in early pregnancy. Environment International (2019) 132, 104949. Accessed Jan. 12, 2022, at https://doi.org/10.1016/j.envint.2019.104949.

[62] Lisa M. McKenzie et al. Childhood hematologic cancer and residential proximity to oil and gas development. PLOS One, 12(2): e0170423. https://doi.org/10.1371/journal.pone.0170423 (2017). Accessed Jan. 12, 2022, at https://journals.plos.org/plosone/article?id=10.1371/journal.pone.0170423.

[63] 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), Seventh Edition (2020). Accessed Jan. 12, 2022, at https://www.psr.org/wp-content/uploads/2020/12/fracking-science-compendium-7.pdf.

[64] U.S. Centers for Disease Control. Infant Mortality. Accessed Jan. 12, 2022, at https://www.cdc.gov/reproductivehealth/maternalinfanthealth/infantmortality.htm.

[65] Southwest Pennsylvania Environmental Health Project. Health Outcomes Associated with Exposure to Shale Gas Development from Peer-Reviewed Epidemiological Literature. Accessed Oct. 17, 2020 at https://7bd2bc49-dce3-4599-9d04-024007410045.filesusr.com/ugd/a9ce25_d265699067214d5d94408b9102b37c72.pdf.

[66] Southwest Pennsylvania Environmental Health Project. Health Outcomes Associated with Exposure to Shale Gas Development from Peer-Reviewed Epidemiological Literature. Accessed Oct. 17, 2020, at https://7bd2bc49-dce3-4599-9d04-024007410045.filesusr.com/ugd/a9ce25_d265699067214d5d94408b9102b37c72.pdf.

[67] Office of the Attorney General, Commonwealth of Pennsylvania. Report 1 of the Forty-Third Statewide Investigating Grand Jury (June 25, 2020), at 4-5. Accessed Jan. 12, 2022, at https://www.attorneygeneral.gov/wp-content/uploads/2020/06/FINAL-fracking-report-w.responses-with-page-number-V2.pdf.

[68] Office of the Attorney General, Commonwealth of Pennsylvania. Report 1 of the Forty-Third Statewide Investigating Grand Jury (June 25, 2020), at 12. Accessed Jan. 12, 2022, at https://www.attorneygeneral.gov/wp-content/uploads/2020/06/FINAL-fracking-report-w.responses-with-page-number-V2.pdf.

[69] U.S. Department of Energy. Energy Information Administration. Natural Gas. Natural Gas Gross Withdrawals and Production. Dry Production, Annual-Million Cubic Feet. Accessed Jan. 12, 2022, at https://www.eia.gov/dnav/ng/ng_prod_sum_a_EPG0_FPD_mmcf_a.htm.

[70] Office of the Attorney General, Commonwealth of Pennsylvania. Report 1 of the Forty-Third Statewide Investigating Grand Jury (June 25, 2020), at 4-5. Accessed Jan. 12, 2022, at https://www.attorneygeneral.gov/wp-content/uploads/2020/06/FINAL-fracking-report-w.responses-with-page-number-V2.pdf.

[71] Concerned Health Professionals of New York, & Physicians for Social Responsibility. Compendium of scientific, medical, and media findings demonstrating risks and harms of fracking (unconventional gas and oil extraction) (7th edition, December 2020), at 52-57. Accessed Jan. 12, 2022, at https://www.psr.org/wp-content/uploads/2020/12/fracking-science-compendium-7.pdf. Zwickl, Klara. 2019. The demographics of fracking: A spatial analysis for four U.S. states. Ecological Economics, vol. 161(C), pages 202-215

[72] Julie Turkewitz. In Colorado a fracking boom and a population explosion collide. New York Times (May 31, 2018). Accessed Jan. 12, 2022, at https://www.nytimes.com/2018/05/31/us/colorado-fracking-debates.html.

[73] Daniela Navarro. CSU student arrested for protesting fracking near Greeley middle school. The Rocky Mountain Collegian (Mar. 21, 2018). Accessed Jan. 14, 2022 at https://collegian.com/news/2018/03/csu-student-arrested-for-protesting-fracking-near-greeley-middle-school/.

[74] John Herrick. Report: Cancer-causing benzene spiked more than once at Bella Romero. The Colorado Independent (Mar. 11, 2021). Colorado Independent. Accessed Jan. 12, 2022, at https://www.coloradoindependent.com/2020/03/11/report-benzene-bella-romero/.

[75] Agency for Toxic Substances and Disease Registry. Toxic Substances Portal. ToxFAQs for Benzene. Accessed Jan. 12, 2022, at https://wwwn.cdc.gov/TSP/ToxFAQs/ToxFAQsDetails.aspx?faqid=38&toxid=14.

[76] Michael Janofsky. Dupont to Pay $16.5 Million for Unreported Risks. New York Times (Dec. 15, 2005). Accessed Jan. 12, 2022, 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 Jan. 12, 2022, 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).

[77] U.S. Environmental Protection Agency. Fact Sheet: 2010/2015 PFOA Stewardship Program. Accessed Jan. 12, 2022, 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 Jan. 12, 2022, 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 Jan. 12, 2022 at https://www.nytimes.com/2016/01/10/magazine/the-lawyer-who-became-duponts-worst-nightmare.html?searchResultPosition=1.

[78] U.S. Environmental Protection Agency. Fact Sheet: 2010/2015 PFOA Stewardship Program. Accessed Jan. 12, 2022, at https://www.epa.gov/assessing-and-managing-chemicals-under-tsca/fact-sheet-20102015-pfoa-stewardship-program.

[79] Earthjustice. EPA's Secret Chemical Problem, Unveiled. Accessed Jan. 12, 2022, 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 Jan. 12, 2022, at https://theintercept.com/2018/10/25/epa-pfoa-pfas-pfos-chemicals/.

[80] Arlene Blum et al. The Madrid Statement on Poly- and Perfluoroalkyl Substances (PFASs). Environmental Health Perspectives (May 1, 2015), Vol. 123, No. 5. Accessed Jan. 12, 2022, at https://ehp.niehs.nih.gov/doi/10.1289/ehp.1509934.

[81] U.S. Environmental Protection Agency. PFAS Strategic Roadmap: EPA's Commitments to Action 2021-2024 (Oct. 21), at 7. Accessed Jan. 12, 2022, at https://www.epa.gov/system/files/documents/2021-10/pfas-roadmap_final-508.pdf.

[82] Letter from U.S. Rep. Jared Huffman et al. to U.S. Environmental Protection Agency Administrator Michael S. Regan (Oct. 27, 2021). Accessed Jan. 12, 2022 at https://huffman.house.gov/media-center/press-releases/huffman-calls-on-epa-to-protect-public-from-chemical-hazards-created-by-hydraulic-fracturing.

[83] 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).

[84] Ian Urbina. Pressure Limits Efforts to Police Drilling for Gas. New York Times (Mar. 3, 2011). Accessed Jan. 12, 2022 at https://www.nytimes.com/2011/03/04/us/04gas.html?ref=us. Related sidebar, Lax Rules for the Natural Gas Industry, accessed Jan. 12, 2022 at https://archive.nytimes.com/www.nytimes.com/interactive/2011/03/03/us/20110303-natural-gas-timeline.html.

[85] Julianne Glüge et al. Information Requirements under the Essential-Use Concept: PFAS Case Studies. Environmental Science & Technology (Oct. 5, 2021). Accessed Jan. 12, 2022 at https://pubs.acs.org/doi/10.1021/acs.est.1c03732.

[86] U.S. Department of Labor. Occupational Safety and Health Administration. Hazard Communication Standard. 29 CFR § 1910.1200; 2017.

[87] 2 CCR 404-1. 200 Series § 205 (b) (effective Nov. 2, 2020). 2 CCR 404-1. 200 Series § 205 (b) (effective April 1, 2009).

[88] Schlumberger. Oilfield Glossary. Workover. Accessed Jan. 12, 2022, https://glossary.oilfield.slb.com/en/terms/w/workover.

[89] 2 CCR 404-1. 200 Series. § 205 (b) and (f) (effective date April 1, 2009). 2 CCR 404-1. 200 Series § 205 (b) and (f) (effective date Nov. 2, 2020).

[90] 2 CCR 404-1. 100-Series. Definitions (defining "chemical inventory"). 200-Series § 205 (effective date April 1, 2009) (using the term "material safety data sheet" (MSDS)). 2 CCR 404-1. 100-Series. Definitions (defining "chemical inventory"). 200-Series § 206 (d) (effective date Jan. 15, 2021) (using the term "safety data sheet").

[91] 2 CCR 404-1. 200 Series. § 206 (d).

[92] 2 CCR 404-1. 200 Series. § 206 (d)(3).

[93] 2 CCR 404-1. 200 Series. § 206 (f)(2)(3).

[94] C.R.S. 24-72-202 (6) (a) (I). Definitions. Public Records.

[95] 2 CCR 404-1. 200 Series § 205 (effective date Jan. 30, 2012). 200 Series § 208 (effective date Jan. 15, 2021).

[96] 2 CCR 404-1. 200 Series § 208 (a)(2) (effective date Jan. 15, 2021). Somewhat different earlier rules can be found at 200 Series § 205 (d) (e) (effective date Jan. 30, 2012).

[97] 2 CCR 404-1. 200 Series. § 208 (a)(2) (effective date Jan. 15, 2021). Somewhat different earlier rules can be found at 200 Series § 205 (d) (e) (effective date Jan. 30, 2012).

[98] 2 CCR 404-1. 200 Series § 205(d)(e) (effective date Jan. 30, 2012). 200 Series § 208(a)(b) (effective date Jan. 15, 2021).

[99] See for example a MSDS for a common PFAS-based firefighting foam that meets the military's specifications, which lists only "proprietary mixture of fluorosurfactants and hydrocarbon surfactants" as <5 percent by weight. Accessed Jan. 12, 2022, at http://buckeyefire.com/wp-content/uploads/2019/01/Buckeye-C6-3-MIL-SPEC-AFFF-SDS.pdf.

[100] 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 Jan. 12, 2022, at https://blogs.harvard.edu/environmentallawprogram/files/2013/04/4-23-2013-LEGAL-FRACTURES.pdf. U.S. Department of Labor. Occupational Safety and Health Administration. Hazard Communication Standard. 29 CFR § 1910.1200; 2017.

[101] 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 Jan. 12, 2022, at https://blogs.harvard.edu/environmentallawprogram/files/2013/04/4-23-2013-LEGAL-FRACTURES.pdf. U.S. Department of Labor. Occupational Safety and Health Administration. Hazard Communication Standard. 29 CFR § 1910.1200; 2017.

[102] 2 CCR 404-1. 200 Series. § 206(d)(1-2) (effective date Jan. 15, 2021).

[103] U.S. Department of Energy. Energy Information Administration. Petroleum & Other Liquids. Crude Oil Production, Annual-Thousand Barrels. Accessed Jan. 12, 2022, at https://www.eia.gov/dnav/pet/pet_crd_crpdn_adc_mbbl_a.htm.

[104] 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."

[105] U.S. Department of Energy. Secretary of Energy Advisory Board Task Force Report on FracFocus 2.0 (Mar. 28, 2014). Accessed Jan. 12, 2022, at https://www.energy.gov/sites/default/files/2014/04/f14/20140328_SEAB_TF_FracFocus2_Report_Final.pdf.

[106] U.S. Department of Energy. Secretary of Energy Advisory Board Task Force Report on FracFocus 2.0 (Mar. 28, 2014). Accessed Jan. 12, 2022, at https://www.energy.gov/sites/default/files/2014/04/f14/20140328_SEAB_TF_FracFocus2_Report_Final.pdf.

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

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

[109] 2 CCR 404-1. 200 Series § 208(c) (effective date Jan. 15, 2021).

[110] For example, in 2014, four attorneys with years of experience litigating oil and gas-related cases in Pennsylvania filed a petition with the state Commonwealth Court suggesting manufacturers often withhold chemical identities from other companies in the supply chain. See Petitioners' pleading filed in Robinson Twp. v. Commonwealth, Docket No. 284 MD 2012 (June 9, 2014), at 13 FN5 (on file with PSR). 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 Material Safety Data Sheets from manufacturers to reply to a request for the chemicals used to fracture or stimulate its wells. "The MSDS are often useful for developing some understanding of what is in a particular chemical or product," Range wrote. "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." See 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).

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