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STILL
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Dedicated to protecting communities and the environment from the adverse impacts of mineral and energy development while promoting sustainable solutions.

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Acronyms

HVHF: High Volume Hydraulic Fracturing

NYDEC: New York Department of Environmental Conservation

ODNR: Ohio Department of Natural Resources

OEPA: Ohio Environmental Protection Agency

PADEP: Pennsylvania Department of Environmental Protection

RCRA: Resource Conservation and Recovery Act

STRONGER: State Review of Oil and Natural Gas Environmental Regulations

EPA: United States Environmental Protection Agency

WVDEP: West Virginia Department of Environmental Protection

1 — Introduction

The United States produces more oil and natural gas than any other nation in the world.[1] Between now and 2030, the U.S. is on track to unleash 60 percent of all new oil and gas production globally – four times more than any other country.[2] Of the many impacts this fossil fuel extraction will have, there is one that is often overlooked. Being the world leader in oil and gas also means the U.S. leads in toxic oil and gas *waste*, which contains carcinogens, heavy metals, and radioactive materials. This waste is produced long after the drilling stops.[3]

Today, most wells are hydraulically fractured and produce skyrocketing amounts of gaseous, liquid and solid waste. Though airborne pollutants are a serious threat to both people and climate, this report is an in-depth look at the liquid and solid waste streams generated by drilling and hydraulic fracturing, specifically:

- **Where oil and gas waste is going, and where it should/should not be**
- **What disposal of toxic oil and gas waste means for our water and land**
- **How communities are affected by waste production, transport, treatment and disposal**
- **What policies need to change to protect the public and environment.**

The trends revealed in this report are disturbing, from the accumulation of radioactive sediment in rivers to the contamination of drinking water, all from the poor management of oil and gas waste. The risks from this waste extend far beyond the places where it originates. It sometimes travels hundreds, even thousands,[4] of miles across the country through unsuspecting communities.

Source: oilandgasthreatmap.com

The United States landed its leading role in oil and gas due, in part, because of the industry's political power to secure major exemptions from our most fundamental environmental laws. Without an exemption from the Resource Conservation and Recovery Act (RCRA), and other statutes, the industry and its impacts would not have flourished so aggressively during what many have dubbed the "shale gas revolution."

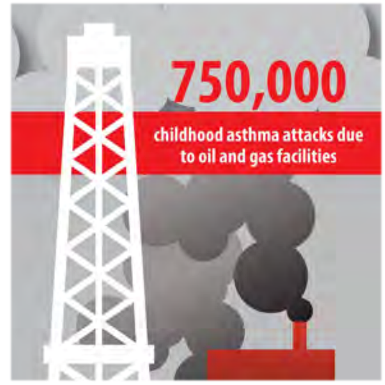
And like other revolutions, this one has harmed, and will continue to harm, people and the environment for generations to come.

We have to make sure that toxic oil and gas waste is managed carefully, and the *Recommendations* at the end of this report can help.

Hazardous Oil & Gas Waste Is Not "Hazardous"

You read that title correctly – hazardous waste from oil and gas operations are exempt from federal and state laws from being classified as "hazardous." And, yes, that does mean that hazardous waste is being transported, treated and disposed of as if it is not hazardous.

Nearly 30 years ago, long before the "shale boom" started, the United States Environmental Protection Agency (EPA) considered whether oil and gas waste should be regulated under federal hazardous waste law, specifically the Resource Conservation and Recovery Act (RCRA).



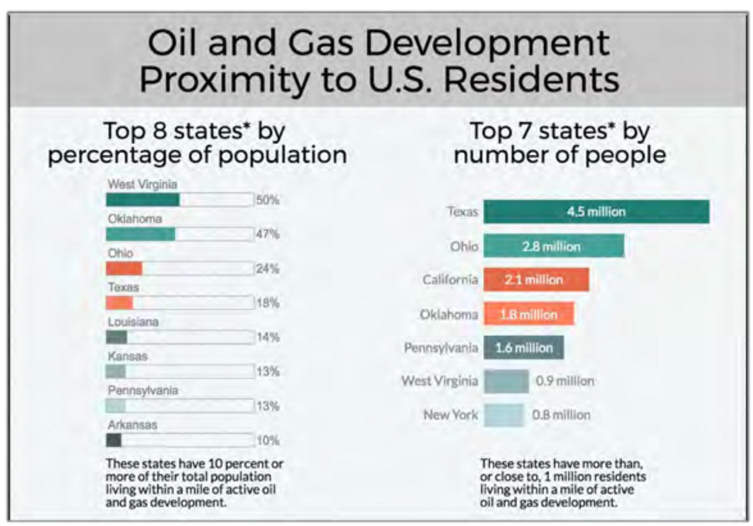
Source: oilandgasthreatmap.com

Among the EPA's many conclusions about oil and gas waste in a 1988 report to Congress were:

- **Oil and gas wastes "contain a wide variety of hazardous constituents."**
- **"Regulatory gaps exist."**
- **"[Waste management] practices vary substantially in the protection they provide to the environment."**
- **"For the major waste streams, EPA was unable to identify any new technologies…that offer promise for wide application in the near term."[5]**

Despite these conclusions, EPA decided to exempt oil and gas development waste from the definition of "hazardous" under RCRA anyway. (Later in this report, we'll show you exactly how the exemption happened and what Earthworks and others are doing to close this loophole today.)

As the saying goes, the more things change, the more they stay the same. Between 1995 and 2009, the number of oil and gas wells in production grew more than 20% (141,000); by 2013, natural gas wells had increased more than 65% (189,000). By 2016, there were more than 1.1 million active oil and gas wells nationwide.[6] Every single oil and gas well produces waste, and the number of waste spills grows along with the number of wells every year.



Graphic from PSE Healthy Energy's 2017 report on population proximity to active oil and gas wells.[7]

Even more astounding is the number of people living near oil and gas operations. According to an August 2017 study, an estimated 17.6 million Americans live within a mile of oil and gas development, including half of the population in West Virginia and almost a quarter of the population in Ohio.[7]

Despite over 30 years of research about the toxic impacts of the industry's waste, it is far from being handled properly. The hazardous waste regulations under RCRA still do not apply to oil and gas development waste today, in 2019. Consequently, oil and gas waste is categorized as non-hazardous and its management is largely handled by state laws that also exempt it from "hazardous" classifications. Thus, there is little consistency in tracking, testing, and monitoring requirements for oil and gas waste in the United States.

Still Wasting Away

Looking ahead, waste pollution and the associated health effects could cost billions to remedy. But whose responsibility would that be – whose liability?

Many of the questions about oil and gas field waste asked decades ago still persist, including what each load contains, or how it should be treated and disposed of. Also debated is whether states have the ability and resources to adequately protect water, soil, and air quality in the process, not to mention public health.

In 2015, Earthworks published *Wasting Away: Four states' failure to manage oil and gas waste in the Marcellus and Utica Shale*, which outlined the gaps in management and laid out solutions. For this report, *Still Wasting Away*, we've found that many of the same problems with oil and gas waste persist, and therefore, many of our policy recommendations remain the same.

Source: oilandgasthreatmap.com

As drilling continues in the U.S. – the world's largest oil and gas producer – this report examines where states are with regard to oil and gas waste management, and where they still need to go.

Still Wasting Away re-examines how oil and gas field waste has been tracked, regulated, and treated across the nation, where and how policy gaps have changed since 2015, and necessary steps that states and the federal government can take to prevent the environmental harm that results from ever-growing volumes of poorly managed toxic waste.

Still Wasting Away includes in-depth analysis of nine oil and gas producing states, each with a report of their own: California, Colorado, New Mexico, New York, North Dakota, Ohio, Pennsylvania, Texas, and West Virginia. Waste is frequently transported across the borders of these and other states, creating a complex web of waste management that begs for federal standards.

The Industry's "Achilles Heel"

Oil and gas waste is sometimes referred to as the "Achilles Heel" of the industry, a vulnerability that carries with it great risk. There is far more toxic waste than the industry has places to put it, and disposal has already led to pollution and earthquakes.[8]

The average household bathtub holds 80 gallons of water. According to the American Petroleum Institute, the oil and gas industry produces about 18 billion barrels (31.5 gallons each) of wastewater annually.[9] That's enough toxic waste to fill over 7 billion bathtubs every year.

According to Argonne National Laboratory, the total estimated volume of produced water for 2007 was about 21 billion barrels, or 57.4 million barrels per day.[10] That's 22.6 million bathtubs of wastewater every single day in 2007 alone.

State	Total Energy Production (Crude Oil + Natural Gas) by Trillion BTU[11]
Texas	17,080
Pennsylvania	7,888
Wyoming	7,518
Oklahoma	4,005
West Virginia	3,785
North Dakota	3,498
Colorado	3,078
New Mexico	2,582
Louisiana	2,555
California	2,431
Ohio	2,411
Illinois	2,406
Alaska	1,433
Kentucky	1,234
Arkansas	1,130

Overall, the amount of waste being generated per oil and gas well is increasing. An analysis by Downstream Strategies found that the amount of liquid waste generated per well in West Virginia has steadily increased since 2016, despite the reduction in producing wells.[12] A national study of hydraulic fracturing found that liquid wastewater volumes generated within the first year of production increased up to 1440% between 2011 and 2016.[13]

Regulatory agencies and legislatures have acknowledged the challenges posed by the surge in oil and gas waste and have taken some action to strengthen policies and regulations. Yet, some states have actually weakened their rules since 2015, and most oil and gas states can still not say for sure how much waste is being produced, where it all ends up, and what happens over time after it gets there.

Environmental health impacts from mismanaged oil and gas waste are a risk to any community where waste operations take place. But to make matters worse, many waste sites are built in disadvantaged communities with higher than average illiteracy rates, aging or minority populations, and people living below the poverty line. In other words, the "Achilles Heel" of the oil and gas industry is stepping down much harder on disempowered communities.

In Ohio, for example, Class II wastewater injection wells are sited in at least 41 counties, 22 of which are in Appalachia where median household incomes can fall below $20,000 per year.[14] Realities like this make the story of oil and gas waste all the more troubling, because disadvantaged communities have fewer resources to hire attorneys, submit complaints or appeals, attend meetings, or abate problems when they occur.

Below is a brief list of the impacts caused by oil and gas waste in recent years…but this list is far comprehensive. There are many, many more.

Shining a Light on Waste

High-profile events have brought public and media attention to the waste problems associated with Marcellus and Utica shale gas development, such as:

2008
Improperly treated shale gas wastewater caused a surge in levels of Total Dissolved Solids (TDS) in the Monongahela River, polluting water and leading to a bottled water advisory for Pittsburgh residents.[15]

2011 and 2013
Clean Water Action and partners filed lawsuits to stop the continued discharge of improperly treated Marcellus Shale drilling wastewater into Pennsylvania rivers; settlements have resulted in requirements for some treatment plants to change their technologies and practices.[16]

2012
A study confirmed that a series of earthquakes in Ohio was linked to the disposal of drilling wastewater in a nearby underground injection well. 17 Following these events, Ohio's Governor issued emergency rules for operators of injection wells to reduce the risk of seismic events related to waste disposal.[18]

2012
A contract waste hauler was found guilty of illegally dumping drilling waste into Pennsylvania streams and mineshafts, a practice that went on for six years before he was caught.[19]

2012
1,000 trucks carrying shale waste triggered radioactivity detectors at landfills, and some of the waste was found to be too hazardous for disposal.[20]

2013
Drill cuttings generated at Pennsylvania well sites were trucked all the way to a specialized facility in Idaho due to their excessive levels of radioactivity.[21]

2013
The U.S. Environmental Protection Agency and XTO Energy settled a lawsuit over the company allowing wastewater to flow off a well site into the Susquehanna River, a problem that continued unabated for more than two months.[22] The Pennsylvania Attorney General also filed criminal charges against XTO for the spill.[23]

2013
There were nearly 600 spills of wastewater, fracturing fluids, and other substances at oil and gas well sites in Pennsylvania, a 70% increase since 2011.[24]

2013
Sierra Club and partners launched a campaign to prohibit New York landfills from accepting drilling waste from Pennsylvania.[25]

2014
PADEP levied a civil complaint and potential fine against EQT Corp. for a 2012 leak of 300-500 gallons of flowback fluid from a pit in Tioga County that polluted soil, groundwater, and a high quality trout stream.[26]

2014
A drilling waste management company in Ohio pled guilty to illegally dumping drilling waste into a tributary of the Mahoning River on at least 20 occasions.[27]

2014
A West Virginia landfill rejected waste from centralized impoundments in Pennsylvania because of high radioactivity levels—signaling a reversal of past practices.[28] A specialized facility in Michigan eventually took the waste and an associated impoundment liner, all of which had to be processed for disposal to dilute the high radioactive content.[29]

2014
Three centralized waste impoundments in Pennsylvania were shut down and the operator fined a record $4.15 million for leaks and spills that resulted in soil and groundwater pollution.[30]

2014
A study by the U.S. Government Accountability Office emphasized the risks of earthquakes and groundwater contamination posed by lax oversight at underground injection wells. The report singled out Ohio for not requiring operators disposing of waste to reveal its chemical content.[31]

2014
Court depositions revealed that Pennsylvania regulators had omitted measurements of harmful contaminants near a waste impoundment from a report on air quality.[32]

2014
Over the course of a few years, concerns about toxic chemicals and radioactivity in wastewater spurred 15 New York counties to adopt bans on the road-spreading of brine.[33]

2015
Three million gallons of produced water leaked from a shallow underground pipeline in the Williston Basin, North Dakota.[34]

2016
Researchers from USGS, Duke University, & University of Minnesota found "[e]vidence indicating the presence of wastewaters from unconventional oil and gas (UOG) production was found in surface waters and surficial sediments near an UOG disposal facility in West Virginia."[35]

2016
Due to mounting pollution problems from oil and gas waste, a group of environmental groups (including Earthworks) filed a lawsuit in federal court, which approved a consent order directing the U.S. Environmental Protection Agency to review and possibly update its regulations on oil and gas waste under RCRA Subtitle D.[36]

2017
WPX (Williams Production & Exploration) was fined $1.2M for contaminating groundwater and five residential drinking water supplies with waste that leaked from underneath an impoundment at its fracking site in Westmoreland County, PA.37 The state's Environmental Hearing Board also fined EQT Corporation $1.1M for contamination resulting from a leaking impoundment in Tioga County.[38]

2017
Energy companies in North Dakota averaged one oil spill every 11 hours and 45 minutes in the year between May 2016 – May 2017.[39]

January 2018
A Duke University study found, even though "conventional oil and gas wastewater is treated to reduce its radium content," it had not prevented "high levels of radioactive build-up in the stream sediments" over time in Pennsylvania. Researchers concluded: "While restricting the disposal of fracking fluids to the environment was important, it's not enough...Conventional oil and gas wastewaters also contain radioactivity,

and their disposal to the environment must be stopped, too."[40]

May 2018
During a case before the Pennsylvania Environmental Hearing Board, PA Dept. of Environmental Protection conceded that it violated state law by approving oil and gas wastewater for roadspreading for the previous 30 years. The Plaintiff and her neighbors complained of illness and health problems following "brine" application on their dirt road.[41]

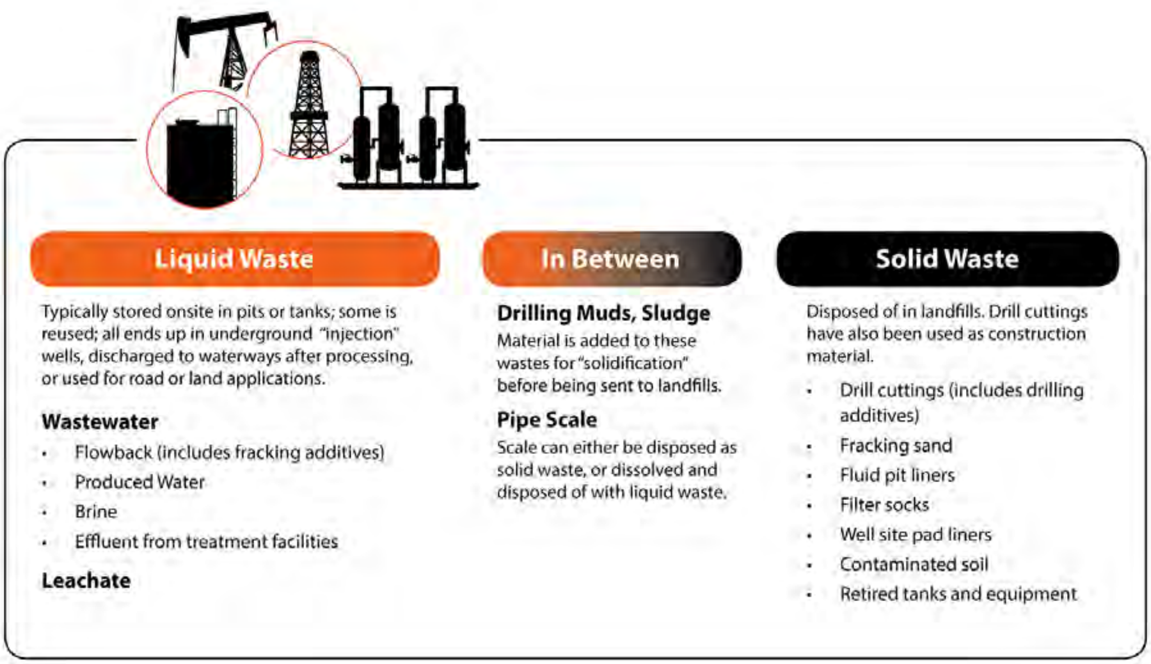
May 2018
A study published in the journal Environmental Science & Technology found that the spreading of oil and gas wastewater on roads "released over 4 times more radium to the environment (320 millicuries) than O&G wastewater treatment facilities and 200 times more radium than spill events." Researchers also found: "...nearly all of the metals from these wastewaters leach from roads after rain events, likely reaching ground and surface water. Release of a known carcinogen (e.g., radium) from roads treated with O&G wastewaters has been largely ignored."[42]

July 2018
The Ohio Department of Natural Resources found alarming levels of radiation in the de-icer product AquaSalina, manufactured using oil and gas produced water. Over the course of three years, more than five million gallons were sold of the de-icer, which tested up to 300 times higher for carcinogenic radium than U.S. EPA Safe Drinking Water Standards.[43]

2 — Types of Waste

Oil and gas operations produce several streams of toxic waste. Some of them contain carcinogens and radioactive material, including wastewater being spread on roads.[44] Oil and gas field waste is generally managed by government agencies and the industry as either liquid or solid, though sometimes waste blurs the line between the two.

When it comes time for disposal, certain wastes might fit the general definition of solid, including drill cuttings, muds, and fracturing sand—but when loads are brought to the surface after drilling, they contain fluids and formation water and form sludges. Produced water, flowback, and fracturing fluids are primarily disposed of at industrial or municipal wastewater treatment plants, but can also end up in landfills designed for solid waste.



Liquid Waste

Oil and gas wastewaters contain varying amounts of salts, heavy metals, hydrocarbons, carcinogens and naturally-occurring radioactive material (**NORM**). This wastewater is part rock and salt water from underground and part chemicals or additives from the drilling and hydraulic fracturing processes.

Initially, liquid waste that comes up the first 2 -3 months after hydraulic fracturing (also known as fracking) a well is called **FLOWBACK** and contains fracking fluids (water and chemicals) and materials from the earth. After the initial flowback period, wastewater volumes decrease over time. The waste's composition changes over time from flowback, at the beginning, to **PRODUCED WATER,** which contains underground salt water, or **BRINE**, that comes to the surface for decades after the drilling stops.[45]

Despite having unique definitions in various states and statutes, the terms BRINE, PRODUCED WATER and FLOWBACK are sometimes used interchangeably.

Sometimes, wastewater is reused by a company for more drilling and fracking, but eventually is becomes unusable and must be disposed of. Ultimately, most liquid waste is either:

- pumped back underground into "injection wells" for permanent storage
- spread on roads for deicing and dust suppression
- processed at industrial or municipal wastewater treatment plants and discharged into waterways
- manufactured into commercial products such as liquid deicer, rock salt, and pool salt[46]

All of these methods come with risks to people and the planet, from water and soil contamination to seismic events. We'll discuss these impacts in more detail later in this report.

Some liquid waste can also end up in landfills designed for solid waste. For example, between 2012 and 2014, operators in Pennsylvania reported sending over 260,000 barrels of "drilling fluid waste," "fracking fluid waste," "produced fluid," and "servicing fluid" to landfills.[47] Oil and gas operators and waste facilities can process sludges and liquids using large volumes of other materials to solidify the waste, such as wood chips, sawdust, cement, or other waste products such as lime kiln dust, the by-products of coal combustion, or the shredded remnants of automobiles and tires.

Often called "dilution" or "downblending," this can occur at well sites or at processing facilities prior to the waste being transported to landfills; some landfills also have the equipment and permits necessary to blend waste. Dilution is a process used to make waste more likely to pass the EPA's "paint filter" test, a method through which landfills use shakers, presses, and centrifuges to determine if waste is solid enough for disposal.[48] Downblending is also frequently used to decrease the concentration of radioactivity in a given volume of waste enough to meet landfill disposal standards.

Solid Waste

Oil and gas production starts by drilling deep into the earth, in some cases several miles underground, which brings rock and earthen debris called "drill cuttings" to the surface. These cuttings can contain naturally-occurring radioactive materials, heavy metals, inorganic compounds, and drilling and fracking additives such as lubricants and other chemicals.

As mentioned, semi-liquid drilling muds and sludge are also solidified with bulking materials so they, like drill cuttings, can be disposed of in landfills. For example, a load of drilling sludge from southwestern Pennsylvania that was rejected by landfills in that state and in West Virginia was finally accepted by a specialized facility in Michigan, which needed to downblend it to get from the sludge's level of 570pCi/g of Ra-226 to the disposal facility's standard of under 50pCi/g.[49]

Scale: Liquid or Solid

Scale is the build-up of precipitates inside an oil or gas well's tubing, pipes, and other equipment. The amount of scale increases over time and contains radioactive materials.[50] It can either be removed as a solid, a process that creates "pipe dust" and poses a radiation risk to workers, or dissolved with acids and disposed of with other liquid waste.

Sludge being blended with wood chips. Photo by US Geological Survey.

Blending Wastes

Operators and waste management companies are pursuing new methods of solidification. **However, it is clear that they are not consistently nor widely conducting chemical testing of the new "combination" products to ensure that they meet thresholds at landfills for particular contaminants or radioactivity, nor that they will remain sufficiently solid and not leach into soil or groundwater over time.** According to Argonne National Laboratory, there are limitations to the effectiveness of solidification and stabilization techniques and varied environmental factors can contribute to leaching of contaminants into the environment.[51]

Coal ash—which contains arsenic, mercury, and lead and is defined as TENORM by EPA—is often mixed with drill cuttings at some West Virginia landfills.

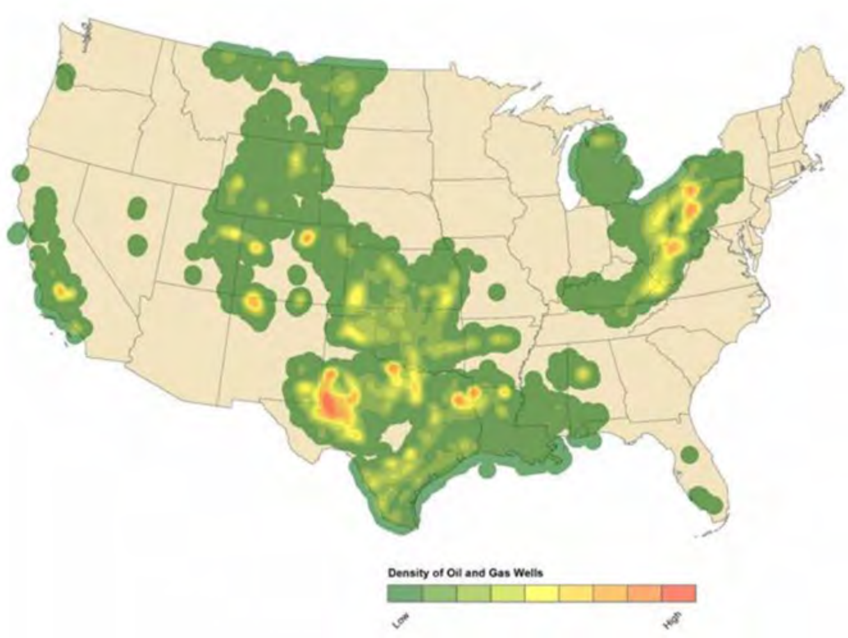
Mixing drilling wastes with materials that already contain toxic and/or radioactive substances is a big concern. For example, coal ash—which contains arsenic, mercury, and lead and is defined as TENORM by EPA—is often mixed with drill cuttings at some West Virginia landfills.[52]

Another contaminated dilution material, auto shredder residue (ASR, or auto fluff), is also used to solidify drilling waste. In 2013, a waste processing facility in Ohio seeking approval from ODNR to expand its operations stated that auto fluff (together with tire fluff and sawdust) would be a primary material used for solidification of natural gas exploration and production wastes.[53]

In 2002, EPA warned operators that if they mixed their wastes with other products: "The resulting mixture might become a non-exempt waste and require management under RCRA Subtitle C regulation"[54] – the law from which the oil and gas industry is otherwise exempt.

Just like oil and gas field waste, some key blending materials are exempt from RCRA, too. In late 2014, EPA declined to designate coal ash as a hazardous waste, instead classifying it as "solid waste."[55] EPA has also refused to classify ASR as a hazardous waste—although according to researchers, ASR may contain enough heavy metals, petroleum products, and PCBs to render it "hazardous wastes according to the U.S. Environmental Protection Agency (EPA) Toxicity Characteristic Leaching Procedure (TCLP)."[56]

In addition, as sludges and liquids are blended with other wastes, levels of contaminated and potentially hazardous contents may rise, along with the sheer volume of "bulked up" waste. This is particularly concerning when it comes to contaminants that do not degrade further through natural processes (e.g., heavy metals and radionuclides) but instead accumulate in waste over time.



Density of onshore oil and gas wells throughout the United States, where liquid and solid wastes are produced. SOURCE: U.S. EPA *Detailed Study of the Centralized Waste Treatment Point Source Category for Facilities Managing Oil and Gas Extraction Wastes*, pages 4-38.

Waste Streams

Brine

This broad term refers to water resulting from oil and gas drilling and production that has a high saline content. In the Marcellus and Utica shales in the northeast U.S., there has been some debate about whether the brine from deep, “unconventional” carbon-rich shales is more toxic than brine from

Brine storage tank. Photo by Nadia Steinzor.

shallower “conventional” oil and gas wells. But multiple studies have recently found that the brine and produced water from conventional operations have been just as effective at contaminating river sediments where treated waste is discharged into rivers.[57]

Though at times misrepresented as mere “salt water,”[58] this waste stream is composed of varying levels of chemical compounds in addition to saline water deposits from underground, including heavy metals like barium and strontium, and Radium-226, which is carcinogenic.

Produced water

In the United States, produced water is the single largest waste product of the oil and gas industry – an estimated 2.3 billion gallons per day.[59] EPA defines produced water as “the fluid brought up from the hydrocarbon-bearing strata during the extraction of oil and gas, and includes, where present, formation water, injection water, and any chemicals added downhole or during the oil/water separation process.”[60] The term is often used to encompass all wastewater, including “brine” and “flowback.”

Geological formations that contain oil and gas also often hold large amounts of water, which is released to the surface during production. The amount of produced water that is generated per well and the concentrations of minerals, metals, oil and grease, and radiological materials it contains vary depending on the formation being drilled.

Studies indicate that produced water from the Marcellus Shale is the second saltiest and most radioactive of all sedimentary basins in the U.S. where large-scale oil and gas development is underway.[61] Produced water from the Marcellus and Utica Shale region is estimated to be 5-10 times saltier than seawater, requiring considerable treatment before it can be reused or properly disposed of.[62]

Produced water may continue to flow over the entire life of a well, and studies increasingly show that "produced water samples from both" unconventional and conventional "well types were equally toxic to human cells and were corrosive at high concentrations."[63]

Flowback

The advent of horizontal drilling has vastly increased the volume of water required for oil and gas production – up to 6 million gallons to hydraulically fracture a shale well between 2011 and 2013.[64] Once fracturing is completed and drilling pressure is released, the injected water, fracking chemicals and formation fluids return to the wellhead as "flowback."

States that track flowback generally require that operators report the volumes created in the initial period after fracturing (e.g., 30 days), as the amount decreases steadily over time. The proportion of fracturing fluid injected into a typical Marcellus or Utica well that returns as flowback varies. One study suggests about 10-30% of injected fracturing fluid is recovered,[65] while a 2013 review of data reported by operators put recovery at 8% in West Virginia and 6% in Pennsylvania.[66]

Samples of flowback from the Marcellus Shale have shown consistently high levels of sodium, chloride, strontium, barium, and bromide. In addition, flowback can contain substances originating from the fractured formation, such as hydrogen sulfide and various volatile organic compounds.

The contaminants present in flowback and their concentration vary depending on the source of water used for fracturing (e.g., freshwater from a stream or recycled produced water) and the acids and chemicals added to fracturing fluid (e.g., to reduce friction, eliminate bacteria, or prevent corrosion of pipes). At the same time, samples of flowback from the Marcellus Shale have shown consistently high levels of sodium, chloride, strontium, barium, and bromide.[67] In addition, flowback can contain substances originating from the fractured formation, such as hydrogen sulfide and various volatile organic compounds.[68]

Flowback can also contain "proprietary" chemicals, the identities of which are undisclosed to the public in some cases, even when associated health problems occur. In Pennsylvania, a recent review of state records found that "companies injected secret fracking chemicals 13,632 times into 2,515 wells" across the state. Exemptions in Pennsylvania law allow the use of secret chemicals in the state's oil and gas wells, and researchers suggest the use is even higher than predicted.[69]

Drill cuttings

After a hole is drilled to develop an oil or gas well, large amounts of ground up rock come back out. The actual volume of drill cuttings generated will vary depending on the depth of a well and length of the laterals in horizontal drilling. Various estimates have been put forth, including 500 tons for a deep Marcellus Shale well;[70] to 600 tons for a Utica Shale well;[71] to 750 tons for an average Marcellus well;[72] to 1000 tons for an average Marcellus well in West Virginia.[73]

The sheer volume, weight, and bulkiness of drill cuttings make their treatment and disposal challenging. Regulatory agencies generally consider drill cuttings to be simply rock and dirt, i.e., a natural material that can be disposed of in landfills. However, cuttings are coated with drilling fluids, and loads can contain a certain amount of liquid made up of the same chemicals used in hydraulic fracturing. Because they are essentially ground up bits of shale formations, they also contain radioactive material, salts, and hydrocarbons.

Drill cuttings at a gas well site in West Virginia. Photo by Bill Hughes.

Drilling muds

The development of deep oil and gas wells in dense shale requires extensive drilling, which is in turn facilitated by fluids known as muds. Muds are used to control pressure in the wellbore, to cool and lubricate the drill bit, to help bring drill cuttings to the surface, and for other purposes. Muds can be water-based, oil-based, synthetic, or even made of air and foam—but they all contain chemical additives.[74]

Because drilling muds are primarily liquid, they have to be separated from cuttings prior to disposal or reuse, and solidified and stabilized if they are destined for disposal in a landfill. In a 2013 report developed for regulators in West Virginia, researchers found that samples of drilling muds from vertical wells in the state contained concentrations of contaminants that exceeded drinking water standards, including those for chlorides, benzene, and surfactants.[75]

Sludge

Sludge accumulates in the bottom of tanks used to store waste and must be removed to maintain storage capacity. Sludge is typically composed of wastewater, residuals, and various solids including scale, sand and rust.[76] Sludge from wastewater treatment facilities also collects in equipment used to process oil and gas wastewater and can contain even higher levels of radioactive material.[77]

Scale

Scale is the name for mineral deposits that accumulate in well tubing, hydraulic fracturing perforations, in the formation itself, or inside other equipment. Scaling is caused by precipitation due to chemical reaction or as saturation of produced water is disturbed by pressure and temperature changes during the drilling or fracking processes. Scale buildup is abated with the use of acids and other chemicals called inhibitors.[78] According to the EPA, "radioactivity in pipe scale can be quite high."[79]

Leachate

Leachate is a liquid formed when rain water filters through wastes disposed of in a landfill. The liquid leaches, or draws out, chemicals or other constituents from those wastes.[80] Landfills that accept oil and gas solid waste in the form of drill cuttings and solidified sludge that contain radioactive materials can produce leachate that is radioactive as well. In a review of data from two landfills in West Virginia that take large volumes of drill cuttings, Downstream Strategies found that leachate frequently contained concentrations of Radium-226 and Radium-228 that exceeded the federal Maximum Contaminant Level.[81]

Filter Socks

These "socks" are used to filter wastewater from oil and gas drilling and hydraulic fracturing operations. Because the wastewater often contains salts, heavy metals, fracking chemicals and naturally-occurring radioactive materials, such as carcinogenic Radium-226, these socks are supposed to be disposed of in landfills that can accept radioactive waste. However, as Forbes magazine has reported,[82] that doesn't always happen.

Wastewater Effluent

When not injected underground for permanent disposal, oil and gas wastewater is often sent to facilities that process the waste and then discharge it to rivers or stream as effluent. EPA has effluent guidelines for discharges from wastewater facilities, however studies have shown that even after treatment, effluent can lead to accumulations of toxins such as ammonia and radium near discharge outfalls.[83]

The EPA is currently studying facilities that allegedly clean fracking wastewater to effluent discharge standards. However, Earthworks' investigation of public records for some of these facilities reveal disturbing gaps in effluent monitoring prior to releasing it into the environment. (See Centralized Waste Treatment Facilities below.)

Fracturing Sand

The essential point of hydraulic fracturing is to open up shale (as well as other geological formations) so that oil and gas can flow out. But for this to happen, the fractures have to be propped open—which is often achieved through the use of fine silica sand treated with chemicals. Thousands of tons of sand are needed per well, and a significant amount returns to the surface after fracturing.

Fracturing sand mining on a Wisconsin farm. Photo by Carol Mitchell.

To date, little information is available about the specific chemical constituents or concentrations in fracturing sand waste or its processing and disposal. Data from the Pennsylvania Department of Environmental Protection indicate that the amount of fracturing sand waste disposed of in the state grew more than 200% between 2011 and 2013, when it reached over 45,000 tons; most of this ended up in landfills.[84]

The Non-Exempts

The oil and gas waste streams listed above are exempt from hazardous waste regulations under federal law. The following, however, are not automatically exempt:

- Soil contaminated by spills, unused fluids, unused sand, etc.
- Pit liners & equipment such as tanks, barrels and pipes
- Unused lubricants, additives, cleaners and fracking chemicals
- And more...[85]

3 — The RCRA Loophole

…Although [oil and gas wastes] are relieved from regulation as hazardous wastes, the exemption does not mean these wastes could not present a hazard to human health and the environment…

—United States Environmental Protection Agency, 2002

In an effort to enact more comprehensive waste disposal standards nationwide, the U.S. Congress passed the Resource Conservation and Recovery Act (RCRA) in 1976. Through RCRA, Congress declared that the "disposal of solid waste…without careful planning and management [was] a danger to human health and the environment."[86]

Over time, however, Congress would also create a special exemption in RCRA for oil and gas waste, which has led to consequences that could last for generations. While exempt from RCRA, oil and gas waste has posed substantial hazards for human health and the environment due to improper management, treatment and disposal.

As the principal federal law that governs the disposal of solid and hazardous wastes, RCRA takes a "cradle to grave" approach to ensure that wastes are documented, tracked, and handled properly from the point of creation through transport to their final disposal—something generally lacking in the management of other kinds of waste. Congress defined hazardous waste in RCRA, but left it up to EPA to decide the specific characteristics of hazardous waste and which wastes meet those characteristics.[87]

The four technical criteria EPA uses to determine if a waste will be considered "hazardous" are <u>ignitability</u>, <u>corrosivity</u>, <u>reactivity</u>, and <u>toxicity</u>; waste will be considered hazardous if it exhibits any of the four characteristics. Some oil and gas wastes meet at least one of these criteria, yet all are exempt.

Under RCRA, a hazardous waste is one that can:

1) cause, or significantly contribute to an increase in mortality or an increase in serious irreversible, or incapacitating reversible, illness; or

2) pose a substantial present or potential hazard to human health or the environment when improperly treated, stored, transported, or disposed of, or otherwise managed.[88]

Under RCRA, waste is considered hazardous if it exhibits *any* of these four characteristics: **ignitability, corrosivity, reactivity, and toxicity**.[89] These properties indicate that a waste poses a potential threat and should be regulated as such.

Even though oil and gas wastes exhibit some of these characteristics, Congress exempted "drilling fluids, produced waters, and other wastes associated with the exploration, development, or production of crude oil or natural gas" from hazardous waste regulations under RCRA in 1980.[90] At the same time, Congress directed EPA to conduct a study to determine whether or not oil and gas wastes should, in fact, be regulated as hazardous under the very regulations they had just amended to exempt the industry. [91]

In 1982, EPA missed the statutory deadline for submitting the oil and gas waste report to Congress. Subsequently, nearly three years later, the Alaska Center for the Environment sued EPA for its failure to conduct the required study and submit its findings. EPA then entered into a consent order obligating it to complete and submit the Report to Congress by August 31, 1987.[92]

Drilling waste pit in Pennsylvania. Photo by Frank Finan.

EPA met the 1987 deadline, completed the required study, and submitted a report to Congress on the *Management of Waste from the Exploration, Development, and Production of Crude Oil, Natural Gas, and Geothermal Energy*.[93]

Shortly after, in 1988, EPA issued a Regulatory Determination in which it decided that regulation of oil and gas wastes under Subtitle C of RCRA was unwarranted.[94] EPA's Regulatory Determination also expanded the exemption to include "rigwash, drill cuttings, and wastes created by agents used in facilitating the extraction, development, and production of the resource, and wastes produced by removing contaminants prior to the transportation or refining of the resource."[95]

With this Regulatory Determination, **EPA chose to exempt oil and gas wastes from RCRA Subtitle C, the rules that govern hazardous wastes — despite simultaneously finding that oil and gas wastes contain toxic substances that endanger both human health and the environment.** For example, EPA found that benzene, phenanthrene, lead, arsenic, barium, antimony, fluoride, and uranium in oil and gas wastes were of major concern and present at "levels that exceed 100 times EPA's health-based standards."[96]

EPA declined to define oil and gas wastes as hazardous despite finding contaminant "levels that exceed 100 times EPA's health based standards."

EPA emphasized that it was exempting oil and natural gas wastes from federal regulation for two main reasons:

1) State regulations already in place were deemed "adequate."
2) The petroleum industry would inevitably face economic impacts should their wastes be regulated under Subtitle C.[97]

But the same report wherein EPA concluded that existing state and federal regulations were generally sufficient to manage oil and gas waste, the agency also revealed that regulatory gaps existed and enforcement of existing regulations was inconsistent. EPA proposed a three-pronged approach to address these concerns that included:

- Improving federal programs under existing statutory authorities in RCRA Subtitle D (Non-hazardous Solid Waste), the Clean Water Act, and the Safe Drinking Water Act.
- Working with states to encourage improvements in the states' regulations and enforcement of existing programs.
- Working with Congress to develop any additional federal statutory authority that may be required.

EPA highlighted necessary improvements to state regulatory programs and collaborated with the Interstate Oil and Gas Compact Commission (IOGCC) on ways to encourage states to fill specific gaps, including:

- Regulations for road-spreading and land-spreading of waste.
- Surface impoundment (i.e., pit) location, design, and maintenance.
- Regulations for wastes associated with oil and gas wastes.
- Plugging abandoned oil and gas wells.[98]

Today, many gaps in federal and state regulation of oil and gas waste management **still remain,** in part due to the industry's heavy influence over U.S. politics and the policies meant to regulate it.

Industry Influence

Though their work together to strengthen state regulations was the first formal collaboration between EPA and the Interstate Oil and Gas Compact Commission (IOGCC), the Commission had its eye on RCRA regulations from the beginning.

In 2016, investigative journalists unearthed documents that revealed IOGCC began lobbying for a federal exemption for the industry as early as 1979.[99] In an IOGCC newsletter published in 2006, the Commission references a "a key event in 1987," prior to EPA exempting the oil and gas industry, when apparently "the IOGCC's efforts...proved successful, thwarting yet another move to diminish state authority."[100]

In 1989, the IOGCC created the Council on Regulatory Needs, which brought together state, environmental, and industry representatives to develop national guidelines for state oil and gas programs.

INDUSTRY INFLUENCE
The Interstate Oil and Gas Compact Commission began lobbying for an exemption for the industry as early as the 1979.

In early 1990, the Council proposed to implement a process by which state oil and gas programs were reviewed in comparison with those guidelines.[101] This resulted in the formation of a multi-stakeholder organization, in 1999, called the State Review of Oil and Natural Gas Environmental Regulations, Inc. (STRONGER). To date, STRONGER has reviewed 24 states, conducted at least 10 follow-up reviews of some of those states, and released updated guidelines in 2017 that included recommendations for pipelines transporting produced water and safety standards for worker exposure to naturally-occurring radioactive materials (NORM).[102]

STRONGER reviews, however, are based on states' willingness to be assessed, and the organization reported in 2016 that "[i]n recent years there has been a decline in the number of states volunteering their programs for review. There is also a level of complacency concerning the potential for congressional actions against the Resource Conservation and Recovery Act (RCRA) exemption and for federal oversight of state programs."[103]

Industry influence continues...

In 2010, the Natural Resources Defense Council (NRDC) sent EPA Administrator Lisa Jackson a letter of petition urging Jackson to use her authority as head of EPA to open the RCRA exemption for reconsideration, citing "numerous reports and data produced since the EPA's Regulatory Determination...which quantify the waste's toxicity, threats to human health and the environment, inadequate state regulatory programs, and readily available solutions."[104]

Eight years later, NRDC has not received a formal response from EPA, but the oil and gas industry wasted no time in responding. Two weeks after NRDC's petition, the Independent Petroleum Association of America (IPAA) went on the defensive, and in its retort bragged that Lee Fuller (Vice President of IOGCC and Executive Director of industry PR firm Energy In Depth) was the prime "architect" of the RCRA exemption for oil and gas wastes during his time as a staffer for Senator Bentsen, after whom the original exemption for oil and gas was named in 1980 (The Bentsen Amendment.)[105]

In the 30 years that have passed since EPA issued its 1988 Regulatory Determination, both the oil and gas industry and the risks associated with its wastes have expanded dramatically. Yet the continued existence of the RCRA exemption has made it possible for states to define and manage oil and gas wastes as "solid" or "residual" despite the fact that some of them meet the definition of hazardous waste. In turn, states have been able to avoid the adoption of additional federal tracking, testing, transport, and disposal requirements established under RCRA.

Drill cuttings stored at a well site in West Virginia. Photo by Bill Hughes.

There has also been confusion over the years about which oil and gas waste is exempt and which is not. EPA published a report in 2002 attempting to clear this up, but added that "the RCRA exemption does allow the operator to **choose a waste management and disposal option that is less stringent** and possibly less costly than those required under RCRA Subtitle C."[106]

The ability to choose "less stringent" disposal options fosters **a race to the bottom** to find the quickest, easiest, cheapest, and often dirtiest waste management option rather than the one with greater protective measures in place.

In May 2016, Earthworks joined the Environmental Integrity Project and several other organizations to file a federal lawsuit against EPA for the agency's failure to review and, if necessary, revise its rules for the disposal and handling of dangerous and harmful oil and gas wastes.

That December, the groups reached a legal settlement with EPA[107] requiring the agency to update rules on the management of solid oil and gas waste by landfills and other facilities, which the agency is obligated to do under Subtitle D of RCRA. EPA's deadline to put a determination in writing was scheduled for March 15, 2019.

RCRA Complexities: Not all wastes are exempt

Hazardous waste is regulated under RCRA under Subtitle C and Non-hazardous waste under Subtitle D. Not all oil and gas wastes are exempt from RCRA Subtitle C hazardous waste regulations – and unfortunately, not all oil and gas operators are clear on which types of waste are not exempt. An online search of non-exempt wastes produces pages of documents from agencies and consulting firms across the U.S. attempting to clarify the distinction.

To clear up "several misunderstanding about the exemption," EPA issued a document in 2002 that explained the RCRA Subtitle C (hazardous waste) exemption "did not preclude these wastes from control under state regulations, under the less stringent RCRA Subtitle D solid waste regulations," and included basic rules for determining whether a waste is actually exempt.[108] To be considered exempt, the waste must have been directly used for or generated during the drilling and fracking processes.

For example, a solvent used to clean equipment or machinery on the well site is not exempt because it is not "uniquely associated with the exploration, development, or production operations." But if the same solvent were pumped down the well and came back to the surface, it would then be exempt. This is the 'magic' of the RCRA loophole – it turns waste streams that should be regulated under hazardous waste law into waste that no longer has to be.

Examples of the non-exempt wastes include unused drilling additives and fracking chemicals (that didn't make it down the hole), waste solvents, equipment lubricating oils, radioactive tracers, compressor oil and fluids, used hydraulic fluids, caustic or acid cleaners, and miscellaneous solids such as synthetic liners and contaminated soils.

This is the 'magic' of the RCRA loophole – it turns waste streams that should be regulated under hazardous waste law into waste that no longer has to be regulated.

Duplicating the loophole: RCRA in the Marcellus Shale states

Ohio does not specifically exempt oil and gas field waste from being defined as hazardous, but regulations state that hazardous waste includes "any substance identified by regulation as hazardous waste under the Resource Conservation and Recovery Act of 1976" (RCRA)—which in effect exempts oil and gas field waste. In addition, in a preliminary draft of waste regulation revisions, ODNR would prohibit oil and gas operators from generating any wastes that are not exempt from RCRA, or allowing "brine or other waste substances [to] come in contact with non-exempt wastes in any manner which causes a loss" of the exemption—a clear indication that Ohio has every intention of maintaining the hazardous waste loophole for the oil and gas industry.[109] In 2013, HB 59 directed ODNR to adopt rules for waste storage and disposal; these preliminary draft revisions are still in draft phase years later, as of May 2019.

Pennsylvania law does not specifically exempt oil and gas field waste from being defined as hazardous. However, Title 25 of the Pennsylvania Code references the Code of Federal Regulations when defining hazardous waste: "40 CFR Part 261 and its appendices (relating to identification and listing of hazardous waste) are incorporated by reference"—in effect including the federal exclusion of oil and gas field waste in state law.[110] Pennsylvania's Solid Waste Management Act does not mention oil and gas field waste, but does appear to leave the door open for the Department of Environmental Protection to decide at any time to regulate a waste as hazardous; the law states that the list of wastes defined as hazardous "shall in no event prevent the department from regulating other wastes…when the department has determined such waste poses a substantial present or potential hazard to the human health or to the environment…"[111] PA updated its oil and gas regulations in 2016, creating separate rules for unconventional and conventional operators, but there we no changes to the "residual" status of any oil and gas waste.

West Virginia has a specific exemption for the oil and gas industry that mirrors RCRA. The state's Hazardous Waste Management Act specifies several types of wastes that are not subject to "promulgation of rules by the director" (of the WVDEP), i.e., they do not require regulation by the state as hazardous substances. This includes "drilling fluids, produced wasters, and other wastes associated with the exploration, development, or production of crude oil or natural gas…"[112] In addition, the law prevents the state from enacting regulations through the Hazardous Waste Management Act that would be similar to what is required under RCRA, unless the oil and gas waste exemption in RCRA is first removed by EPA and the U.S. Congress.[113]

New York categorically excludes from its definition of hazardous waste any and all "drilling fluids, produced waters, and other wastes associated with the exploration, development, or production of crude oil, natural gas or geothermal energy."[114] At the same time, the state's laws governing such waste provide definitional criteria and maximum contaminant levels of numerous parameters that could well apply to oil and gas field waste.[115] For this reason, environmental organizations have been calling for legislation to subject oil and gas field waste to hazardous waste testing requirements and, if it meets the definitional criteria, to dispose of it accordingly; a bill to accomplish this has twice passed the state Assembly, but not the Senate.[116] In 2017, Earthworks and partner organizations send recommendations to NYDEC during the state's update to its Part 360 Regulations for Solid Waste Management Facilities, including a the prohibition of oil and gas waste disposal at landfills or use as a roads due to "the inherently toxic and potentially hazardous and radioactive nature of oil and gas wastes."[117] However, these recommendations were not included in NYDEC's final regulations.

The Timeline of the Resource Conservation and Recovery Act (RCRA)

OCTOBER 1976	**Congress Passes Resource Conservation and Recovery Act (RCRA) to Manage Hazardous Waste**	Congress passed the Resource Conservation & Recovery Act (RCRA) in 1976 which required EPA to develop regulations governing the identification and management of hazardous waste. Using a "cradle to grave" approach, RCRA ensures that waste is documented, tracked, and properly handled from the point of creation through transport to final disposal. Unfortunately, however, Congress later created a special exemption in RCRA for oil and gas waste, with consequences that have lasted for decades.
DECEMBER 1978	**EPA Publishes First Hazardous Waste Standards**	Two years later, EPA released the first waste standards under RCRA, with four technical criteria to determine if a waste is hazardous – 1) ignitability 2) corrosivity 3) reactivity and 4) toxicity. Waste is considered hazardous if it exhibits one or more of these characteristics, and oil and gas waste often does. However, EPA recommended later publishing separate rules for six high volume "special wastes" like "oil and gas drilling muds and oil production brines."
JUNE 1979	**Interstate Oil & Gas Compact Commission Makes a Goal to Influence the EPA**	At a meeting six months after EPA published its first hazardous waste standards, the Interstate Oil & Gas Compact Commission commits to influencing the EPA and shares the economic costs of federal regulations with the agency. According to investigative journalists, IOGCC is a U.S. Congress-chartered interstate compact consisting of U.S. oil and gas producing states, with a membership roll that includes state-level regulators, industry lobbyists and executives. [Steve Horn, "IOGCC-Spawned Loophole Creating Frackquake Crisis Faces Federal Lawsuit," DeSmog Blog, May 24, 2016.]
OCTOBER 1980	Congress Temporarily Exempts Oil & Gas (O&G) Waste from RCRA – The Bentsen Amendment	In 1980, Congress amended RCRA to temporarily exempt oil and gas "drilling fluids, produced waters, and other wastes" from hazardous waste classification while EPA studied whether the wastes are hazardous and determine if RCRA C or D (non-hazardous) should apply. This became known as the Bentsen Amendment* to RCRA. *The late US Senator from Texas, Lloyd Bentsen, after whom the amendment was named, had a staffer working on RCRA at the time named Lee Fuller, who ended up leaving public service to become a lobbyist for the Independent Petroleum Association of America (IPAA). Fuller later became the Executive Director of IPAA's powerful fracking front group, Energy in Depth.
OCTOBER 1982	EPA Misses Deadline for O&G Waste Study & Report	EPA didn't conduct the study about whether oil and gas wastes should be regulated under RCRA hazardous waste rules within Congress's deadline, but Congress didn't seem to notice.
AUGUST 1985	Alaska Center for the Environment Sues EPA For Not Studying O&G Waste	Congress may not have noticed, but Alaska Center for the Environment did and sued EPA for its failure to conduct a study of oil and gas waste. As a result, EPA is ordered to complete and submit the report to Congress by August 31, 1987.
AUGUST 31, 1987	EPA Studies O&G Waste, Submits Its Report to Congress	In its 1987 report regarding whether the oil and gas industry should be exempt from RCRA, the EPA stated that toxic substances in oil and gas wastes appeared at "levels that exceed 100 times EPA's health based standards" and that 10 to 70 percent of oil and gas wastes sampled "could potentially exhibit RCRA hazardous waste characteristics." [Report: Management of Waste from the Exploration, Development, and Production of Crude Oil, Natural Gas, and Geothermal Energy]
DATE 1987	**Interstate Oil & Gas Compact (IOGCC) Pushes For State Control**	According to a newsletter published in 2006, IOGCC admits to its role in the RCRA exemption. At "a key event in 1987, the IOGCC's efforts to preserve state regulation of drilling muds and produced wastes, proved successful, thwarting yet another move to diminish state authority." [Making A Difference: a historical look at the IOGCC (newsletter) January 2006]
JULY 1988	**EPA Exempts O&G Waste from Federal RCRA Regs Despite Finding It Could Be Hazardous**	Despite the facts about the hazards of oil and gas waste found in their study less than a year before, the EPA issued a Regulatory Determination exempting oil and gas exploration and production wastes from RCRA Subtitle C. In this very same Determination, EPA concluded that "some portions of both the large volume and associated waste would have to be treated as hazardous" if the exemption the agency granted was ever lifted. Because EPA identified gaps in state regulations and noted inconsistent enforcement, the agency pledged to promulgate specially tailored rules under RCRA Subtitle D for these wastes EPA exempted from RCRA Subtitle C. [Regulatory Determination for Oil, Gas, and Geothermal Exploration, Development and Production Wastes, July 6, 1988 (53 FR 25466)]

RCRA TIMELINE

1989	Interstate Oil & Gas Compact Commission (IOGCC) Creates Council on Regulatory Needs to Address Gaps in State Regs	In an effort to fill the regulatory gaps identified by EPA, the Interstate Oil and Gas Compact Commission (IOGCC) created the Council on Regulatory Needs, which brought together state, environmental, and industry representatives to develop national guidelines for state oil and gas programs, continuing its successful push to prevent oil and gas waste from being regulated at the federal level.
1990	IOGCC's Council on Regulatory Needs Suggests Impementation of State Review Process	In early 1990, the Council released a report establishing guidelines for the integration of recommended criteria in state regulatory regimes. It also proposed to implement a process by which state oil and gas programs were reviewed in comparison to the guidelines.
MARCH 1993	EPA Clarifies Which Oil & Gas Waste Are Exempt	Without altering the original exemption in any way, EPA issued a clarification on the status of wastes generated by the crude oil reclamation industry, service companies, gas plants and feeder pipelines, and crude oil pipelines. [Clarification of the Regulatory Determination for Wastes from the Exploration, Development and Production of Crude Oil, Natural Gas and Geothermal Energy, March 22, 1993 (58 FR 15284)]
OCTOBER 2002	EPA Clarifies The Exemption...Again	To clear up "several misunderstandings," EPA issued a document in 2002 that included basic rules for determining whether a waste is actually exempt, as well as a clarification that the RCRA Subtitle C (hazardous waste) exemption "did not preclude these wastes from control under state regulations, under the less stringent RCRA Subtitle D solid waste regulations, or under other federal regulations." The EPA also had to remind everyone that just because oil and gas wastes were exempt, did not mean the wastes "could not present a hazard to human health and the environment if improperly managed." [Exemption of Oil and Gas Exploration and Production Wastes from Federal Hazardous Waste Regulations]
SEPTEMBER 2010	Natural Resources Defense Council (NRDC) Files Petition Asking EPA to Reconsider RCRA Exemption	NRDC sent EPA Administrator Lisa Jackson a letter of petition urging Jackson to use her authority as head of EPA to open the RCRA exemption for reconsideration, citing "numerous reports and data produced since the EPA's Regulatory Determination...which quantify the waste's toxicity, threats to human health and the environment, inadequate state regulatory programs, and readily available solutions." As of September 2018, NRDC hasn't heard back from EPA. [Petition for Rulemaking Pursuant to Section 6974(a) of the Resource Conservation and Recovery Act Concerning the Regulation of Wastes Associated with the Exploration, Development, or Production of Crude Oil or Natural Gas or Geothermal Energy.]
SEPTEMBER 2010	Independent Oil Association of America (IPAA) Brags, Their Own Lee Fuller Was 'Prime Architect' of RCRA Exemption for Oil & Gas	Independent Petroleum Association of America went on the defensive after NRDC's requested EPA reconsider the RCRA exemption, and in its retort bragged that Lee Fuller (VP of IOGCC and Executive Director of Energy In Depth) was the prime "architect" of the RCRA exemption for oil and gas wastes during his time as a staffer for Senator Bentsen, for whom the original exemption for oil and gas was named in 1980. [IPAA, "Oil and Natural Gas RCRA Exemption Under Attack," September 10, 2010.]
JULY 2013	U.S. Rep. Matt Cartwright Introduces CLEANER Bill to Remove Exemptions	U.S. Rep. Matthew Cartwright (D-PA) introduced a bill to remove the RCRA oil and gas wastes exemption in July 2013, three years after NRDC filed its petition. The legislation has 43 co-sponsors and was endorsed by 137 organizations from across the country, but never made it out of the U.S. House Subcommittee on Environment and the Economy.
DECEMBER 2015	Round Two: Rep. Cartright Goes After The RCRA Exemption Again	Rep. Cartright re-introduced the CLEANER Act to remove RCRA exemptions for the oil and gas industry, this time with 100 co-sponsors and endorsed by 206 organizations. But once again, the bill never made it out of subcommittee.
MAY 2016	**Earthworks & Others Sue EPA Over RCRA D**	Earthworks, Environmental Integrity Project, NRDC and several other organizations filed a federal lawsuit against EPA for the agency's failure under RCRA D to review and, if necessary, revise its rules for the disposal and handling of dangerous and harmful oil and gas wastes. The organizations had filed a federal lawsuit against EPA in May due to the agency's failure to review these rules for nearly thirty years. [Environmental Integrity Project et al. v. McCarthy, No. 1:16-cv-00842]
DECEMBER 2016	Court Approves Settlement, EPA Must Review O&G RCRA D Waste Rules	The U.S. District Court for the District of Columbia approved a consent decree requiring EPA to review, and "if necessary" revise, oil and gas waste rules under RCRA Subtitle D. The Plaintiffs, Environmental Integrity Project, NRDC, Earthworks and others, recommended that EPA address earthquakes related to underground injection of waste, ban the spreading of waste on roads, and require landfills and pits to be built with adequate liners and structural integrity to prevent spills and leaks into groundwater and streams. EPA has until March 15, 2019 to decide whether oil and gas waste rules need updating.
MARCH 15 2019	**EPA's Deadline for Deciding Whether It Will Revise O&G Waste Rules Under RCRA Subtitle D**	To be continued! Stay tuned on the latest from Earthworks about closing this dangerous loophole at Earthworks.org.

4 —Pivotal Challenges

States neither established the regulations and policies nor dedicated the oversight and enforcement resources needed to protect the environment and human health *before* proceeding with a rapid expansion of drilling in the early 2000's. As a result, states are still struggling to catch up with ever-growing volumes of both liquid and solid waste. To make matters worse, recent research shows that flowback and produced water volumes alone have increased by up to 1,440%[118] between 2011 – 2016.

States are faced with several pivotal challenges to waste management, detailed below, from identifying the content and contamination potential of waste to addressing the limitations of current storage and disposal practices. But with current research and documentation in hand, regulators and policymakers on both the state and federal levels have ample opportunities to face and reduce the significant problems related to oil and gas waste and the associated risks to human health and the environment:

- **Radioactivity: Types, Testing, Detection and Exposure**
- **Storage: Pits, Impoundments and Tanks**
- **Disposal: Underground Injection, Centralized Wastewater Treatment and Landfills**
- **Repurposing: Road Spreading, Land Application and Commercial Byproducts**

Radioactivity

Many of the contaminants in oil and gas field waste have not yet been identified, while the risks of others are only partially understood. This is not the case with radioactive elements, which are indisputably present in shale formations and are known to increase the risk of developing several types of cancer.

Two of these radioactive elements are Radium-226 and Radium-228, decay products of uranium and thorium that can be soluble in water or settle out and stick to materials like clay or rock. Because they have long half-lives (about 1,600 and 5.75 years, respectively), they can persist in the environmental and accumulate gradually over time.[119]

More vigorously debated is the level of radioactivity that exists in oil and gas waste and, in turn, how the waste should be managed to protect workers and residents from exposure or natural systems from contamination. This longstanding question has become more focused as drilling expands, in particular with development of the Marcellus Shale—which has been found to contain considerably higher levels of radioactivity than many other formations.[120] The even deeper Utica Shale is also understood to be enriched with radioactive materials, although this aspect of the formation has not been well studied.

Levels of radioactivity can vary across shale formations in the U.S. depending on depth and concentration. Oil and gas development is known to bring radioactivity to the surface through produced water, drill cuttings, and drilling muds, and can also result in radioactive deposits in sludges and scale that accumulate on pipes and equipment.[121]

The potentially high levels of radioactivity in drilling waste have been primarily documented with regard to produced water and flowback.[122] According to a 2011 review of sampling data by the U.S. Geological Survey, the median total radium activity for produced water from the Marcellus Shale in the Northeastern U.S. was 2,460 picocuries per liter (piC/L), compared to 1,011 piC/L for the non-shale samples; for comparison, the federal total radium limit for industrial effluent is 60 picocuries per liter (pCi/L) and the drinking water limit is 5 pCi/L of combined radium (Ra-226 and Ra-228).[123]

Investigations have found that treatment plants servicing oil and gas operators are often unable to remove radium and other contaminants (such as barium and strontium), likely because of the high salinity of the wastewater.[124]

A) Types of Radioactivity: NORM vs. TENORM

Radioactivity in oil and gas waste is defined by an array of federal and state agencies as either NORM or TENORM. Generally, naturally occurring radioactive material (NORM) wastes are those that contain radioactivity at concentrations considered to be "background," or a natural state. Technologically enhanced naturally occurring radioactive material (TENORM) wastes are, generally, those in which the radioactivity has become concentrated because of human activities. However, precise definitions of NORM and TENORM vary from state to state, as do the rules for handling these wastes. Colorado, New Mexico and Texas have some of the clearest state policies for managing radioactive oil and gas waste, while New York and West Virginia have some of the worst.

RADIOACTIVE OIL & GAS WASTE POLICY	OH	PA	NY	WV	TX	CO	ND	NM	CA
Does the state specifically regulate the disposal of oil & gas wastes containing NORM or TENORM?	Y	Y	N	N	Y	Y	Y	Y	Y
Does the state set TENORM disposal limits for oil and gas waste?	Y	N	N	N	Y as NORM	Y	Y	Y	Y per Facility
Does the state law define TENORM?	Y	Y	Y	Y	N	Y	Y	N	N
Does the state law define NORM?	Y	Y	Y	N	Y	Y	N	Y	N
WORKER SAFETY: Does the state protect workers from oil and gas waste NORM/TENORM specifically?	N	N	N	N	Y	Y	N	Y	N
PUBLIC SAFETY: Does the state protect the public from oil and gas waste NORM/TENORM specifically?	N	N	N	N	N	Y	N	Y	N
Does the state include produced water in the regulation of NORM or TENORM?	N	N	N	N	Y	N	N	Y	N
Does the state include drill cuttings in the regulation of NORM or TENORM?	N	N	N	N	N	N	N	N	N
Does the state include sludge in the regulations of NORM or TENORM?	N	Y	N	N	Y	Y	Y	Y	N
Does the state include scale in the regulation of NORM or TENORM?	Y	N	N	N	Y	Y	Y	Y	N
Does the state include contaminated equipment in the regulation of NORM or TENORM?	Y	Y	N	Y	Y	Y	Y	Y	N
Does the state prohibit the disposal of TENORM/NORM in rules that are applicable to the entire state?	N	N	Y	N	Y	N	Y	N	N
Questions adapted from LawAtlas.org; answers updated to March 2019 by Earthworks.	**Colorado, New Mexico and Texas have some of the clearest state policies for managing radioactive oil and gas waste, while New York and West Virginia have some of the worst.**								

Before the accumulation of TENORM in oil production equipment was understood, contaminated materials were used in steel products like load-supporting beams in house construction, plumbing for culinary water, fencing materials, awning supports, and even practice welding material for class rooms.[125]

Today, the EPA defines NORM as materials that are "undisturbed," and TENORM as "materials that have been concentrated or exposed to the accessible environment as a result of human activities."[126]

Meanwhile, STRONGER does not distinguish between NORM and TENORM, instead defining both as materials "whose radionuclide concentrations have been enhanced by human activities." [127] In Pennsylvania and Texas, TENORM and NORM have separate definitions, yet in New York and West Virginia, there are no legal definitions for NORM. In North Dakota, NORM is defined as any waste over 5 piC/g of radioactivity and cannot be disposed of in state, so oil and gas NORM waste must be shipped to other states like Colorado, Idaho and Texas.[128]

The inconsistency in regulation and management of radioactive oil and gas waste puts the public and environment at risk in several ways, from poor identification and testing to movement of these hazardous materials across state borders into communities where fewer protective laws are in place.

EPA regulates TENORM from some sources, but the management of oil and gas waste that may be classified as TENORM is largely left up to the states. **In the absence of clear federal standards, states can choose to define waste products in ways that support industry rather than protect public health.** For example, states also set their own limits for landfills that accept waste containing radium, which may be many times higher than the federal standards that do exist.

In addition, there is no federal requirement to test radionuclide concentrations in solid waste prior to disposal.[129] Despite the prevalence of carcinogenic Radium-226 and Radium-228 in Marcellus and Utica waste, none of the states in the Marcellus and Utica Shale region have consistent requirements for the testing of these radionuclides in oil and gas field waste prior to treatment and disposal:

- New York excludes NORM from regulations requiring specialized disposal and discharge of radioactive material, unless it is "processed and concentrated."[130] Any waste going into a landfill must have a minimum of 20 percent solid content; although drill cuttings often have to be dewatered and bulked with other material to meet this standard, the state does not consider this as fitting the definition of "processed or concentrated."[131] As a result, state laws governing the disposal of low-level radioactive waste do not apply to drill cuttings. In 2017, New York added TENORM to updated regulations and defines it as "naturally occurring radioactive material whose radionuclide concentrations are increased by or as a result of past or present human practices, such as manufacturing or water processing."[132]

- Regulatory agencies in Ohio prohibit operators from disposing of TENORM waste at well sites and disposal facilities can only accept wastes that have concentrations at less than 5 pCi/g above background levels—although this requirement does not apply to wastes that ODNR defines as NORM.[133] Ohio's regulatory agencies have done little testing of oil and gas field wastes to determine their radioactivity content, particularly with regard to the Utica Shale. However, in 2012, the Ohio Department of Health sampled muds from horizontal wells and found they contained concentrations of Ra-228 at almost 20 times and Ra-226 at more than 40 times the federal limit for combined radium in subsurface soil.[134] Ohio's TENORM testing requirements don't apply to "earthen material" resulting from the drilling process or to brine, both of which are classified as NORM; an exception to this "brine" rule is recycled flowback, which is considered TENORM.[135] In 2013, HB59 specifically excluded drill cuttings from the definition of TENORM.[136] Yet the state's legal definition of drill cuttings acknowledges that they "may include a de minimus amount of fluid that results from a drilling process."[137] This implies that drill cuttings (as well as other wastes such as drilling muds) may contain fluids that, if contained in any other type of waste, would qualify as "technologically enhanced" and trigger TENORM testing protocols. OEPA makes clear that landfills taking drilling muds and fracturing sand have to ensure that loads don't exceed 5pCi/g above background levels for combined Ra-226 and Ra-228.[138] However, since drill cuttings in Ohio are by definition NORM, they are not subject to requirements that solid waste facilities test for Ra-226 and Ra-228.[139]

- West Virginia addresses TENORM in the state's radiation requirements as materials "whose concentrations are increased by or as a result of past or present human practices," but excludes the "natural radioactivity of rocks and soil" from the definition.[140] According to WVDEP, the state's definitions of TENORM or NORM are not being used in the management of drilling waste, although it is possible that the state would eventually develop regulations to do so.[141]

- Unlike the other states in the region, Pennsylvania does not distinguish between NORM and TENORM with regard to drill cuttings or other types of waste, stating that, "Since naturally occurring radioactive material is brought to the surface during drilling, the wastes are classified as TENORM."[142]

B) Testing and Characterizing Waste

In order to properly manage oil and gas waste, one must first know what it contains. A 2014 study on environmental risks related to Marcellus Shale gas concluded that, "little is known about the risks associated with the solid wastes from hydraulic fracturing in the Marcellus…Characterization of their inorganic, organic, and radioactive contaminants is, at present, incomplete. A systematic study, including worker, environmental, and community risks, is needed."[143]

Subtitle D of RCRA (from which the oil and gas industry is ***not*** exempt) establishes certain minimum design and operating criteria for solid waste landfills nationwide.[144] But even though these criteria exist as 'words on paper,' states are not required to employ or enforced them. [145]

Instead, it appears that states leave it up to oil and gas operators and waste disposal facilities to define the type of waste they receive and determine the degree to which it may contain toxic substances.

In most states, waste characterization forms are used by generators of waste to document the type of waste generated and where it ends up. However, these forms allow for only basic descriptions and few require an operator to submit actual laboratory analysis of the content of the waste. In addition, operators are not required to provide sampling data for waste from every well or well site, but may be approved to use a single sample result to cover many loads or tons of waste from different locations over the course of several months or more.

For example, Pennsylvania requires generators of residual wastes to complete a chemical analysis form that has to be submitted annually to PADEP; it allows for a general description of the physical appearance of waste, but also requires documentation of chemical analysis using EPA methods, including specific constituents of Marcellus Shale wastewater.[146] However, regulations allow generators of waste to provide certification that the properties of the waste and how they were generated haven't changed from the previous year, in lieu of having to actually conduct a new analysis.[147]

Waste truck at a drilling site in Pennsylvania. Photo by Iris Marie Bloom.

Meanwhile, in New York, waste haulers have only been required to submit documentation to the state since May 2018, despite the state importing oil and gas fracking waste from Pennsylvania since at least 2011. Though this new "non-exempt Drilling and Production Waste Tracking Document" accounts for the volume of waste disposed, it does not specify the type of waste or include any chemical analysis. What's worse – as of January 2019, the New York Department of Environmental Conservation still "had not received any drilling or production waste tracking documents to date."[148]

The lack of consistent, binding protocols for the testing of the chemical constituents of raw and solidified waste prior to disposal could prove problematic for landfills and places soil and water quality in question. As long as comprehensive chemical testing is not required, and landfills instead rely on such factors as appearance and the general opinions or declarations of waste generators in order to determine how waste should be managed and disposed, the actual content of waste and its potential impacts will remain largely unknown.

C) Detecting Radioactivity

A 2015 report on TENORM in drilling wastes by Pennsylvania Department of Environmental Protection (PA DEP) stated, “Because landfills accept natural gas industry wastes such as drill cuttings and treatment sludge that may contain TENORM, there is a potential for leachate from those facilities to also contain TENORM.” In a review of data from two landfills in West Virginia that take large volumes of drill cuttings, Downstream Strategies found that leachate frequently contained concentrations of Radium-226 and Radium-228 that exceeded the federal Maximum Contaminant Level (MCL).

However, wastewater treatment plants where landfill leachate is sent for disposal do not generally monitor for Radium-226 and Radium-228 prior to release into rivers and streams because federal National Pollutant Discharge Elimination System (NPDES) permits don’t require them to. Nor is radium on the federal list of substances that landfills are required to test for as part of routine groundwater monitoring.

The data contained in the PA DEP report indicated significant levels of radioactivity associated with gas field waste management, including:

- Samples of produced water from unconventional well sites had concentrations of Radium-226 more than 20 times as high and Radium-228 more than three times as high as those from conventional well sites. Samples of horizontal drill cuttings had Ra-226 levels nearly twice as high as samples of vertical cuttings.
- Surface radioactivity on equipment used to handle and store wastewater was measured above safety guidelines; this level could increase as equipment is reused and pose a risk to the surrounding environment.
- Flowback samples had Radium-226 concentrations about 100-5,000 times higher than the EPA drinking water standard for combined radium (551-25,500 pCi/L); concentrations of Radium-228 were 50-350 times as high (248-1,740 pCi/L).
- Samples of produced water had Radium-226 concentrations 8-5,300 times higher than the EPA drinking water standard for combined radium (40-26,600 pCi/L); Radium-228 concentrations were 5-380 times as high (26-1,900 pCi/L).
- Radiation levels in filter cakes were many times higher than typical background concentrations in soil at publicly owned treatment works (POTWs), centralized/industrial wastewater treatment (CWT) plants, and zero liquid discharge (ZLD) plants that accept Marcellus Shale wastewater.

With regard to the last point, the high concentration of radiation in filter cakes indicates filtration systems are working; however, it also underscores the inherent challenges of ultimately disposing of the waste. In addition, the oil and gas industry has touted technologies such as ZLD plants as a solution to the problem of water recovery, as they remove solids from wastewater and process it for reuse in operations. Notably, the PA DEP study found that about 30% of measurements of surface radioactivity at ZLDs and 24-60% of such measurements at CWTs exceeded federal guidelines; the study report concluded that workers and members of the public may be exposed to surface radioactivity at both types of plants.

The PA DEP study used various methods to sample and test waste and facilities. Yet it is very clear that in the course of daily operations, waste facilities themselves do not conduct comprehensive testing for radiation.

Pennsylvania is among the list of states that require radiation detectors at the entrances of landfill facilities, however waste facilities and regulatory agencies may not always use the appropriate testing methods to detect radiation. Gamma radiation is used to measure Radium-226 and Radium-228 in waste samples, but it can take 21 days in the laboratory for it to emerge, as they emit alpha and beta radiation much more strongly. As a result, if waste samples used by operators and facilities to obtain permits and by regulators for monitoring purposes are not correctly analyzed, radiation concentrations in both waste and landfill leachate—and in turn the potential risks posed to health and the environment—may be underestimated.

Similarly, the radioactivity content of Marcellus Shale wastewater may be underestimated because of the use of inappropriate testing methods. A recent study points out that regulatory agencies (including PADEP and NYDEC) rely on EPA methods for testing radium in drinking water—but drilling wastewater has a much higher concentration of salts and organic materials, which can confound the methods to detect radium in the lab and to remove it in treatment plants.[149]

D) Exposure and Handling

The public can be exposed to radioactive oil and gas waste via several exposure pathways.

- **WASTEWATER "BRINE" ON ROADS** – In at least 13 states across the country, oil and gas wastewater is spread on roads for dust and ice control. According to a recent study at Penn State University, the practice concluded: "Release of a known carcinogen (e.g., radium) from roads treated with O&G wastewaters has been largely ignored. In Pennsylvania from 2008 to 2014, spreading O&G wastewater on roads released over 4 times more radium to the environment (320 millicuries) than O&G wastewater treatment facilities and 200 times more radium than spill events."[150]
- **DISCHARGE TO WATERWAYS** – Researchers have found accumulations of radium up to 650 times higher in river sediments where treated conventional oil and gas wastewater is discharged than the levels detected at sampling locations directly upstream. According to a Duke University study released in January 2018, even though "conventional oil and gas wastewater is treated to reduce its radium content," this has not prevented "high levels of radioactive build-up in the stream sediments" over time.[151]
- **LANDFILLS, PITS and SPREADING** – Wherever radioactive waste is buried or spread, rainwater can leach toxins into the surrounding landscape, including groundwater. In many oil and gas states, waste can buried on site or spread over land with minimal testing that generally does not include radioactive materials. In Texas, for example, drilling muds and cuttings can be buried onsite, with landowner consent, if chloride concentrations are 3,000 mg/L or less.[152] As part of its 2018 fiscal plan, EPA (SHC) is evaluating the performance of containment systems at hazardous waste landfills nation-wide per Subtitle C of RCRA. Due to the industry's exemption, it appears landfills for radioactive waste from oil and gas operations will not be included in the study.[153]

- **PIPE SCALE** – Pipes used in oil and gas fields collect radioactive scale that can become airborne during pipe cleaning. Without proper safety gear, workers can be exposed by breathing, eating, drinking and standing near contaminated pipes and other equipment.

Storage and Burial

A) Pits and Impoundments

Drilling waste being dumped at a landfill in Pennsylvania. Photo by David Walczak.

For decades, oil and gas operators nationwide have relied on open pits to store waste at well sites until it evaporates or can be trucked away for disposal. This practice has caused water and air contamination in several states. In 2016, Pennsylvania enacted restrictions for waste pits due to groundwater contamination and other pollution resulting from leaking and overflowing impoundments. But in other states, like California, waste pits are still the norm. In fact, the number of waste pits in California grew from 630 in 2014 to 1165 by February 2016. According to a report by Clean Water Action, 68.9% (803) of all pits in California either don't have a permit or have a permit that was issued prior to implementation of new local standards.[154]

Between 1996 and 2002, the U.S. Environmental Protection Agency (EPA) in Wyoming, Utah, Colorado, Montana, South Dakota and north Dakota conducted 475 field inspections at sites having one or more production pits or commercial facilities using disposal pits. Problems were found at 290 (more than 60%) of the sites.[155] Issues of concern included:

- Ongoing discharges to surface and groundwater were documented at 22% of the sites inspected, and those discharges were unpermitted at 35 of those sites (34% of the sites with ongoing discharges observed).
- Leaks and spills were observed from equipment, and secondary containment for oil storage tanks was inadequate or non-existent at many sites.
- Pits were improperly designed, located, and operated (including exposed oil on pits)
- Half of the pits observed were either entirely or partially covered in oil. In EPA's view, the number of sites with exposed oil on pits and bird mortality was higher than expected given that advance notice of inspections was provided to site operators.
- There were ineffective or non-existent wildlife exclusion devices at the sites.

In 2006, U.S. Fish and Wildlife reported that between 1992 to 2005, a minimum of 2060 individual birds were identified from remains recovered from oil pits," and that "92 percent of identified bird remains belonged to protected species."[156]

As waste volumes grow and drilling expands into more populated areas, the concerns about soil and groundwater pollution from waste pits, along with complaints about odors and air contaminants, continue to increase as well.

The record of such problems includes:

- A document published by New Mexico Oil Conservation Division in 2008 revealed 369 cases of groundwater contamination from waste pits.[157] The findings led to a ban on the use of pits in 2009, but the industry pushed back hard enough to win back the use of some pits in 2013.[158]
- In 2011, a comprehensive investigation of groundwater contamination from oil and gas development in Ohio found that improper construction or maintenance of production pits was the primary cause, accounting for nearly 44% (63) of all documented contamination incidents.[159]
- A 2012 study commissioned by the West Virginia DEP found that without adequate standards and oversight, impoundments and pits can be improperly constructed and built larger than allowed in their permits, in turn raising concerns about their stability and safety "due to unknown storage volumes and stresses on the foundation, slopes, and geomembrane liner systems."[160]
- A 2010 Pennsylvania DEP study identified 17 Volatile Organic Compounds in the air near a centralized waste impoundment and concluded that several of the contaminants were likely related to Marcellus shale gas activities.[161]
- In 2014, researchers in West Virginia launched a focused study of air emissions at waste storage and disposal sites, the first nationwide.[162]
- In 2014, PA DEP and Range Resources reached a settlement over several violations of five state laws, following investigations into soil and groundwater contamination at eight centralized waste impoundments in Washington County (for which the driller was fined a record $4.15 million).[163]

These trends have led Earthworks and its partners to call for a prohibition of open-air pits and impoundments and their mandated replacement with closed-loop tank systems.[164] Such systems would help prevent spills, contain volatile materials and wastes, prevent the death of migratory birds, and capture vapors; they can also be more efficient, eliminating the need for hundreds of truck trips to move waste away from well sites and enabling the transfer of contained waste directly to a processing facility.

Some oil and gas industry trade groups are on record requesting that operators use "best management practices" (BMPs) related to waste storage and processing. The Marcellus Shale Coalition urges operators to consider "[u]sing 'closed loop' fluids management systems (i.e., eliminating the need for lined earthen pits at the drilling site) where practicable."[165] The American Petroleum Institute states:

> **"Consideration should be given to the use of tanks or lined pits to protect soil and groundwater, especially for brines and oil-based fluids."[166] The Center for Sustainable Shale Development states that operators "shall contain drilling fluid and flowback water in a closed loop system at the well pad, eliminating the use of pits for all wells."[167]**

Types of Pits

PRODUCTION PITS

Used to temporarily store solid waste (such as drill cuttings), sludges (such as drilling mud and used fracturing sand), and liquid waste (such as produced water and fracturing fluids) generated during drilling and fracturing activities, production or reserve pits are located at well sites and are either dug directly into the earth or constructed above ground with embankments.

Production pits at a gas well site in Pennsylvania. Photo by PADEP.

Production pits are often included in well permits, so operators do not have to submit information about their construction and use. A significant concern with production pits is their burial onsite, a step frequently taken at the end of drilling operations as part of site reclamation. However, most regulatory agencies don't specifically track or require operators to report the number and location of buried pits, in effect allowing this method of waste disposal to occur with little oversight. As a result, **it is nearly impossible for the public to find out if waste was left behind by drillers—or how close to houses or farm fields—and, in turn, whether a buried pit is the cause of water or soil pollution that does occur.** Even though it seems obvious that waste should not be buried near a water source, it is often done anyway.

CASE STUDY

Buried Pit not Disclosed to Landowner with Contaminated Drinking Water

In 2010, after being told by her doctor to stop drinking her water, a Pennsylvania resident found out there were oil and gas waste contaminants in her water well, including arsenic, radon, and manganese.

An investigation by the nonprofit Public Herald found that a waste pit had been illegally buried by the oil and gas operator despite PA DEP denying the company's request due to the pit's proximity to the resident's water supply. Instead of requiring the pit to be removed, DEP let the pit stay buried and never told the resident about the buried waste.[168]

Judy Eckert's water supply tested positive for contaminants related to oil and gas drilling waste. PA DEP allowed an illegal waste pit to remain buried 450 feet from her private water well. Photo by Public Herald.

After her doctor found high levels of arsenic in her blood, Judy was told to stop using her water for drinking, cooking, and bathing. "What am I supposed to do," Judy stated in the documentary film *Triple Divide*, which highlighted the cover up of drinking water contamination related to oil and gas operations across Pennsylvania.

The oil and gas company, Guardian Exploration, brought Judy bottled water for over a year, but never claimed responsibility for contaminating her water by burying its waste too close to her water well. Pennsylvania DEP let the company off the hook, as well, since Judy didn't inform the Department about her water problems within six months of the company's fracking operation. A couple years later, state legislators updated oil and gas laws to include a "presumption of liability" for water complaints within 12 months of an operation. However, no one ever revisited Judy's case, which is still listed as "non-impact" in the state's water supply complaint records. ■

States do not have protocols in place to monitor whether or not buried pits remain stable and impermeable over time. An additional concern is the potentially hazardous nature of used pit liners; in 2010, EPA stated that pit liners are non-exempt RCRA waste, which means that they could meet the definition of hazardous and would need to be disposed of accordingly.[169]

Pennsylvania established regulations to guide pit burial, but reviews of well files conducted by Earthworks and partner organizations found no evidence that PADEP inspectors ensure that they are followed, such as by being present during the process (e.g., to ensure that liners don't tear and waste isn't placed closer to streams or water wells than regulations allow).[170]

PADEP has not always required operators to perform chemical analysis of waste prior to burial, despite regulatory limits on the chemical content of the leachate coming from pits.[171] In 2016, Pennsylvania updated its regulations for oil and gas surface activities, which disallowed the onsite burial of waste pits for the unconventional, or fracking, operators (Chapter 78a) but allows conventional drillers use and bury pits of drill cuttings at the well site without the need for a permit.

IMPOUNDMENTS

Impoundments pose the same risks to water, air, and soil that production pits do—except on an even larger scale. Impoundments are generally used to store either freshwater for hydraulic fracturing or waste fluids and may be constructed to service nearby wells or to support operations across a wide geographic area.

The capacity of impoundments varies with their size and depth, but some can store tens of millions of gallons of fluids. The largest impoundments are centralized waste storage facilities that service multiple well sites. Their use may also shift over time; for example, while initially permitted as a site-specific facility, Range Resources' Carter Impoundment in Washington County, Pennsylvania became the destination for contaminated waste from over 190 wells in a dozen townships.[172]

States do not maintain publicly available data on the number, size, and use of impoundments. In 2014, SkyTruth used a combination of satellite imagery and verified information submitted by residents to develop this information. The organization concluded that in 2013, there were at least 529 large pits and impoundments in Pennsylvania, more than twice as many as in 2008; current ones are now on average more than seven times the previous average size, growing from about 1,000 square meters (about 1/4 acre) to over 7,500 (nearly two acres).[173]

B) Tanks

Perhaps due to the increase in high profile contamination events from leaking pits and impoundments, more operators are storing their waste in above-ground tanks. While this is certainly a better practice than storing waste in pits lined with plastic, the reality is that tanks leak, overflow and corrode resulting in spills as well. Some states require "secondary containment" around tanks that includes earthen barriers and synthetic liners, but even then, pollution still occurs. An Earthworks analysis of violation data from Pennsylvania revealed dozens of tank-related pollution events every year between 2011 and 2018, including:

- Discharges of wastewater "brine" from corroded tanks
- Uncontrolled releases from tanks holding flowback from fracking
- Spills of liquid waste from overflowing storage tanks and secondary containment
- Leaks from faulty tank pipes and valves
- Contamination due to improper construction of tanks and containments[174]

In Pennsylvania, operators can apply for "tank farm" permits that allow for the storage of millions of gallons of toxic wastewater in one place for years at a time. These tank facilities are used to hold waste for reuse in fracking operations, which is a positive trend for the industry. However, the spills associated with onsite storage are very real. For example, a single company (JKLM Energy) operating in just one county in Pennsylvania (Potter County) was issued two "tank farm" permits in March 2019 despite receiving several violations for spills on the same frack pads where the tank farms were permitted by PA DEP:

- Nov. 2017 – Waste fluid spills, threatening pollution of waters of Commonwealth
- Dec. 2017 – Frack fluid spills, threatening pollution of waters of Commonwealth
- Feb. 2018 – Another frack fluid spill & failure to notify regulators, water pollution
- June 2018 – Failure to properly handle waste to prevent water pollution
- June 2018 (two weeks later, another waste spill) – Failure to properly report pollution incident
- July 2018 – Spill of a substance threatening water pollution & failure to properly report
- August 2018 – Failure to contain residual waste & pollution (again) of the watershed
- Sept. 2018 – Failure to remove spilled substances
- Sept. 2018 (two weeks later) – Spills from improper storage and management of waste, new violations for outstanding prior spills
- October 2018 – Pollution to waters of the Commonwealth & failure to contain drilling or fracking fluids

JKLM Energy accrued 105 violations to between April 2015 and January 2019, but only 20 enforcements, for drinking water contamination, pollution due to wastewater spills, and more. Like most oil and gas states, Pennsylvania does not have a "bad actor" policy to penalize companies that repeatedly violate the law. Instead, companies like JKLM Energy are allowed to repeatedly pollute, spill and contaminate but still get issued permits for more fracking, increased waste production, and facilities like tank farms that hold millions of gallons of toxic waste. In Smithfield Township, Bradford County, Pa., residents appealed a permit that allowed a fracking company to keep "756,000 gallons of oil and gas liquid waste in tanks for six years on a tract of land owned by Lamb's Farm Storage."[175] Residents were unwilling to assume any risk of leaks at the tank farm, which is upgradient from a pond where children swim and in the groundwater zone for residential drinking water wells.

Drilling waste storage on a "tank farm" in Smithfield Township, Pennsylvania. Photo by Joshua Pribanic.

Wastewater Disposal

"Centralized waste treatment facilities accepting oil and gas extraction (O&G) wastewaters can release pollutants into the environment that impact aquatic ecosystems and human health."

– United States Environmental Protection Agency, 2018[176]

According to Environmental Defense Fund, the oil and gas industry produces over 800 billion gallons of wastewater annually.[177] That's enough to fill over 12,116 Olympic-size swimming pools every year.

Historically, oil and gas operators have taken the bulk of their wastewater to underground injection wells for disposal. But with the advent of high-volume hydraulic fracturing, ever-increasing volumes of wastewater have overwhelmed injection wells, compromised their structural integrity, and wastewater injection has been linked to earthquakes in places like Ohio, Texas, Colorado, New Mexico and Oklahoma.

If companies can't inject wastewater underground, where is it supposed to go?

800 billion gallons of wastewater annually is enough to fill over 12,116 Olympic-size swimming pools every year.

In most drilling states, many types of industrial wastewater can be processed or diluted and then dumped into rivers. Federal and state laws impose some limits on how much pollution can be discharged to water bodies, and under the Clean Water Act (40 CFR Part 435), the direct discharge of oil and gas wastewater from fracking operations to water bodies is prohibited. However, the portion of the Clean Water Act that pertains to oil and gas, Part 435, only prohibits ***direct*** discharges of fracking wastewater to waterways – it says nothing of ***indirect*** discharges. Using this loophole, industry began taking its waste to other facilities for discharge, centralized wastewater treatment (CWT) facilities and publicly-owned sewage treatment plants.[178] This practice "severely impaired" aquatic life downstream from a discharge facility in Warren, Pennsylvania.[179]

Unusually high levels of cancer-causing trihalomethanes (THMs) were also discovered by the Pittsburgh Water and Sewer Authority and traced back to wastewater effluent discharges upstream..[180] EPA internal memos described this pollution, resulting from improper oil and gas waste disposal, as **"one of the largest failures in U.S. history to supply clean drinking water to the public."**[181]

Due to these and other pollution cases, the Pennsylvania Department of Environmental Protection (DEP) asked unconventional oil and gas operators in April 2011 to voluntarily stop taking their liquid waste to discharge facilities. But the lack of an outright prohibition led to uncertainty about which facilities continued taking unconventional (fracking) oil and gas waste since there was no enforceable regulation.[182]

Several years later, in 2016, EPA updated its Oil and Gas Extraction Effluent Guidelines to officially prohibit unconventional oil and gas wastewater from being treated at ***publicly-owned*** treatment works (POTWs).[183] However, the guidelines failed to explicitly prohibit oil and gas companies from taking their waste to ***privately-owned*** centralized wastewater treatment (CWT) facilities, which can then divert the processed waste to POTWs with whom they have agreements. Herein lies yet another loophole that allows for indirect discharge of unconventional oil and gas wastewater effluent. The accountability gap widened even further when EPA, due to a legal challenge from the industry, extended the deadline to comply with the Effluent Guidelines for certain facilities to August 29, 2019.

EPA's updated effluent standard also **fails to prohibit** facilities from accepting and discharging waste from conventional oil and gas operators, which often contains the same toxic and hazardous substances as unconventional waste.

Aerial imagery of Fairmont Brine Facility in Fairmont, WV. Source: EPA's May 2018 CWT study.

In May 2018, the EPA released a study of CWT facilities accepting and discharging oil and gas wastewater across the U.S. [184] In this study, the agency identified three ways oil and gas waste pollutants can reach the environment:

1) Through effluent discharging to surface waters either directly from a CWT facility or indirectly from publicly owned treatment works (POTWs) accepting CWT effluent,

2) During managed use of wastewater, such as irrigation,

3) By releases from storage impoundments and spills.

Despite recognizing the risks that effluent discharges pose to the environment, EPA announced a new "holistic study" the very same month, the purpose of which is to examine "whether any potential federal regulations may allow for broader discharge of treated [oil and gas] produced water to surface waters..."[185] About two months later, in July 2018, EPA entered into a Memorandum of Understanding with the State of New Mexico to explore the treatment of "wastewater from oil and natural gas extraction for re-introduction into the hydrologic cycle" for uses such as crop irrigation, livestock watering, and even drinking water.[186]

It appears the EPA is positioning itself to roll back 2016 protections by allowing even more discharge of wastewater effluent to water bodies and encouraging the reuse of the liquid for other purposes, such as irrigation and livestock watering. However, as EPA reports in its CWT study, even 'the best of the best' available technology comes with a host of issues that can threaten human health and the environment.

A) Centralized Treatment Major Concerns

Major concerns exist with regard to the treatment of oil and gas waste at centralized treatment facilities that discharge to water bodies or provide for its reuse in land or road applications:

TESTING PARAMETERS DO NOT COVER KEY CONTAMINANTS

- As noted by the EPA in its May 2018 study of CWT facilities, the "pollutants present in and characteristics of oil and gas extraction wastes can vary greatly" based on the geologic formation drilled, the type of drilling and stimulation methods, and the types and quantities of additives used.

- Although CWTs that discharge wastewater effluent into rivers or streams are required to obtain a federal National Pollution Discharge Elimination System (NPDES) permit and any applicable state permits, which require sampling of waste before discharge to water bodies, **testing parameters under these permits only partially correspond with the actual contaminants in oil and gas waste.** Current federal regulations do not require CWTs to test for key oil and gas contaminants, such as drilling and fracking chemicals, barium, strontium, bromide, gross alpha, gross beta, radium 226 and radium 228, total dissolved solids (TDS), and chlorides.[187]

- The fact that oil and gas operators are exempt from federal law from having to disclose "proprietary" chemicals used in hydraulic fracturing only further complicates the issue; regulators cannot require sampling and facilities cannot test for what they don't know may be present. Even for known chemicals, there is a lack of toxicology data available. In 2016, for example, researchers at Yale University reported that an analysis of 1021 chemicals identified in hydraulic-fracturing fluids, oil and gas wastewater, or both found "toxicity information was lacking for 781 (76%) chemicals."[188]

TECHNOLOGY DOES NOT REMOVE ALL CONTAMINANTS

- The EPA has outlined inadequate oil and gas waste treatment methods at some CWT operations and reported that "direct discharges of treated wastewater effluent from CWT facilities accepting O&G wastewater have caused environmental impacts, particularly on water quality, drinking water, and aquatic health."[189]

- A 2013 academic study found that effluent discharges from a CWT in western Pennsylvania "increased downstream concentrations of chloride and bromide above background levels." [190] Although barium and radium were substantially reduced during the treatment process, radium 226 levels "at the point of discharge were ~200 times greater than upstream and background sediments (22-44 Bq/kg) and above radioactive waste disposal threshold regulations, posing potential environmental risks of radium bioaccumulation in localized areas of shale gas wastewater disposal."

- Radium 226 has a half-life of 1,600 years, so even if technology can remove nearly all of the radioactive element, "over time even a small amount of radium being discharged into a stream accumulates to generate high radioactivity in the stream sediments." [191]

- A 2014 study by researchers at Duke University found that oil and gas wastewater effluent discharged into streams and rivers after treatment in Pennsylvania, and also spilled in West Virginia, contained high levels of ammonium and iodide, which can be toxic to aquatic life and form by-products in drinking water that are toxic to humans. [192]

CONVENTIONAL OIL & GAS EFFLUENT

- EPA's "zero discharge" of oil and gas waste to POTWs rule only applies to unconventional operators and continues to allow waste from conventional oil and gas companies to be treated and discharged from facilities that are seldom equipped to handle all known contaminants.

- According to a Duke University study released in January 2018, even though "conventional oil and gas wastewater is treated to reduce its radium content" at CWT facilities, this has not prevented "high levels of radioactive build-up in the stream sediments" over time. [193] Researchers found accumulations of radium up to 650 times higher in river sediments downstream from locations where treated conventional oil and gas wastewater has been discharged than the levels detected at sampling locations directly upstream.

- The researchers concluded: "While restricting the disposal of fracking fluids to the environment was important, it's not enough...Conventional oil and gas wastewaters also contain radioactivity, and their disposal to the environment must be stopped, too."

COMMUNITY IMPACTS

- CWT facilities require the transport of toxic, radioactive, potentially hazardous waste through and into communities, creating heavy truck traffic, air emissions, potential drinking water impacts, and the risk of pollution from spills and other releases. According to a fact sheet prepared for FreshWater Accountability Project of Ohio, and cited in EPA's 2018 study, "the likelihood of spills during transportation increases as the volume of wastewater and number of trips increases." [194] The likelihood of traffic and pedestrian accidents increases as well.

- The discharge of effluent into water bodies increases exposure risks in the places where these releases happen. Furthermore, effluent outfalls are rarely marked with any signage, and therefore water recreators (swimmers, boaters, fishermen) may not be aware of where potential exposure points exist.

- The EPA and others have also documented that CWT effluent containing high concentrations of halides, including bromide and chloride, interacts with disinfection products used in drinking water systems downstream. The byproducts of these interactions, such as trihalomethanes, can increase the risks of cancers and other human illnesses.[195] Community drinking water systems have already been impacted by trihalomethanes in Pennsylvania.[196]

- CWT facilities also cause air pollution. Wastewater can be stored and settled in open-air impoundments before the treatment process begins, in turn releasing health-harming volatile organic compounds (VOCs) into the air.[197] The EPA notes in its 2018 CWT study that "reliable data characterizing VOC emissions from active CWT facilities associated with [oil and gas] activities appear to be relatively scarce."[198] Therefore, the risk of exposure to VOCs from CWTs in nearby communities is still unknown, although the science on the health impacts of VOC pollution (ranging from respiratory to neurological problems) is well-established.

THREATS TO AQUATIC LIFE

- CWT discharges result in impacts to the biological community as well. Studies cited by EPA have documented that "macroinvertebrate and phytoplankton communities upstream and downstream of CWT discharges" show lower concentrations of pollution-tolerant species downstream.[199]

- In 2013, PA DEP found that the "Index Biotic Integrity (IBI)" at some sites downstream of CWT effluent discharges were below "aquatic life use (ALU) thresholds, meaning that those streams were not supporting aquatic life."[200]

- In 2015, another study found that survival rates of federally listed endangered mussel species diminished significantly downstream of CWT discharge as opposed to upstream.[201] Survival rates were between 80 and 100% 2 km downstream but only 20–50% 0.5 km from the waste discharge.

SPILLS & RELEASES

- A study released in 2017 determined that wastewater is one of the top three materials spilled in fracking-related activities in Pennsylvania, New Mexico, Colorado, and north Dakota.[202] Spills of untreated waste can persist in the environment for years; wastewater spills in North Dakota have persisted up to four years after spill events and included elevated total dissolved solids (TDS) and the accumulation of carcinogenic radium in soil and sediment.[203] A study of flowback spills in the Marcellus region specifically found negative impacts to aquatic life, as well.[204]

- A CWT facility operated by Eureka Resources in rural Pennsylvania, which discharges waste into the Upper Susquehanna River, has received violations from PA DEP for several years as a result of spills. In December 2014, the company was fined $25,000 for two spills of an estimated 4,400 - 6,500 gallons of "residual waste Frac-Water." In 2015, the company reported a 300-gallon spill at the facility, and the PA DEP fined the company another $15,000 for two more spills in 2017.[205]

- Oil and gas wastewater contains elevated levels of technologically-enhanced naturally-occurring radioactive materials (TENORM), and according to EPA "dissolved TENORM co-precipitates with other ions during certain treatment processes" [206] at CWT facilities. Effluent from these facilities has a wide-range of Radium 226 and Radium 288 concentrations, which correlate with levels of total dissolved solids. In other words, where there is TDS, there can be TENORM. [207] These radioactive materials accumulate in river sediments over time, making the discharge of even small amounts a cumulative problem and potential health risk.

"TENORM and associated radioactivity tends to become concentrated in the residual solids or sludge produced by the treatment unit."
— EPA

- EPA also acknowledges that "TENORM and associated radioactivity tends to become concentrated in the residual solids or sludge produced by the treatment unit." [208] TENORM enriched solid waste can also be generated during storage of flowback and produced waters before treatment. These solid wastes are then transported from CWT facilities along public roads to landfills, where TENORM can also end up in leachate.

Production pits at a gas well site in Pennsylvania. Photo by PADEP.

CASE STUDY
CWT plan defeated by broad-based opposition and concern

In 2018, plans by Epiphany Water Solutions LLC to build a centralized waste treatment facility for unconventional oil and gas fracking wastewater on the headwaters of the Allegheny River in Potter County, PA fell apart after months of debate by a broad range of voices. Residents, community groups, the Seneca Nation of Indians, and several state and federal agencies submitted dozens of technical comments highlighting a chorus of similar concerns to PA DEP and Coudersport Area Water Authority (CAMA), the municipal sewage plant through which Epiphany planned to route its fracking wastewater effluent:

- "The proposed facility…will be located in a 100-year floodplain. In the event of a flood or spill…the risk to water resources is high…USACE recommends that the permit require continual water quality monitoring of the 'treated distillate' and the discharge for parameters of concern [radioisotopes, bromide, boron, strontium, ammonia, TKN, sodium, chloride, magnesium, arsenic, benzene, lithium, and TDS]." – *U.S. Army Corp of Engineers, letter to PA DEP, January 26, 2018*
- "The federally endangered rayed bean mussel has been observed downstream of the [site]…we are concerned about water quality and mussel toxicity if the [site] begins receiving treated wastewater…" – *U.S. Fish and Wildlife, letter to PA DEP, January 26, 2018*
- "The Commission is concerned about the discharge of potentially harmful contaminants to the Allegheny River including salts, metals and radiological material…" – *Pennsylvania Fish & Boat Commission, letter to PA DEP, January 25th, 2018*
- "The CAMA POTW discharge permit [should] include influent and effluent sampling along with effluent limits or action levels…for the following parameters commonly found in flowback and produced water: TDS, benzene, ethylbenzene, toluene, xylene, barium, radium-226, and gross alpha/gross beta scans…" – *New York State Dept. of Conservation, letter to PA DEP, January 29th, 2018*

Degaweno:das (he who thunderz) of the Seneca Nation of Indians expressed opposition to a proposed fracking wastewater treatment facility at the headwaters of the OHI:YO' (Allegheny River) during a meeting in Coudersport, Pennsylvania in 2018. Photo: Steve Rubin for *Public Herald*.

CAMA withdrew its support in April, signaling the end of Epiphany's CWT plan. ■

B) Underground Injection of Wastewater

"There is no certainty at all in any of this, and whoever tells you the opposite is not telling you the truth. You have changed the system with pressure and temperature and fracturing, so you don't know how it will behave."

– Stefan Finsterle, a leading hydrogeologist at Lawrence Berkeley National Laboratory[209]

Many types of industries dispose of their waste underground. Injection wells aid in this process, pushing everything from medical fluids to motor oil into porous rock formations (such as limestone or sandstone). Over the last decade, the most common disposal practice for oil and gas wastewater has involved injection into Class II brine disposal wells. These wells, however, have failed to contain wastes, contaminated nearby areas, and induced small earthquakes.

Two active underground injection control wells in Ohio. Photos by Donna Carver.

As part of mandates under the Safe Drinking Water Act (SDWA), the EPA oversees the Underground Injection Control (UIC) program, which includes six classes of wells.[210] Designated specifically for the oil and gas industry, most of the estimated 180,000 Class II wells nationwide accept produced water to increase pressure and aid in the recovery of oil and gas, but many are used for the disposal of wastewater, fluids, and sludges.[211]

According to federal estimates, at least two billion gallons of oil and gas liquids are injected underground every day and, along with the shale gas and oil boom, the number of Class II wells in use grew 20% (28,000 wells) from 2005 to 2012.[212] EPA can grant approval for states, U.S. territories and tribes, to hold primary enforcement responsibility for UIC activities, a status known as "primacy."[213] For Class II wells, states seeking primacy have to demonstrate that they have an "effective program" and will follow a set of federal criteria, but not federal regulations (in contrast to the primacy standard for all other classes of UIC wells).[214]

In managing UIC programs, states with primacy have responsibility for issuing permits, inspecting wells, enforcing regulations, and collecting and reporting data to EPA.

Underground Injection (UIC) Program Quality

In a 2014 report on the federal UIC program, the U.S. Government Accountability Office (GAO) concluded that:

- The safeguards many states currently have in place to protect groundwater "do not address emerging underground injection risks, such as seismic activity and overly high pressure in geologic formations leading to surface outbreaks of fluids"
- The EPA is not consistently conducting key oversight and enforcement duties for Class II wells to ensure that requirements are being upheld.[215]
- In addition, GAO emphasized that unless UIC-related regulations adopted by states (such as those related to seismic activity, discussed below) are incorporated into federal law, EPA may not be able to enforce them if violations occur that states leave unaddressed.[216]

Concerns over the potential impacts of wastewater injection on water and soil quality and private property have spurred objections to new projects by residents and local officials. In West Virginia, the United States Geological Survey (USGS) discovered contaminants from an unconventional oil and gas waste injection well in nearby streams and sediments.[217] In Pennsylvania, EPA recently issued an injection well permit despite widespread opposition by residents and county officials.[218] Opposition to new injection wells in eastern Ohio is on the rise,[219] while West Virginia residents have enlisted state and national environmental groups to fight the renewal of a permit for an older injection well.[220]

In the meantime, the growing need for disposal capacity is likely to continue to drive the debate over injection wells. In a recent interview, an Ohio Department of Natural Resources employee indicated that "market demand" would dictate Ohio's policy on how many new injection wells to permit, and that more would inevitably be needed as Utica Shale development expands.[221] It is possible that over time, operators will seek to reopen plugged conventional wells from past oil and gas drilling in sandstone and limestone formations and convert them to waste disposal wells. The GAO report noted that, "If

U.S. EPA Underground Injection Well Inventory (2017)

State or Tribe	Class II Disposal, (Number of Wells)
Texas	13,143
Kansas	5,445
Oklahoma	4,358
Louisiana	2,903
Ohio	2,219
California	1,775
Illinois	1,100
Osage Nation	1002
New Mexico	927
Michigan	876
Arkansas	818
North Dakota	601
Mississippi	571
Wyoming	458
Colorado	383
Montana	271
Indiana	214
Nebraska	151
Kentucky	112
Alabama	94
Utah	83
Ute Tribe (Uintah and Ouray)	79
West Virginia	58
Alaska	50
Southern Ute Tribe	34
Fort Peck Tribes	30
Florida	20
South Dakota	19
Navajo Nation	19
Pennsylvania	15
Virginia	13
Fort Berthold (MHA Nation)	13
Nevada	12
Missouri	10
Blackfeet Nation	10
Saginaw Chippewa Tribal Nation	8
New York	6
Wind River	5
Pawnee Nation	5
Iowa	4
Tennessee	2
Comanche Nation	2
Jicarilla Apache Nation	2
Apache Tribe	2
Ute Mountain Ute Tribe	1
Ponca Nation	1
Washington	1

https://www.epa.gov/uic/uic-injection-well-inventory the number of available Class II wastewater disposal wells remains the same, the volume of injected fluid in each well must increase to accommodate the increased wastewater" — even though the impacts of this trend remain unknown.[222]

Seismicity

Several recent seismic events have been linked to the hydraulic fracturing process; an even larger number are now known to have resulted from underground wastewater injection.[223] The essential reason is that injection increases pressure on faults, causing them to slip; however, questions remain regarding the precise relationship (e.g., distances from UIC wells to earthquake epicenters and the time it takes for a seismic event to occur after injection).

According to the National Academies of Sciences, at least 27 cases of seismic activity caused by or likely related to wastewater injection (for both disposal and secondary oil and gas recovery) have been documented in the United States the last several decades.[224] The report recommends the adoption of policies and practices to map and evaluate the risk of induced seismicity at both existing and planned injection well sites and to reduce injection volumes, rates, and pressures.

Federal regulations do not currently address seismic risk from underground waste injection, despite the fact they've known about these risks since 1951.

Federal regulations do not currently address seismic risk from underground waste injection, although they include some potentially related construction requirements designed to protect underground sources of drinking water (such as injection pressure and loading and the "physical characteristics" of the injection zone).[225] EPA's UIC National Technical Workgroup issued recommendations in 2015 to minimize the risk of injection-induced seismicity, including assessment of sites for the likelihood of activating faults, reduction of pressure, and seismic monitoring.[226] However, the agency is clear that these are non-regulatory "practical steps" for states and operators to consider and are also "within the [state] Class II Director's discretion to apply."

Seismic Events Across the States

- Earthquakes measuring 3.0 or greater linked to wastewater disposal by injection in Oklahoma increased from two in 2008 to about 900 by 2015. Regulators ordered some disposal wells to shut down, and required others to decrease the speed and volume of disposal.[227]

- In 2010, a series of earthquakes ranging from 2.2-3.4 on the Richter scale were set off in an area (Braxton County) with a history of seismicity, near a Class II injection well that had recently begun to inject wastewater from Marcellus Shale operations.[228] WVDEP reduced the maximum injection volume allowed at the site, and in 2012 began requiring UIC permit applicants to provide information on subsurface faults, fractures, and other aspects related to seismic activity.[229] WVDEP later allowed the operator of the Braxton well (Chesapeake Energy) to increase injection pressure again, although no additional seismic monitoring was required; in 2012, another earthquake (magnitude 2.8) occurred near the site.[230]

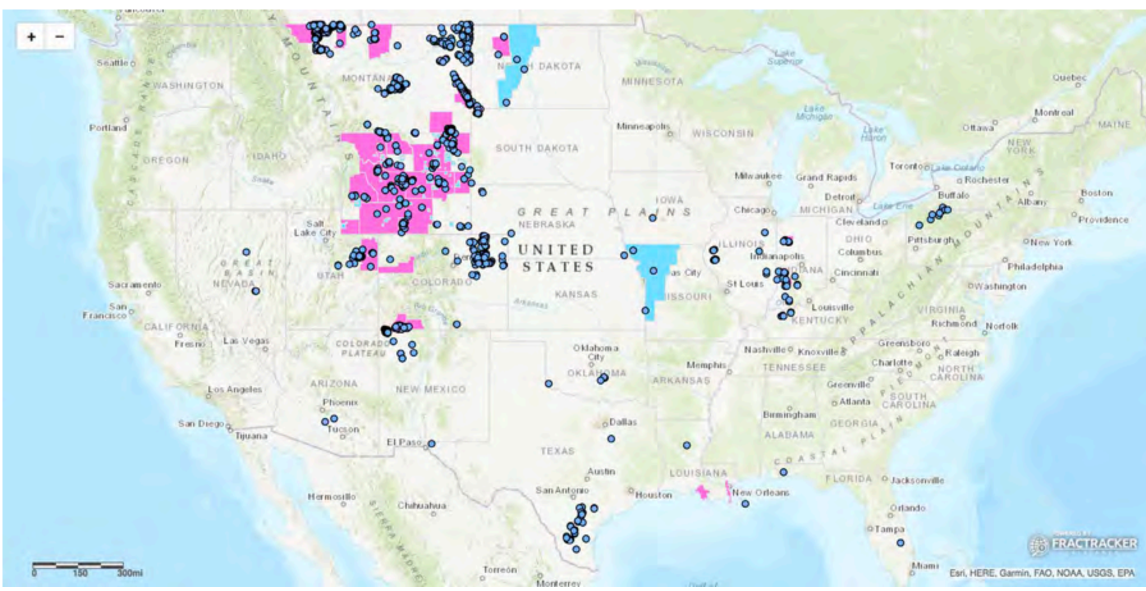
- The number of earthquakes measuring 2.5 or greater in the Delaware Basin of Texas tripled to more than 60 per year, according to the U.S. Geological Survey. Nine man-made earthquakes rattled the Dallas-Fort Worth area in 2015.[231]

- Following a series of over 100 earthquakes in northeastern Ohio in 2011-2012—12 of which registered at nearly 2 and one almost 4 on the Richter scale—researchers at Columbia University confirmed the cause to be drilling wastewater disposal at a large injection well.[232] The well was subsequently shut down, and in 2012, ODNR and legislators revised the Ohio Administrative Code to require operators of deep underground injection wells in certain formations (ranging from about 1,000-13,000 feet) to survey the location for potential faults, submit a plan for monitoring seismic activity, conduct pressure tests, and potentially limit the rate and volume of injection.[233] In 2014, two more injection wells were shut down following another earthquake.[234]

- Seismometers recorded 1,881 quakes along the border of New Mexico and Colorado between 2008 and 2010, 1,442 of them are in New Mexico. Colorado also saw a swarm of 12 quakes in 2001 and a 5.3 quake in 2011 that have been linked to oil and gas wastewater injection wells by U.S. Geological Service.[235]

Aquifer Exemptions

The U.S. EPA grants Aquifer Exemptions to energy and mining companies for the underground disposal of liquid waste in aquifers that are not currently used as sources of drinking water. As of January 2017, there were 3,300 aquifer exemptions, and 95% of them were for Class II injection wells for oil and gas waste disposal.[236] The majority exist in Colorado, Wyoming, Texas, Utah, Montana, and Indian Country, but there are several in Pennsylvania, Indiana, and Illinois as well.



FracTracker Alliance map of aquifer exemptions in the U.S. as of October 2017. The full, interactive map is available at https://www.fractracker.org/2017/10/aquifer-exemptions/. Blue dots represent aquifer exemptions.

The "exemption" is specifically from portions of the Safe Drinking Water Act that prohibit contamination of drinking water resources and effectively allows companies to pollute groundwater sources. While these aquifers exist at depths typically not used for drinking water, increasing water scarcity nationwide may change the viability of these aquifers as freshwater sources. Destroying aquifers for oil and gas waste disposal only exacerbates the water scarcity problem in the U.S.

Pressure and Leaks

Even as oil and gas companies set their sights on new injection wells (and aquifers) to increase disposal capacity, current facilities are receiving increasing volumes of waste. As seen in Table 1, the volume of waste injected underground in Ohio and Pennsylvania increased significantly between 2011 and 2014 once fracking took hold, raising the question of whether capacity can ultimately keep pace with the volumes of waste being produced. In West Virginia in 2010, 12% of flowback fluid (the only waste systematically reported by operators) was disposed of in UIC wells, and this increased to 26% in 2011 and 35% in 2012.[237] According to data available from Pennsylvania, the proportion of injected waste coming from Marcellus Shale wells also increased from 79% in 2011 to 93% in 2014.[238]

Table 1: Volume of waste disposed of at injection wells in barrells - Ohio and Pennsylvania (2011-2014)

	YEAR				% CHANGE
Ohio	**2011**	**2012**	**2013**	**2014**	**2011-2014**
	12.6 million bbl	14.1 million bbl	16.4 million bbl	22 million bbl	+75%
Pennsylvania	**2011**	**2012**	**2013**	**2014**	**2011-2014**
	2.8 million bbl	4.3 million bbl	3.5 million bbl	4 million bbl	+43%

Ohio figures based on annual injection well fee data provided by ODNR to the Center for Health, Environment, and Justice.
Pennsylvania figures calculated using "injection well" (as disposal method) data from PADEP's Oil & Gas Reporting website, "State data downloads, waste."

The increase in waste disposed of underground raises the possibility that injecting more into a well than it can handle may compromise the stability of UIC wells to the point where they can fail and leak either underground or at the surface. When this happens, toxic waste may enter drinking water sources, agricultural land, or migrate onto neighboring properties. Possible causes include the location of injection wells near natural faults, which can cause cracks in the rock where fluids are injected, and old oil and gas production wells, which provide openings through which contaminants spread. In addition, seismic activity near injection wells can damage casing or cementing, allowing waste fluids and chemicals to leak out.[239]

An in-depth investigation by ProPublica of UIC well records, cases, and government documentation found that from 2007-2010, one well integrity violation was issued for every six deep injection wells nationwide (more than 17,000 violations) and over 7,000 wells were known to have leaking walls.[240] Documents also revealed over 1,000 instances in which facility operators pumped waste into Class II wells at pressure levels they knew could fracture rock and possibly result in leaks.[241]

In 2013, environmental and citizen's organizations and residents in Ohio wrote to the Region 5 Administrator of EPA asking for a full audit of the state's ability to manage its UIC program, in large part because ODNR has not taken enforcement action in numerous cases when inspectors found regulatory violations at injection wells.[242] A key example is the Ginsburg injection well, which has been cited for failing mechanical integrity tests, spilling oil and brine, and causing significant erosion in the surrounding area since 1986, when ODNR stated that it "presents an imminent danger to public health or safety or is likely to result in immediate substantial damage to natural resources."[243] Yet despite citation for numerous violations, an ODNR order to cease operations, and indication that the health of animals and people nearby might be at risk, the injection well has continued to operate.

Storage pit at the Ginsburg injection well, Ohio. Photo courtesy of Athens County Fracking Action Network.

In West Virginia, in 2014, a resident living near the Lochgelly site, together with national and state organizations, filed a legal appeal to WVDEP's continued allowance of waste injection—despite the fact that the operator didn't have a valid permit for extended periods of time and had failed to comply with state orders related to violations for waste management and stream monitoring.[244] Residents have collected extensive evidence that the injection well's sediment pits are failing and leaking. Tests by a Duke University scientist from a stream below the facility indicated elevated levels of chloride, bromide, manganese, strontium, and barium, which are typically found in oil and gas wastewater."[245]

According to the Government Accountability Office (GAO), few states have reported any instances of water contamination resulting from UIC well leaks; between 2008 and 2012, neither Ohio nor Pennsylvania reported any such cases.[246] However, GAO has also emphasized that states don't generally conduct groundwater monitoring near injection wells, since "When it first developed the UIC program and its regulations, EPA considered, but did not include, monitoring of groundwater for contamination as a means of evaluating the effectiveness of the program and its safeguards."[247]

Between 2001-2010, one out of every six injection wells had violations related to the well's structural integrity, and over 7,000 of them had leaking walls.

Actual contamination resulting from leaking injection wells is therefore likely to be detected only when state regulatory agencies conduct investigations following complaints from residents or other evidence of damage to groundwater emerges. GAO has also criticized Ohio for not requiring operators to test or disclose the chemicals in its waste before injecting it underground, an omission that poses a risk to groundwater—the only one of the eight oil and gas producing states that the GAO examined for its recent report that doesn't have such rules.[248]

Lochgelly injection well and sediment pits in West Virginia, with seepage at the surface. Photo courtesy of DirtySecretWater.com.

"Beneficial" Reuse

Any industry, factory, or company that generates waste faces complications and costs in getting rid of it. With this in mind, states offer the option to reconfigure various types of waste to serve other purposes. This process often results in new products; for example, water treatment sludge or food processing waste may become agricultural fertilizer and old tires may be used to make fuel.

Along with the increase in volume and types of waste generated, oil and gas operators are seeking new ways to repurpose both solid and liquid waste. In light of ongoing questions about the content and environmental risks of drilling waste, concerns also exist about the safety of alternative uses—as well as whether regulatory agencies are taking the steps necessary to safeguard against risks posed to air, water, and soil.

Many states have established beneficial use determination (BUD) programs and regulations to guide the review of proposals to repurpose waste and related permitting and restrictions, including Colorado, New York, Ohio, and Pennsylvania, and Texas.[249] Overall, BUD requirements stipulate that only solid or residual (i.e., not hazardous) wastes can be re-used, that the resulting product must be similar or analogous to the existing one it is intended to replace, and that the new product will not harm the environment or human health. West Virginia does not have BUD programs for oil and gas waste but has adopted regulations for the beneficial use of specific wastes (such as coal combustion products, scrap tires, and sewage sludge).[250]

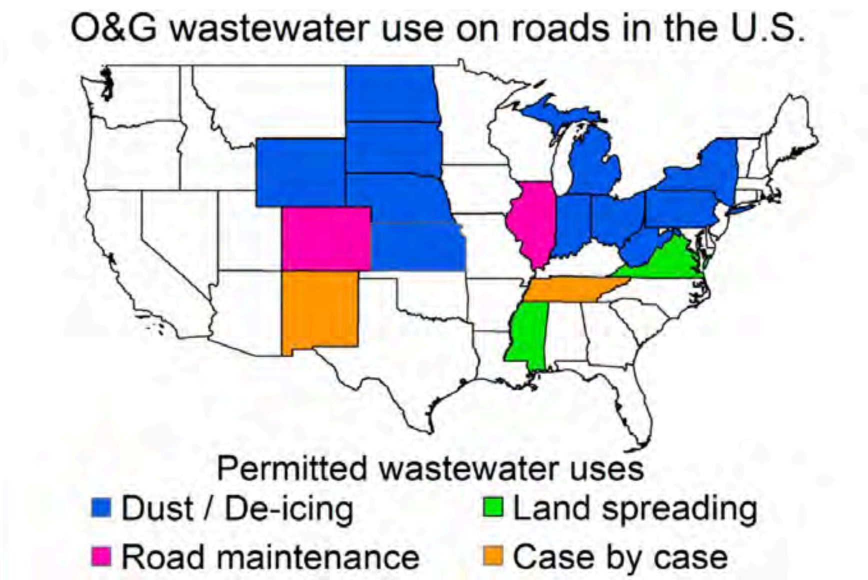
Under Pennsylvania's BUD program, CleanEarth Resources has conduct at least two experimental "Research and Development (R&D)" programs using horizontal Marcellus Shale drill cuttings as fill material at reclamation and construction sites in the state. Though the company reported the project a success, PADEP relied on the company and its affiliates to make that determination.

New Mexico is working with U.S. EPA on new rules to beneficially reuse fracking wastewater for irrigation, livestock, and even drinking water.[251]

A) Road Spreading

Currently, the most widespread repurposing of oil and gas waste is the spreading of brine on roads for dust control and de-icing. The primary environmental concern with this practice is the high levels of salt, chloride, radioactive elements (e.g., radium) and chemical contaminants (e.g., benzene and toluene) in the waste used, which can harm human health, aquatic life, and vegetation. This happens when melting snow and rain carry toxins into soil, streams, rivers, and groundwater.

Currently, Colorado, Ohio, New York, North Dakota and West Virginia are among 16 states that allow road-spreading of "brine," which in this context appears to be limited to produced water (i.e., not flowback or other fluids) from conventional (non-fracked) oil and gas operations. Pennsylvania allowed brines from conventional gas wells to be used as a dust suppressant and stabilizer on unpaved roads until May 2018 when the PA DEP revoked approvals for the process during a lawsuit, conceding that those approvals had been issued in error.[252] Though the state's approvals were developed using the state's Clean Streams Law, Solid Waste Management Act, and oil and gas regulations,[253] PA DEP never approved of road-spreading as a BUD process.



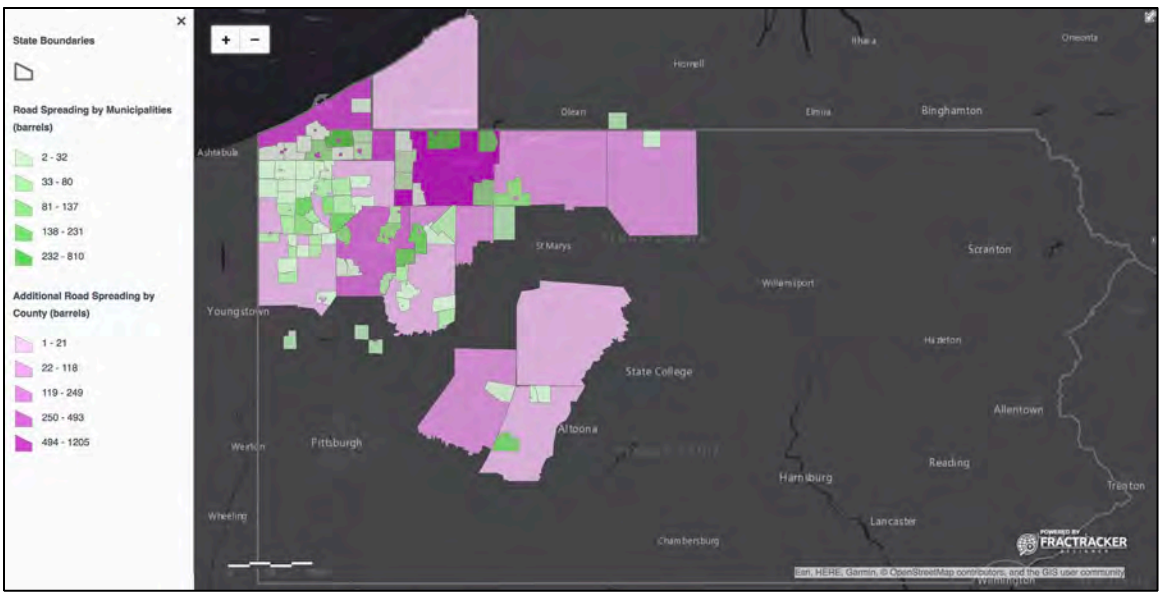
Road spreading of oil and gas wastewater is used in these states. (Credit: Tasker, et al https://pubs.acs.org/doi/10.1021/acs.est.8b00716)

Truck spreading brine in New York. Photo courtesy of No Fracking Way.

The states still approving road-spreading have varying requirements, including those related to the testing of chemical content, allowable limits of total dissolved solids, calcium, chloride, and other contaminants, methods used, and the rate of application (i.e., the amount of waste that can be spread on a given area of road). However, key gaps remain, such as the exclusion of radionuclides in testing requirements and the testing of only "representative samples" of waste submitted by operators and waste haulers rather than testing samples from each source. The testing of each source of wastewater is important, as noted by EPA in its 2012 comments on New York's draft environmental impact statement on high-volume hydraulic fracturing: *"[T]he actual concentration and/or radioactivity of contaminants in the produced water spread on land or roads would be unknown at any given time, since the amount and type of contaminants in produced water varies from well to well and even in the same well over time unless each truckload is tested."*

All four Marcellus Shale states prohibit the use of brine from shale gas formations for road-spreading, which contains even higher concentrations of contaminants, and the use of flowback, which contains fracturing chemicals. However, they lack processes to confirm that the brine used is not, in fact, derived from the Marcellus or Utica Shale or a mix of produced water and flowback. In addition, even conventional brine can potentially affect the environment, depending on how it is treated and applied and the degree to which it becomes diluted or concentrated as it enters soil and water.

A 1990 study of the road-spreading of conventional oil field brine in Ohio found that the practice caused chloride concentrations in nearby groundwater to exceed EPA drinking water standards two-fold in the winter and five-fold in the summer.[254] Ohio's 2004 guidance for road-spreading of brine details high concentrations of heavy metals (e.g., mercury, lead, and barium), hydrocarbons, and volatile organic compounds.[255] Most recently, a 2015 PADEP study on TENORM concluded that the potential exists for recreationists using roads treated with brine to be exposed to radiation, and recommended that the radiological environmental impacts of using oil and gas field brine for dust suppression and de-icing be studied further.[256]



Map of oil and gas liquid waste applications to roads in Pennsylvania by FracTracker Alliance. To see the full, interactive map visit https://www.fractracker.org/2017/08/roadspreading-og-waste-dumping/.

CASE STUDY: Pennsylvania "BRINE" Spreading Debate

A heated debate over road spreading of conventional oil and gas wastewater or "brine" has recently transpired in Pennsylvania. The debate hinges on new research and a lawsuit against the PA DEP.

While researching centralized waste treatment facilities in PA, Dr. William Burgos and his team at Penn State University discovered that "road spreading" was a recurring disposal method for many oil and gas operators in the state. Surprised by this, his team turned their attention to collecting samples from municipal "roadmasters" for testing.

> "We didn't know exactly what it meant in the beginning; we didn't even think it was real," Dr. Burgos told a reporter.[257]
>
> "We went deep on the 14 samples that we collected that were spread on roads in 2017 and characterized them for far more than what appeared on the certificate of analyses [required by PADEP], including the obvious ones with respect to salt, total dissolved solids, sodium chloride, calcium, et cetera," Dr. Burgos added. "We also looked at other metals such as iron and lead, and radioactive elements such as radium, and organic compounds."

Burgos's team found elevated radium at higher levels than anticipated. Of the 14 samples, the median amount of radium detected was 1.230 picocuries per liter. The drinking water standard is 5 picocuries per liter, and the industrial wastewater standard is 60 picocuries per liter. Some samples tested even higher, up to 2,270 piC/L.

Wastewater like the samples tested by Burgos et. al. has been spread on Pennsylvania roads for 30 years. Radium has a half-life of 1,640 years and can accumulates in the environment where it is repeatedly exposed. It is also a known carcinogen that increases the risk for bone, breast, and liver cancer.

At the same time Burgos's team was conducting its study, the *Siri Lawson vs. Commonwealth of Pennsylvania, Department of Environmental Protection* case was playing out before the Environmental Hearing Board. During that case, the PADEP conceded that it violated the law by issuing approvals for road spreading of oil and gas waste.

Just weeks after repudiating its policy allowing road spreading of wastewater for dust control, the Department reported that it was engaged in a process to legalize approvals of wastewater for road spreading. Earthworks quickly formed a coalition of allies, and with nearly 40 signatories submitted a letter to PA DEP on July 31, 2018 asking the Department to cease its efforts to resume road spreading approvals and instead investigate the environmental health impacts of oil and gas wastewater dispersal on roads over the last 30 years.[258] After receiving no response for months, our coalition sent another letter in November. As of March 15, 2019, PA DEP has still not responded.

In response to the Department's cessation of road spreading approvals, two bills were introduced in March 2018 aimed at rolling back regulations for the conventional oil and gas industry that compel PADEP to resume approvals for the road spreading of brine – HB 2154 and SB 1088. Though Governor Tom Wolf has vowed to veto the bills, his tenure ends in just a few years. Therefore, the fate of waste spreading also lies in the hands of the next Governor. ■

B) Creating New Materials

Oil and gas operators are increasingly finding ways to monetize their waste products by creating new materials. While ingenuity can reduce the amount of overall waste that ends up in landfills, rivers, etc., the testing regimes for these products are not sufficient to ensure protection of public health and the environment

DRILL CUTTINGS

Drill cuttings are being used by grinding and mixing them with other materials. According to the Argonne National Lab, potential uses for drill cuttings include stabilization materials for roads and well sites, construction materials, road pavement, cover material at landfills, and fillers in concrete, brick, or asphalt manufacturing.[259] The lab notes that extensive treatment and washing of drill cuttings is necessary to adequately remove hydrocarbons, salinity, moisture, and other contaminants, but that operators nonetheless seek to develop new products because, “The economics of this approach is rarely based on the value of the finished product, but rather on the alternative cost for the other disposal options.”[260]

The Texas Railroad Commission allows oil and gas companies to use drilling cuttings as “road base” and fill material, as well as construction and bulking agents for cement. Cuttings must be tested for metals, chloride and Total Petroleum Hydrocarbons but not radioactive materials.[261]

In Pennsylvania, DEP has allowed companies to use contaminated soils, drill cuttings, and pipeline cuttings to create roads, drilling sites and construction materials. In 2011, a company called CleanEarth opened a Research and Development (R&D) facility and processed more than 80,000 tons of shale cuttings by the end of 2013 for projects demonstrating that the waste could be used to cap contaminated brownfield sites, to construct well sites, as a road base, and in mine reclamation.[262] Following required testing, Clean Earth estimated that 10% of the waste it collected for R&D processing wasn’t usable because of excessively high levels of radioactive materials and contaminants such as arsenic, lead, and barium.[263]

In December 2013, the Pennsylvania DEP granted a permit to Range Resources to conduct R&D on the use of drill cuttings in the creation of construction materials at gas well sites. Earthworks and its partners recommended to PA DEP that the permit be rejected because the proposed project would occur near protected streams and the applicant failed to provide critical information on substances that the waste contained. The groups’ primary concern was that the application didn’t meet legal requirements for a BUD. PADEP failed to analyze and address the long-term and cumulative impacts of the project on water resources and the surrounding community.[264]

Established in Ohio in 2012, enerGREEEN360 promises to use “chemical and geotechnical-modified solutions” to engineer new construction and fill materials from drilling waste; in turn, the company would provide the materials to be used in land and building development projects.[265] In early 2014, ODNR authorized enerGREEN360 to operate a facility that would blend drill cuttings with coal ash to create construction materials for a nearby industrial park; the company claimed this could be done as a “beneficial use.”[266] However, ODNR approved the project through a “Chief’s Order” that circumvents public notification requirements and local government review.[267]

ODNR has not yet developed regulations on the beneficial use of drilling waste, which the passage of HB59 in 2013 enabled the agency to do.[268] At the same time, Ohio law stipulates that any material from a horizontal well can be used in any manner that is authorized as a beneficial use, as long as it is not defined as TENORM— from which HB59 specifically excludes drill cuttings.[269] As a result, Ohio has opened the door to using drill cuttings to create new products, but has no regulations to help ensure that future uses would actually be more "beneficial" than harmful.

SALT PRODUCTS

The oil and gas industry's liquid waste has been used for a variety of commercial and industrial purposes over the years. But never has the "beneficial use" of its wastewater been so grossly applied, or so close to home, as it is today. Liquid waste from drilling and fracking operations contain high levels of salts, and companies are now creating commercial products that use those salts for other uses.

The treatment of liquid waste from fracking at high-tech centralized wastewater treatment facilities involves the removal of salts from the chemical slurry. In recent years, one company in Pennsylvania – Eureka Resources – has been permitted by state regulators to sell the leftover salt to companies like Clorox, Cargill, Walmart, Home Depot and Lowes. This was exposed by a Public Herald investigation, which also revealed that Eureka has been packaging the salt byproduct as "Clorox Pool Salt" for distribution since 2017.[270] Earthworks took the investigation one step further and found that Eureka's "frack salt" is also used by Cargill to prepare and preserve animal hides after meat processing.[271]

Though Eureka's salt is tested for an array of toxic constituents, analysis does not include a full list of fracking chemicals since companies are not required to reveal the chemicals used for fracking. A study released in 2015 confirmed that wastewater from oil and gas fracking operations is carcinogenic. [272] But the companies using oil and gas wastewater to make products for the mainstream market fail to mention this.

Another company, misleadingly named Nature's Own Source, manufactures a product called AquaSalina for de-icing roads. AquaSalina is approved by Ohio Department of Natural Resources (ODNR) for de-icing and dust suppression on roads despite the agency finding that the product contained high levels of the carcinogenic Radium-226 and Radium-228 — more than 300 times higher than federal limits for drinking water – during a 2017 study that was initially withheld from the public.[273]

AquaSalina is also used by the Pacific Northwest Snowfighters Association (PNSA), which evaluates the safety of products used for winter road maintenance. However, according to the PNSA's protocols, radioactive materials present in oil and gas waste — such as Radium-226, which has half-life of 1,600 years — is not part of the testing regime. AquaSalina is also used in several states across the U.S.[274]

AquaSalina is described on the company website as "natural saltwater solution produced from ancient seas." But Dr. John Stolz at Duquesne University has tested AquaSalina from bottles he bought online from Lowes. "AquaSalina is not just ancient sea water, nor is it just salt brine," Stolz said. "It's a complex chemical mixture that includes toxic and radioactive elements."

C) Reuse and Recycling

With volumes of liquid waste growing, oil and gas companies have sought to reuse wastewater and fluids, either at the well site where it is generated or in operations elsewhere. The quest for effective methods to treat the waste has also been driven by a growing need to reduce the use of freshwater, particularly in arid regions. Recycling has also been touted by industry as a way to reduce waste transport and disposal.[275]

In order to reuse it, wastewater has to be stored and processed onsite, upping the potential for spills and leaks that can lead to soil and groundwater contamination. Emerging science on reuse and recycling of wastewater and fluids indicate inherent challenges in treating contaminated waste products so they can be used again, including the high-saline content of produced water from shale formations; interactions between contaminants in the wastewater with chemicals used in hydraulic fracturing; and the accumulation of radioactive material in waste each time it is reused, which itself can pose environmental and health risks and disposal challenges.

In 2014, researchers at Rice University identified chemicals present in fracturing fluids and potential methods to remove them, finding that certain treatments could actually increase toxic compounds (e.g., organobromides).[276] A 2015 PADEP study on TENORM found high levels of radiation in filter cakes and effluent from centralized/industrial wastewater treatment (CWT) and zero liquid discharge (ZLD) plants.[277] (See section on radioactivity for more information.) **Such evidence underscores the potential risks posed by new wastes created in the process of treating shale gas wastewater and fluids, and the inherent challenge of disposal.**

In addition, the ability of operators to reuse wastewater and fluids may diminish over the long-term. In 2013, researchers from the University of Pittsburgh and Pennsylvania State University noted that, "The wastewater reuse program represents a somewhat temporary solution to wastewater management problems in any shale play…As the well field matures and the rate of hydraulic fracturing diminishes, the field becomes a net water producer because the volume of produced water will exceed the amount of water needed for hydraulic fracturing operations."[278]

Numerous oil and gas companies, as well as entrepreneurial "start-ups," have invested in the development of technologies to solve these problems, but the costs and complexities of wastewater recycling systems—especially ones that can fit diverse geologies and water chemistries—have also been prohibitive.[279]

But other "opportunities" for the reuse of wastewater are on the horizon.

Currently, the EPA is studying recent developments in treatment technologies that could open the door for increased discharge of treated fracking wastewater into rivers and reuse for agriculture, ice and dust control on roads, and more. According to EPA, "Some states and stakeholders are asking whether it makes sense to continue to waste this water, particularly in water scarce areas of the country, and what steps would be necessary to treat and renew it for other purposes."[280]

The EPA entered into an agreement with New Mexico in 2018 to "to clarify the existing regulatory and permitting frameworks related to the way produced water from oil and gas extraction activities can be re-used, recycled, and renewed for other purposes."[281] A white paper was published in January 2019, and a bill was passed in New Mexico in March 2019 compelling regulators to create rules that cover the compels the commission to adopt regulations for the use of produced water for "road construction maintenance, roadway ice or dust control or other construction, or in the application of treated produced water to land" and "for surface water discharges."

Data on the volume of waste that is reused and recycled are scarce, although rates as high as 90 percent have been claimed for Marcellus Shale operators.[282] As detailed in Table 2, data reported by unconventional operators in Pennsylvania indicate lower rates; in addition, **the proportion that is reused or recycled has not kept pace with the volume generated.** Reuse/recycling rates have also dropped significantly among conventional operators, along with volumes of waste produced. Available data from operators in West Virginia for an earlier period show a similar trend, with the percent of total flowback waste that was reused decreasing from 88% in 2010 to 73% in 2011 to 65% in 2012.[283]

The disposal type "reuse other than roadspreading" makes up the highest proportion of reused/recycled waste reported by Pennsylvania operators. However, it is unclear what this means in terms of actual applications or whether the waste is reused at the same well site or transported to other locations. The other and less frequently reported disposal type, "centralized treatment plant for recycle," implies that the treated liquids would be returned to the operator for further use (e.g., in hydraulic fracturing). However, without comparable data from the treatment plants, it is impossible to know how much was returned to operators for secondary uses, or disposed of in other ways.

Table 2: Reuse and recycling of liquid waste, Pennsylvania - 2011-2014

	Total barrels of waste	Total barrels reused and recycled	% of all waste that is reused	% of all waste that is recycled
Unconventional wells				
2011	20.2 million	17.5 million	56%	31%
2012	29.1 million	24.7 million	70%	15%
2013	32.3 million	24.4 million	67%	9%
2014	41.3 million	25.7 million	62%	0.11%
% Change (2011-2014)	**+104%**	**+47%**	--	--
Conventional wells				
2011	5.7 million	4.6 million	21%	59%
2012	7.1 million	5.3 million	42%	34%
2013	4.3 million	668,000	15%	0.05%
2014	4 million	700,000	17%	0.06%
% Change (2011-2014)	**-30%**	**-400%**	--	--

Figures calculated using operator data submitted to PADEP, Oil & Gas Reporting website, "State data downloads, waste" spreadsheets. Includes volumes for waste disposal categories "centralized treatment plant for recycle" and "reuse other than roadspreading" for unconventional and conventional wells. Types of waste reported include drilling, fracking, and produced fluids.

5 — The State of the States

Every oil and gas producing state faces a challenge in how to dispose of growing volumes of waste. Some variation exists in the actual content of waste (e.g., levels of salt and radioactivity) and in disposal locations (e.g., whether geology allows for underground injection). But what is consistent across states and nationwide are the risks posed to water, soil, air, and health from improper waste management.

Regardless of where it is generated, oil and gas field waste contains chemicals, heavy metals, and other contaminating substances—which ideally would be identified prior to disposal, at facilities that are designed to handle the waste in question. Earthworks' Still Wasting Away investigation includes supplemental reports for nine oil and gas states: California, Colorado, New Mexico, New York, North Dakota, Ohio, Pennsylvania, Texas, and West Virginia. Each report reviews regulatory structures, oversight processes, tracking and reporting specific to these key states.

To see the state reports, visit Earthworks.org/still-wasting

Conclusions

Across the U.S shale states, a "create now, figure it out later" view has guided the regulatory and policy response to a growing stream of drilling waste.

This process reflects the norm of regulatory and policy change, which generally occurs in response to existing problems and only when public concern and pressure to take action mount.

Oil and gas states like Pennsylvania, New York, New Mexico and Colorado have addressed oil and gas field waste management in distinct ways and taken steps in the past to improve regulations, operator practices, and data collection. However, there is still a very long way to go. All states have missed the mark, and these seven key trends explain why:

1. **The classification of oil and gas field waste as residual or solid, rather than as industrial or hazardous**. This makes it possible for operators and regulators to treat oil and gas waste like other wastes and to use existing treatment and disposal systems. States do not govern the waste based upon its characteristics, i.e., they do not determine if waste is actually hazardous according to RCRA Subtitle C's definition (were it not exempted by EPA).
2. States are beginning to face the inherent challenges of oil and gas waste management by revising particular regulations and addressing emerging problems. **However, initiatives continue to be piecemeal and reactive, and gaps in regulations and oversight remain.**
3. **The division of responsibilities across regulatory agencies and departments prevents the comprehensive oversight** of waste generators, transporters, and disposal facilities and hampers the consistent application of regulations and policies.
4. Waste tracking and reporting systems are limited and operators and waste facilities have wide discretion in deciding how to characterize and dispose of waste. The result is **general, incomplete information that is not verified by regulators.**
5. **Publicly available data are limited**, making it difficult to fully assess or verify the origin, volumes, types, and ultimate destination of gas and oil field waste. This is the case both within each state and even more so when it crosses state borders. Data discrepancies between volumes reported from one state regulatory agency to another, when data are available, make it even more impossible to understand how much waste is going where.
6. **EPA is only now getting a handle on the Centralized Wastewater Treatment (CWT) facilities accepting unconventional oil and gas drilling and fracking waste,** yet these facilities are currently in operation and already discharging to water bodies. Allowing CWTs to continue discharging effluent while the EPA considers potential rules or standards or these facilities creates unknowns and potential hazards.
7. **The fracking chemicals used remains a mystery.** Despite having a general idea of what kinds of chemicals are used for fracking, companies still have the ability to keep the particular chemical

mixture for specific operations a secret. Without knowing the exact chemical makeup of fracking waste, it is impossible to ensure safety with proper testing.

These trends reflect a status quo of oil and gas waste management that poses current and future risks to the environment and human health, particularly as drilling continues to expand. In all of the states examined, inconsistent regulations and data gaps call into question the adequacy of state oversight.

EPA's 1988 decision that oil and gas waste did not need to be regulated as hazardous under RCRA was based largely on the assumption that states would be able to oversee waste management going forward. Yet our in-depth review of the regulatory frameworks, reporting and tracking systems, and current practices in nine oil and gas states makes it clear that, 30 years later, this assumption was incorrect.

In the meantime, a growing body of science on the chemical and radioactive characteristics of oil and gas wastes indicates that, if properly tested, it is likely that at least some of the waste generated would meet established criteria for classification as hazardous (i.e., ignitability, corrosivity, reactivity, and toxicity). In addition, practices are in place in oil and gas states that are enabled by the RCRA exemption but which cause specific problems that are not being fully addressed. These include:

- The absence of "cradle to grave" tracking of waste, i.e., from the well site where it is created to the location where it is ultimately disposed.
- The lack of comprehensive analysis of wastes to determine whether their chemical content and characteristics would in actuality render them hazardous.
- Processing, and disposal of waste at municipal landfills and wastewater treatment plants, rather than at specialized facilities.
- Re-use of oil and gas wastes under "beneficial use" laws, which do not allow hazardous waste to be used for such purposes (e.g., road-spreading or construction materials).
- Underground injection of wastewater and fluids in Class II wells, rather than the more stringently constructed and regulated Class I wells designed for hazardous materials and industrial liquids.

The projected expansion of oil and gas development nationwide challenges the presumption that current storage, treatment, and disposal methods and the capacity of existing facilities will be sufficient going forward. Yet as the quest to increase domestic oil and gas production continues, nearly absent from any debate on both the state and federal levels is the imperative for operators to responsibly classify the waste they create.

Until measures are in place to ensure that these steps are taken, oil and gas waste management will continue to be, at its core, an experiment—one with potentially serious consequences for environment and communities nationwide.

Recommendations

Despite years of unconventional oil and gas development, and decades of conventional development, states have failed to adequately manage oil and gas waste. Since the initial 2015 release of this report, there has been little improvement. Therefore, our recommendations from 2015 remain the same. **To stem further risks to water, soil, air quality, and the public, immediate action must be taken at the federal and state levels.**

- **The federal exemption for oil and gas waste in the Resource Conservation and Recovery Act should be reversed—an action that Earthworks and its partners have called for in the past.** In addition, individual states, rather than emulate the current federal exemption to hazardous regulations, should build stronger protections based on the physical characteristics of waste (ignitability, corrosivity, reactivity, toxicity), not the politically-derived definitions of regulatory code.

- **Apply hazardous waste policies to oil and gas wastes through new regulations and/or legislation.** This would ensure that oil and gas operators follow the same rules as other similar industries; if the wastes they create meet the definition of hazardous, they should be managed as such.

- **Implement "cradle-to-grave" waste tracking and reporting systems that are comprehensive, consistent, binding, verifiable, and transparent.** These would require online forms for operators and databases for regulatory agencies that encompass origin, destination, transport, volumes, types, and disposal method. Although operators, transporters, and waste facilities would provide this information, regulatory agencies should adopt mechanisms to verify its accuracy and compare records from different parties. The data should be accessible to any agency or division managing waste, with primary responsibility for oversight held by oil and gas divisions. All reports and data should be made available online to the public. Regulatory agencies in different states should share information and ensure that waste transported across borders is properly recorded, tracked, and disposed of.

- **Prohibition of open-air reserve pits and centralized impoundments;** only fully contained, "closed-loop" storage and treatment systems should be allowed.

- **Prohibition of the burial and land-spreading of waste.** All waste should be safely removed from well sites within established timeframes related to well development and completion stages, and be included in well restoration guidelines.

- **Expansion of existing bonding or adoption of new financial assurance mechanisms for oil and operators that cover the costs of waste removal,** in order to ensure that the public does not bear the burden of long-term environmental remediation.

- **Prohibit the application of "beneficial use" laws and permitting processes to oil and gas wastes, including but not limited to the road-spreading of wastewater and creation of new construction or pavement materials.** Currently, it does not appear that the chemical and radioactive content of oil and gas wastes meet the same standards as any other municipal, solid, or residual waste considered for beneficial use applications, Nor that new products can be deemed no more harmful than the original products they are intended to replace.

- **Require treatment and disposal of wastes at specialized facilities designed and equipped to remove chemicals, radioactive elements, total dissolved solids, metals, and other contaminants.** Municipal landfills and wastewater treatment plants should be prohibited from accepting all oil and gas field wastes, conventional and unconventional.

- **Require operators to conduct comprehensive, consistent testing of wastes before they leave the well site.** All data should be submitted to regulatory agencies, provided to both waste transporters and disposal facilities, and made available to the public. This step is necessary to ensure that the wastes are properly characterized and taken to appropriate facilities, and would give regulators the opportunity to require operators to use different testing and management protocols if necessary.

- **Require disposal facilities to obtain consistent, detailed documentation from waste generators and transporters regarding the type, characteristics, and content of waste.** State regulators should revise their waste characterization forms to include binding standards for allowable concentrations of chemicals, radioactivity, and other contaminants and to ensure that operators submit testing results from certified, independent laboratories. Factors such as "operator knowledge" or written declarations should not be considered a sufficient means of verification.

- **Require operators and disposal facilities to test all oil and gas wastes that are diluted, downblended, solidified, or bulked with other materials, prior to disposal.** Testing should be based on comprehensive parameters for chemicals, radioactivity, and other contaminants and be conducted by certified, independent laboratories. States should conduct studies and develop related regulations that detail the materials and processes that are allowed and prohibited, and establish limits on all potential contaminants in "mixed" products.

- **Adopt policies for the frequent monitoring of groundwater, surface waters, sediment, soil, leachate, and effluent from and near waste treatment and disposal facilities.** Regulatory agencies should approach waste management as an ongoing process that requires follow up and continuous monitoring for changes in environmental conditions.

- **Test and handle radioactive oil and gas wastes according to more stringent guidelines.** Drinking water standards are the wrong standards for any oil and gas waste stream, because there over 2,000 chemicals used for hydraulic fracturing or present in produced water for which there is no drinking water standard. Waste needs to be tested for what is actually there, and fact that radioactivity is "naturally occurring" should never be the basis for declaring a waste safe for disposal. Agencies with experience in the testing, detection, and handling of radioactive material should be involved with the management of oil and gas wastes that contain radioactivity. Existing regulations related to radioactive material should be expanded to include oil and gas wastes.

- **Strengthen standards for current and future underground injection control well facilities that accept oil and gas wastes, including but not limited to comprehensive chemical testing;**

more frequent injection rate and pressure monitoring; mapping and analysis of faults and seismic risk; and stronger leak detection systems.

- **Apply a "zero discharge" prohibition on all oil and gas wastewater from treatment facilities.** Specially-equipped, centralized wastewater treatment facilities should only be permitted for the treatment of produced water and flowback for recycling purposes so as to reduce the use of freshwater resources. There should be no reuse of wastewater effluent for agricultural or livestock watering without comprehensive and continuous testing, and the salt byproducts from specialized treatment facilities should be used in applications that have no connection to food, water or soil.

'Loophole Economics'

In 1988, the EPA concluded that regulation of oil and gas wastes under RCRA was unnecessary due to **1)** economic concerns for the industry and the fact that **2)** "gaps in State and Federal regulatory programs [could] be effectively addressed by formulating requirements under Subtitle D of RCRA and by working with the States;"[284]

EPA, once again compelled by consent order, must now revisit RCRA Subtitle D. As this report clearly demonstrates, the regulatory gaps with regard to this industry's waste streams are (still) both wide and deep. EPA can fill these gaps by following Earthworks' recommendations above.

But as the agency looks ahead at the future of oil and gas waste regulation, perhaps the most beneficial change EPA could make would be to regulate oil and gas waste based on its physical properties, rather than 'loophole economics.'

> **By loophole economics, we mean the theoretical defense which alleges that regulations threaten the economic viability of oil and gas companies, and that the industry should therefore be exempt. This exemption effectively serves as a subsidy, and this argument, which has never been thoroughly vetted, is being made by one of the richest industries in the world.**

In 1979, the American Petroleum Institute estimated that regulation under RCRA's hazardous waste standards would cost the oil and gas industry "$45 billion over a 20 to 25 year period for compliance with siting, monitoring, fencing, and closure requirements."[285] By now, that estimate may have changed, but if we carry the API's math forward, the industry, together as a whole, would have paid an estimated $1.8 to $2.25 billion dollars a year to treat its hazardous waste as hazardous.

Instead, those costs have been socialized, unfairly diverted onto unsuspecting communities and future generations. Meanwhile, in the 30 years since RCRA was enacted, the oil and gas industry has earned hundreds of billions of dollars in profits.

In 2008, Exxon broke profit records by earning $11.7 billion in their second quarter alone.[286]

According to CNN Money's Global 500[287] Royal Dutch Shell's annual net earnings were over $30 billion in 2012. That same year, Exxon Mobil's profits were over $41 billion, BP's over $25 billion, Chevron's over $26 billion, ConocoPhillips' over $12 billion.[288] These companies landed five of the top ten positions in 2012 for most profitable corporations in the world, and together, they alone profited over $137 billion dollars in a single year.

In 2011, these same companies earned over $80 billion. In 2010, their collective profits exceeded $63 billion, for a total of more than $280 billion dollars in just three years. Remember, API said it would cost $45 billion to comply with waste regulations over 20-25 years.

In other words, the oil and gas industry could have afforded to treat hazardous waste as hazardous more than 30 years ago--and they most certainly can now. Starting with these five major players, it is the industry itself that can and should set the bar for better environmental protection standards by lobbying for the closure of federal loopholes, because they can afford to comply with the law. And while it is true that hazardous waste regulations will have more impact on smaller players, the costs of tracking, testing, and disposing of hazardous waste should be balanced by the marketplace, not by stripping away the laws that protect us. The costs of proper waste management is simply the cost of doing business, and should be guided by accountability, not dumped onto the American taxpayer in the form of pollution and health impacts.

It is clear that the absence of federal hazardous waste standards for the oil and gas industry has created many problems with mismanagement, evidenced by the growing list of pollution sites, lack of clear data, the transport of waste across state lines to where permits are easier to procure, and the duplicate lack of hazardous waste standards for oil and gas at the state level.

Whether by removing the RCRA loophole altogether, or adding requirements for the safe and scientifically based tracking, monitoring, and disposal of potentially hazardous oil and gas waste to the requirements of RCRA Subtitle D, it's well past time that the United States regulate all hazardous wastes, regardless of origin, according to what they really are – hazardous.

Methods

Earthworks took the following steps to assess the policy and regulatory context and trends associated with oil and gas waste:

- Identification of key aspects of waste management and related challenges.
- Review of laws and regulations related to waste management in California, Colorado, New Mexico, New York, North Dakota, Ohio, Pennsylvania, Texas, and West Virginia, both generally and with regard to the definition, storage, treatment, handling, and disposal of waste.
- Review of research studies, reports, and other documentation related to the content, management, and risks of different types of oil and gas waste.
- Analysis of data availability and relevant gaps in reporting and tracking.

Much of the data referenced throughout the report were obtained through secondary sources. However, figures in the tables and other sections that required original calculations are based on data gathered and provided by state regulatory agencies. Because data often don't exist or are not available to the public, it was not possible to develop figures on several aspects of waste discussed in the report or to consistently compare trends across all states (e.g., volumes and disposal method). In addition, any available state data are self-reported by oil and gas operators, and could not be verified.

Endnotes

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[1] U.S. Energy Information Administration (2018). Frequently Asked Questions. Retrieved from https://www.eia.gov/tools/faqs/faq.php?id=709&t=6.

2 Oil Change International (January 2019). Drilling Toward Disaster: Why U.S. Oil and Gas Expansion Is Incompatible with Climate Limits. Retrieved from http://priceofoil.org/2019/01/16/report-drilling-towards-disaster/.

[3] Kondash, Andrew J., et al. (2017) Quality of flowback and produced waters from unconventional oil and gas exploration. Science of The Total Environment, 574, pp. 314-321. doi: 10.1016/j.scitotenv.2016.09.069.

4 Tara Kinsell, "Rejected waste taken to Idaho." *Washington Observer-Reporter*, July 12, 2013.

[5] EPA, Regulatory Determination for Oil and Gas and Geothermal Exploration, Development, and Production Wastes. 53 FR 25447, 1988.

[6] U.S. Energy Information Administration, Distribution of U.S. Oil and Natural Gas Wells by Production Rate. Report. December 2017.

[7] PSE Healthy Energy, "Toward consistent Methodology to Quantify Populations in Proximity to Oil and Gas Development: A National Spatial Analysis and Review." Environmental Health Perspectives. 2017.

8 T.H.W. Goebel el al., "The spatial footprint of injection wells in a global compilation of induced earthquake sequences," Science (2018).

9 U.S. EPA. TENORM Oil and Gas Production Wastes. Retrieved from https://www.epa.gov/radiation/tenorm-oil-and-gas-production-wastes. (Accessed December 3, 2018).

10 Clark CE, Veil JA. Produced Water Volumes and Management Practices in the United States. Argonne, IL:Environmental Science Division, Argonne National Laboratory (September 2009). Available: http://www.ipd.anl.gov/anlpubs/2009/07/64622.pdf [accessed 10 November 2018].

11 U.S. Energy Information Administration (2016). Rankings: Total Energy Production by State. Retrieved from https://www.eia.gov/state/rankings/#/series/101/.

[12] M. Betcher and M. Glass. Oil and Gas Liquid Waste in West Virginia. Downstream Strategies, January 8, 2019.

[13] Kondash, A.J., Lauer, N.E., Vengosh, A. "The intensification of the water footprint of hydraulic fracturing." *Science Advances*, Vol. 4, no. 8. August 15, 2018.

[14] Allison Stine, "Far away from witnesses, my small town is being poisoned by fracking waste." *The Guardian*, September 21, 2017.

[15] Joaquin Sapien, "What can be done with wastewater?" *ProPublica*, October 4, 2009.

[16] Clean Water Action, press releases on the McKeesport case: http://www.cleanwateraction.org/press/groups-reach-settlement-mckeesport-gas-drilling-wastewater-dumping-case; and the Waste Treatment Corporation case: http://www.cleanwateraction.org/press/settlement-reached-lawsuit-over-alleged-illegal-discharge-gas-drilling-wastewater-pennsylvania

[17] Lamont-Doherty Earth Observatory, "Ohio Quakes Probably Triggered by Waste Disposal Well, Say Seismologists." Press Release, January 6, 2012.

[18] ODNR Emergency Action, Ohio Administrative Code, Chapter 1501, Section 9-3-06. July 2012. http://oilandgas.ohiodnr.gov/portals/oilgas/pdf/UIC_emergency_rule_9-3-06.pdf

[19] Jennifer Reeger, "Man pleads guilty to dumping millions of gallons of waste*." Pittsburgh Business Tribune*, February 11, 2012.

[20] Anya Litvak. "Marcellus Shale waste trips more radioactivity alarms than other products left at landfills." *Pittsburgh Post-Gazette*, August 22, 2013.

[21] Tara Kinsell, "Rejected waste taken to Idaho." *Washington Observer-Reporter*, July 12, 2013.

[22] Susan Phillips, "EPA Fines XTO Energy for Lycoming County Frack Water Spills." StateImpact, July 18, 2013.

[23] Marie Cusick, "Attorney General Files Criminal Charges Against XTO for Wastewater Spill." StateImpact, September 10, 2013.

[24] Mike Soraghan, "Spills up 17 percent in US in 2013." EnergyWire, May 12, 2014.

[25] Peter Mantius, "New York imports Pennyslvania's radioactive fracking waste despite falsified water tests." DC Bureau, August 14, 2013.

[26] Katie Colaneri, "DEP seeks record fine against driller as AG files criminal charges." StateImpact, October 7, 2014.

[27] James F. McCarty, "Fracking company owner pleads guilty to ordering toxic waste dumped into Mahoning River." *Cleveland Plain Dealer*, March 24, 2014.

[28] Don Hopey, "West Virginia won't accept additional drilling waste tainted with radioactivity." *Pittsburgh Post-Gazette*, May 29, 2014.

[29] Keith Matheny, "Michigan landfill taking other states' radioactive fracking waste*." Detroit Free Press*, August 19, 2014. Documents on waste processing obtained through a FOIA request by Ban Michigan Fracking; http://banmichiganfracking.org/?p=2405

[30] Don Hopey, "Range Resources to pay $4.15 million penalty." *Pittsburgh Post Gazette*, September 18, 2014.

[31] Susan Phillips, "Congressional Watch-Dog Warns Fracking Waste Could Threaten Drinking Water." StateImpact, July 28, 2014.

[32] Don Hopey, "Pa. studies on shale-site air emissions incomplete, according to court documents." *Pittsburgh Post Gazette*. October 20, 2014.

[33] Riverkeeper, "The Facts about New York and Fracking Waste." County Bans. http://www.riverkeeper.org/campaigns/safeguard/gas-drilling/the-facts-about-new-york-and-fracking-waste/#

34 Cozzarelli, I.M. et al. (2017). Environmental signatures and effects of an oil and gas wastewater spill in the Williston Basin, North Dakota. Sci. Total Environ., 579, 1781-1793.

[35] USGS, Indication of Unconventional Oil and Gas Wastewater Found in Local Surface Waters." *USGS GeoHealth Newsletter*, Vol. 13, No. 1. (2016).

[36] Jon Hurdle, "Court tells EPA to review its rules on oil and gas waste." StateImpact PA, December 29, 2016.

[37] "Pennsylvania Fines Fracking Company $1.2M For Leak That Tainted Groundwater." Lexis Legal News, March 9, 2017.

[38] Laura Legere, "EQT fined $1.1 million for Marcellus Shale pit leak," *Pittsburgh Post-Gazette*. May 31, 2017.

[39] Lorraine Chow, "North Dakota Plagued by Oil Spills: 745 in One Year." EcoWatch, May 4, 2017.

[40] "Sources of Radium Accumulation in Stream Sediments Near Disposal Sites in Pennsylvania: Implications for Disposal of Conventional Oil and Gas Wastewater," N. Lauer, N. Warner, A. Vengosh, Environmental Science and Technology, Jan 4, 2018, DOI: 10.1021/acs.est.7b04952

[41] Siri Lawson v. DEP, EHB Docket No. 2017-051-B

[42] "Environmental and Human Health Impacts of Spreading Oil and Gas Wastewater on Roads," T. L. Tasker, W. D. Burgos, et al., Environmental Science & Technology, May 30, 2018, 52 (12), 7081-7091 DOI: 10.1021/acs.est.8b00716

[43] "ODNR study finds alarming radiation levels in de-icer being sold to consumers," *Columbus Dispatch*. July 4, 2018.

[44] Don Hopey. "Radium found in commercial roadway de-icing, dust suppression brine." *Pittsburgh Post-Gazette*, July 2, 2018.

[45] Kondash, A.J., Albright, E., Vengosh, A., "Quality of flowback and produced water volume from unconventional oil and gas exploration." Science of the Environment 574 (2017) 314-321.

[46] Joshua B. Pribanic, "Clorox Selling Pool Salt Made From Fracking Wastewater." *Public Herald*, February 11, 2019.

[47] Figure calculated using data in PADEP's Oil & Gas Reporting Website, state downloads of waste reports.

[48] ODNR, OEPA, and ODH. "Landfill acceptance and disposal of waste substances from horizontal wells—update." Memo to waste facility operators, November 17, 2014. See description of the Paint Filter Liquids Test (Method 9095B) at http://www.epa.gov/osw/hazard/testmethods/sw846/pdfs/9095b.pdf

[49] Email exchange between Robert Showronek at the Office of Waste Management and Radiological Protection, Michigan Department of Environmental Quality, and Sylwia Chrostowski, Michigan Disposal, Inc., August 2014. Obtained via FOIA request by Ban Michigan Fracking; http://banmichiganfracking.org/?p=2405

[50] Hamilton, I.S., et al., "Radiological assessment of petroleum pipe scale from pipe-rattling operations." Health Physics 87(4): (2004) 382-397.

[51] Argonne National Laboratory, "Solidification and stabilization." Fact sheet, http://web.ead.anl.gov/dwm/techdesc/solid/index.cfm.

[52] Personal communication, Bill Hughes, Wetzel County Solid Waste Authority. See EPA, "Radiation Protection: Coal Fly Ash, Bottom Ash, and Boiler Slag." http://www.epa.gov/radiation/tenorm/coalandcoalash.html

[53] Letter to ODNR from EnviroClean Services re: Request for Temporary Authorization. December 24, 2013.

[54] EPA. "Exemption of Oil and Gas Exploration and Production Wastes from Federal Hazardous Waste Regulations." 2002.

[55] Emmarie Huetteman, "EPA Issues Rules on Disposal of Coal Ash to Protect Water Supply." *New York Times*, December 19, 2014.

[56] Michael C. Mensinger, Amir Rehmat, Satish Saxena, and N.S. Rao. "Treatment Technology for Auto Fluff." *ACS Fuels.* 1993.

[57] N. Lauer, N. Warner, A. Vengosh, "Sources of Radium Accumulation in Stream Sediments Near Disposal Sites in Pennsylvania: Implications for Disposal of Conventional Oil and Gas Wastewater," *Environmental Science and Technology* (2018)

[58] Tiarra Braddock,"Rome Twp officials are concerned about future of their dirt roads," WJET YourErie.com, July 31, 2018.

[59] Konkel, L., "Salting the Earth: The Environmental Impact of Oil and Gas Wastewater Spills." Environmental Health Perspectives, December 1, 2016.

[60] U.S. EPA, "Unconventional Oil and Gas Extraction Effluent Guidelines." https://www.epa.gov/eg/unconventional-oil-and-gas-extraction-effluent-guidelines. Accessed July 13, 2018.

[61] Vidic, R.D., Brantley, S.L., Vandenbossche, M., Yoxtheimer, D. and Abad, J.D. "Impact of Shale Gas Development on Regional Water Quality." *Science*. Vol. 340. 2013.

[62] US Office of Fossil Energy, "Produced water R&D." http://energy.gov/fe/science-innovation/oil-gas/shale-gas-rd/produced-water-rd.

[63] Crosby, L.M., Tatu, C.A., Varonia, M., Charles, K.M., Orem, W.H. "Toxicological and chemical studies of wastewater from hydraulic fracture and conventional shale gas wells." *Environmental Toxicology and Chemistry*, 2018.

[64] U.S. EPA, "Hydraulic Fracturing for Oil and Gas: Impacts from the Hydraulic Fracturing Water Cycle on Drinking Water Resources in the U.S.," December, 2016.

[65] Paul Ziemkiewicz, John Quaranta, and Michael McCawley, "Practical measures for reducing the risk of environmental contamination in shale energy production." *Environmental Science,* 2014.

[66] E. Hansen, D. Mulvaney, and M. Betcher. Water Resource Reporting and Water Footprint from Marcellus Shale Development in West Virginia and Pennsylvania. Downstream Strategies and San Jose State University, 2013.

[67] Paul Ziemkiewicz, John Quaranta, and Michael McCawley, "Practical measures for reducing the risk of environmental contamination in shale energy production." *Environmental Science,* 2014.

[68] US Occupational Safety and Health Administration, "Hydraulic fracturing and flowback hazards other than respirable silica." 2014.

[69] Horwitt, Dusty, J.D., "Keystone Secrets: Records Show Widespread Use of Secret Fracking Chemicals a Looming Risk for Delaware River Basin, Pennsylvania Communities." Partnership for Policy Integrity, September 11, 2018.

[70] Paul Ziemkiewicz, John Quaranta, and Michael McCawley, "Practical measures for reducing the risk of environmental contamination in shale energy production." *Environmental Science,* 2014.

[71] Ted Auch, FracTracker, "Utica Shale Drill Cuttings Production—Back of the Envelope Recipe." May 2014. http://www.fractracker.org/2014/05/utica-drill-cuttings-production/.

[72] CleanEarth and Penn State Extension. "Recycling & Reuse of Marcellus Shale Drill Cuttings." Presentation, December 2013.

[73] M. Glass and K. Hatcher. Comments on Proposed Changes to the West Virginia Solid Waste Management Rule, 33CSR1. Downstream Strategies, 2014.

[74] US Occupational Safety and Health Administration, "Drilling fluid." https://www.osha.gov/SLTC/etools/oilandgas/drilling/drillingfluid.html.

[75] West Virginia Water Research Institute. Assessing Environmental Impacts of Horizontal Gas Well Drilling Operations. WVDEP, 2013.

[76] Mamdouh Sabour, "Oil & Gas Industry Waste Management." Innovative Environmental Solutions Center, December 12, 2015.

[77] Larry Shilling, "Disposal of Oil & Gas Waste." Casella Resource Solutions, October 3, 2015.

[78] Schlumberger, Oilfield Glossary. https://www.glossary.oilfield.slb.com/en/Terms/s/scale.aspx, Accessed Sept. 11, 2018

[79] US EPA, Welcome to RadTown USA. https://www3.epa.gov/radtown/index.html, accessed Sept. 12, 2018.

[80] US EPA, https://www.epa.gov/landfills/municipal-solid-waste-landfills, accessed Sept. 11, 2018.

[81] M. Glass and K. Hatcher. Comments on Proposed Changes to the West Virginia Solid Waste Management Rule, 33CSR1. Downstream Strategies, 2014.

[82] McMahon, Jeff. "Strange Byproduct of Fracking Boom: Radioactive Socks." Forbes, July 24, 2013.

[83] N. Lauer, N. Warner, A. Vengosh, "Sources of Radium Accumulation in Stream Sediments Near Disposal Sites in Pennsylvania: Implications for Disposal of Conventional Oil and Gas Wastewater," *Environmental Science and Technology* (2018)

[84] Data provided in a response letter from PADEP to US Representative Matthew Cartwright, November 7, 2014. Disposal method based on PADEP's Oil & Gas Reporting Website, state downloads of waste reports.

[85] Exemption of Oil and Gas Exploration and Production Wastes from Federal Hazardous Waste Regulations (PDF), US EPA. October 2002. https://archive.epa.gov/epawaste/nonhaz/industrial/special/web/pdf/oil-gas.pdf

[86] 42 US Code §6901 (b)(2).

[87] A Regulatory Determination is an agency decision founded on authority granted by the US Congress to determine specific details of legislation based on its expertise in the field.

[88] 42 US Code §6903-6992; RCRA § 1004(5).

[89] EPA, RCRA Orientation Manual, Chapter III: RCRA Subtitle C – Managing Hazardous Waste; 40 CFR §261.20 et seq.

[90] Public Law §96-482.

[91] 42 U.S.C. § 6921(b)(2)(B).

[92] EPA, "Crude Oil and Natural Gas Waste." www.epa.gov/osw/nonhaz/industrial/special/oil/

[93] EPA, Report to Congress, Management of Wastes from the Exploration, Development, and Production of Crude Oil, Natural Gas, and Geothermal Energy. Vols. 1-3 EPA530-SW-88-003 (1987).

[94] EPA. "Regulatory Determination for Oil and Gas and Geothermal Exploration, Development and Production Wastes." 53 Federal Register. §25446, 25447. 1988.

[95] 53 Federal Register §25454 and RCRA §3001(b)(2)(A).

[96] 53 Federal Register §25448.

[97] 53 Federal Register §25447.

[98] EPA. "Regulatory Determination for Oil and Gas and Geothermal Exploration, Development and Production Wastes." 53 Federal Register. §25446. 1988.

[99] Steve Horn, "Documents: How IOGCC Created Loophole Ushering in Frackquakes and Allowing Methane Leakage." DeSmog Blog, April, 15, 2016.

[100] "Making A Difference: a historical look at the IOGCC." IOGCC Newsletter, January 2006

[101] STRONGER, www.strongerinc.org.

[102] STRONGER, 2017 Edition Guildelines, https://www.strongerinc.org/stronger-publishes-guidelines-produced-water-pipelines/.

[103] STRONGER, "A Report and History of STRONGER and the State Review Process," January, 5, 2016.

[104] NRDC, "Petition for Rulemaking Pursuant to Section 6974(a) of the Resource Conservation and Recovery Act Concerning the Regulation of Wastes Associated with the Exploration, Development, or Production of Crude Oil or Natural Gas or Geothermal Energy." September 8, 2010.

[105] IPAA, "Oil and Natural Gas RCRA Exemption Under Attack," September 10, 2010.

[106] U.S. Envtl. Prot. Agency, Office of Solid Waste, EPA530-K-01-004, *Exemption of Oil and Gas Exploration and Production Wastes from Federal Hazardous Waste Regulations* (2002)

[107] Environmental Integrity Project, "Court Approves Settlement for EPA Rules on Drilling and Fracking Waste," December 29, 2016. http://www.environmentalintegrity.org/news/court-approves-settlement-for-epa-rules-on-drilling-and-fracking-waste/.

[108] Exemption of Oil and Gas Exploration and Production Wastes from Federal Hazardous Waste Regulations (PDF), US EPA. October 2002. https://archive.epa.gov/epawaste/nonhaz/industrial/special/web/pdf/oil-gas.pdf

[109] Earthworks obtained the pre-draft revisions to OAC Chapter 1501:9-1-10 on Facilities from staff at partner organizations in Ohio.

[110] Pennsylvania Code, Title 25, Chapter 261a, Subchapter A (General).

[111] Pennsylvania Solid Waste Management Act. House Bill 1840, Act 97, July 1980. §401, Hazardous Waste.

[112] West Virginia Code, §22-18-6(2)(A) (iv).

[113] West Virginia Code, §22-18-6(2)(A).

[114] NY DEC, Chapter IV, Quality Services, Part 371, "Identification and Listing of Hazardous Wastes." Exclusions, section 371.1 (e)(2)(v).

[115] NY DEC, Chapter IV, Quality Services, Part 371.3, "Characteristics of Hazardous Waste."

[116] Environmental Advocates of New York, "Water Rangers Host Toxic Fracking Cocktail Party for NYS Senate." Press release, June 6, 2012.

[117] Earthworks, et. al., Recommendation letter to NYDEC RE: Part 360 Series Regulations, Solid Waste Management Facilities. July 21, 2017

[118] Kondash, A.J., Lauer, N.E., Vengosh, A., "The intensification of the water footprint of hydraulic fracturing." Science Advances, Vol. 4, no.8 (2018).

[119] US Geological Survey. Water Resources and Shale Gas/Oil Production in the Appalachian Basin—Critical Issue and Evolving Developments. 2013.

[120] E.L. Rowan, M.A. Engle, C.S. Kirby, and T.F. Kraemer. *Radium Content of Oil- and Gas-Field Produced Waters in the Northern Appalachian Basin.* US Geological Survey Scientific Investigation Report, 2011-5135.

[121] EPA, Bureau of Radiation Protection. "Oil and Gas Production Wastes." http://www.epa.gov/radiation/tenorm/oilandgas.html

[122] E.L. Rowan, M.A. Engle, C.S. Kirby, and T.F. Kraemer. *Radium Content of Oil- and Gas-Field Produced Waters in the Northern Appalachian Basin.* US Geological Survey Scientific Investigation Report, 2011-5135. See also Penn State, "Analysis of Marcellus flowback finds high levels of ancient brines"; and Marvin Resnikoff, *Radioactivity in Marcellus Shale: Challenge for regulators and water treatment plants."* Radioactive Waste Management Associates, 2012.

[123] E.L. Rowan, M.A. Engle, C.S. Kirby, and T.F. Kraemer. *Radium Content of Oil- and Gas-Field Produced Waters in the Northern Appalachian Basin*. US Geological Survey Scientific Investigation Report, 2011-5135.

[124] N.R. Warner, C.A. Christie, R.B. Jackson, A. Vengosh "Impacts of Shale Gas Wastewater Disposal on Water Quality in Western Pennsylvania." *Environmental Science & Technology,* 2013. See also Consent Decree, PA Department of Environmental Protection v. Waste Treatment Corporation. Filed in the Commonwealth Court of Pennsylvania, November 25, 2013.

[125] Environmental Protection Agency, Radiation Protection: TENORM: Oil and Gas Production Wastes. Accessed online March 1, 2019: https://www.epa.gov/radiation/tenorm-oil-and-gas-production-wastes#tab-2

[126] US EPA. Technical Report on Technologically Enhanced Naturally Occurring Radioactive Materials from Uranium Mining, Volume 2. 2008.

[127] 2014 STRONGER Guidelines, Section 7, Naturally Occurring Radioactive Materials.

[128] "NORM," North Dakota Petroleum Foundation. Accessed online March 3, 2019: https://energyofnorthdakota.com/home-menu/impacts-solutions/norm/.

[129] Ibid.

[130] NYDEC, Chapter IV, Quality Services, §380-1.2(e).

[131] Richard Clarkson, NY DEC Division of Materials Management, presentation on "Current Solid Waste Disposal Regulatory Framework for Gas Development Wastes." 2013.

[132] 6 NYCRR Part 380: Section 380-2.1 General Definitions (66). Effective May 10, 2018.

[133] ODH, OEPA, and ODNR. NORM/TENORM Information Sheet. http://www.odh.ohio.gov/~/media/ODH/ASSETS/Files/rp/Raducation/Module%203%20-%20NORM%20TENORM%20Information%20Sheet.ashx

[134] Data obtained from ODH through a Freedom-of-Information-Act request by Julie Weatherington-Rice, Bennett and Williams Environmental Consultants. Data presented at Youngstown University in 2014; https://www.youtube.com/watch?v=CGGOX9NxOb4

[135] ODH, OEPA, and ODNR. NORM/TENORM Information Sheet. http://www.odh.ohio.gov/~/media/ODH/ASSETS/Files/rp/Raducation/Module%203%20-%20NORM%20TENORM%20Information%20Sheet.ashx.

[136] Jennifer Parker and Megan Cummiskey. Final Analysis, Am. Sub. HB 59. Ohio Legislative Service Commission, 2013.

[137] Ohio Revised Code §3748.01(Y).

[138] OEPA Advisory. "Solidification and disposal activities associated with drilling-related wastes at solid waste landfills." September 18, 2012.

[139] ODNR, OEPA, and ODH. "Landfill acceptance and disposal of waste substances from horizontal wells—update." Letter to facility operators, November 17, 2014. http://epa.ohio.gov/Portals/0/Drilling%20Waste%20Ltr.pdf See also Ohio Revised Code §3734.02 (P)(2-3).

[140] West Virginia Code of State Regulations §64-23-16.

[141] Personal communication, Ken Holliday, WVDEP waste permitting unit. February 26, 2015.

[142] PADEP Bureau of Waste Management. "Origin of TENORM-containing drill cuttings and treatment sludges generated at well sites and wastewater treatment facilities in the 2012 calendar year." Presentation, May 2013.

[143] Paul Ziemkiewicz, John Quaranta, and Michael McCawley. "Practical measures for reducing the risk of environmental contamination in shale energy production." *Environmental Science: Process & Impacts.* 2014.

[144] EPA, "Landfills." http://www.epa.gov/solidwaste/nonhaz/municipal/landfill.htm. The applicable law is the US Code of Federal Regulations, Title 40, Subchapter 1, §258, also known as RCRA Subtitle D.

[145] EPA, Solid Waste Laws and Regulations, RCRA Subtitle D. http://www.epa.gov/region9/waste/solid/laws.html

[146] PADEP Form 26R, instructions for chemical analysis of residual waste. http://www.elibrary.dep.state.pa.us/dsweb/Get/Document-80512/01%20Instructions%202540-PM-BWM0347.pdf

[147] PA Code §287.54(3)(f).

[148] Email correspondence from NY Department of Environmental Conservation Administrative Specialist Patti Leonardo to Melissa Troutman regarding FOIA request #W045695-121418, January 2, 2019.

[149] Andrew W. Nelson, Dustin May, Andrew W. Knight, et al. "Matrix complications in the detection of radium levels in hydraulic fracturing flowback water from Marcellus Shale." Environmental Science and Technology Letters. 2014.

[150] "Environmental and Human Health Impacts of Spreading Oil and Gas Wastewater on Roads," T. L. Tasker, W. D. Burgos, et al., Environmental Science & Technology, May 30, 2018, 52 (12), 7081-7091 DOI: 10.1021/acs.est.8b00716

[151] "Sources of Radium Accumulation in Stream Sediments Near Disposal Sites in Pennsylvania: Implications for Disposal of Conventional Oil and Gas Wastewater," N. Lauer, N. Warner, A. Vengosh, Environmental Science and Technology, Jan 4, 2018, DOI: 10.1021/acs.est.7b04952

[152] "Landfarming, Landtreatment, and Land Application Facilities." Railroad Commission of Texas online, accessed March 3,2019.

[153] U.S. EPA, Fiscal Year 2018 Justification of Appropriation Estimates for the Committee on Appropriations, May 2017. www.epa.gov/ocfo

[154] Clean Water Action, Still in The Pits: Update on Oil and Gas Wastewater Disposal in California. March 2016.

[155] U.S. EPA Region 8 Report, Oil and Gas Environmental Assessment 1996-2002, January 2003.

[156] National Fish and Wildlife Forensics Laboratory, "Avian mortality at oil pits in the United States." U.S. Fish and Wildlife, October 2006.

[157] Kyle Ferrar, "Groundwater Threats in Colorado." FracTracker Alliance, September 20, 2016.

[158] "New Mexico Pit Rule Changes Agreeable to Industry." Natural Gas Intelligence, June 13, 2013.

[159] Scott Kell. Groundwater Investigations and their Role in Advancing Regulatory Reforms. A Two-State Review: Ohio and Texas. Groundwater Protection Council, 2011.

[160] John Quaranta, Richard Wise, and Andrew Darnell. "Pits and Impoundments Final Report" for Assessing Environmental Impacts of Horizontal Gas Well Drilling Operations. West Virginia University. 2012.

[161] PADEP, *Marcellus Shale Short-Term Ambient Air Sampling Report* for the Southwest region, 2010 www.dep.state.pa.us/dep/deputate/airwaste/aq/aqm/docs/Marcellus_SW_11-01-10.pdf.

[162] Zahra Hirji, Lisa Song, and David Hasemyer. "Small Study May Have Big Answers on Health Risks of Fracking's Open Waste Ponds." Inside Climate News, October 10, 2014.

[163] Commonwealth of Pennsylvania, Department of Environmental Protection and Range Resources-Appalachia. Consent Order and Agreement. September 17, 2014.

[164] See comments on the proposed revisions to Title 25, Chapter 78 of the Pennsylvania Code by Earthworks at http://www.earthworksaction.org/library/detail/comments_re_25_pa._code_chapter_78_subchapter_c ; PennFuture at http://www.pennfuture.org/UserFiles/File/Legal/Drill_LetterComment_EQB_20140314_OilGasChap78_LawStaff.pdf; and Earthjustice et al. at http://bit.ly/1BT5XAB.

[165] Marcellus Shale Coalition. Recommended Practices: Drilling and Completions. 2013.

[166] API, Environmental Protection for Onshore Oil and Gas Production Operations and Leases. Recommended Practce 51R, 2009.

[167] Center for Sustainable Shale Development. Performance Standards and Regulatory Standards across the Appalachian Basin. Water Standards. 2014.

[168] "A Look at Drill Waste Pits and Groundwater." Public Herald, November 13, 2012. http://publicherald.org/triple-divide-the-judys-2/

[169] Letter from Robert Dellinger, Materials Recovery and Waste Management Division, EPA to Michael S. Freeman, Earthjustice. September 15, 2010.

[170] See pit burial criteria in the Pennsylvania Code, Title 25, §78.62, Disposal of residual waste—pits.

[171] Personal communication between Earthworks and Scott Perry, Deputy Secretary, Office of Oil and Gas Management, PADEP. August 2013.

[172] Joint Stipulation, Range Resources Appalachia, LLC, Appellant, v. Mt. Pleasant Township, Washington County, PA, Appellee, before the Mt. Pleasant Township Zoning Hearing Board, August 13, 2013. Sections D28-29 on Carter Impoundment.

[173] SkyTruth Blog, "SkyTruth Releases Map of Drilling-Related Impoundments in PA." October 3, 2014. http://blog.skytruth.org/2014/10/PA-drilling-impoundments-2005-2013.html

[174] PA DEP Oil and Gas Production/Waste Reports Website, https://www.paoilandgasreporting.state.pa.us/publicreports/Modules/Welcome/Agreement.aspx. Accessed September 2018.

[175] Joshua Pribanic, Amanda Gillooly, "Permit Allows Fracking Waste Storage in Backyards, Community Fights Back. Public Herald, May 19, 2014.

[176] US EPA, "Detailed Study of the Centralized Waste Treatment Point Source Category for Facilities Managing Oil and Gas Extraction Wastes." EPA-821-R-18-004, May 2018.

[177] Dan Mueller, "Recycling Wastewater from Oil and Gas Wells Poses Challenges." Environmental Defense Fund Blog, November 11, 2015.

[178] US EPA, Effluent Guidelines: Unconventional Oil & Gas Extraction Effluent. https://www.epa.gov/eg/unconventional-oil-and-gas-extraction-effluent-guidelines#compliance, accessed 9/12/2018.

[179] Patnode, K.A., et al., "Effects of high salinity wastewater discharges on unionid mussels in the Allegheny River, Pennsylvania." *Journal of Fish and Wildlife Management*, vol. 6, issue 1, 2015.

[180] States, S., et al., "Marcellus Shale drilling and brominated THMs in Pittsburgh, Pa., drinking water." *American Water Works Association Journal*, August 1, 2013.

[181] Sharon Kelly, "How Trump's EPA Is Moving to Undo Fracking Wastewater Protections." DeSmog Blog, May 11, 2018.

[182] Bob Bauder & Timothy Puko, "Four treatment plants accused of raising bromide levels in Allegheny." Tribune Review, November 5, 2011.

[183] US EPA, "Pretreatment Standards for the Oil & Gas Extraction Point Source Category." Office of Water, June 2016.

[184] US EPA, "Detailed Study of the Centralized Waste Treatment Point Source Category for Facilities Managing Oil and Gas Extraction Wastes." EPA-821-R-18-004, page 9-1, May 2018.

[185] EPA, Study of Oil and Gas Extraction Wastewater Management" webpage: https://www.epa.gov/eg/study-oil-and-gas-extraction-wastewater-management, accessed August 18, 2018.

[186] EPA Region 6, "EPA Signs MOU with New Mexico to Explore Wastewater Reuse Option in Oil and Gas Industry." EPA.gov News Releases, July 19, 2018.

[187] 40 CFR Part 437

[188] Elliot, E.G., Ettinger, A.S., Leaderer, B.P., Bracken, M.B., and Deziel, N.C. "A systematic evaluation of chemicals in hydraulic-fracturing fluids and wastewater for reproductive and developmental toxicity." *Journal of Exposure Science and Environmental Epidemiology*. Vol. 27, pages 90–99. 2017.

[189] US EPA, "Detailed Study of the Centralized Waste Treatment Point Source Category for Facilities Managing Oil and Gas Extraction Wastes." EPA-821-R-18-004, page 9-1, May 2018.

[190] Warner, N.R., Christie, C.A., Jackson, R.B., Vengosh, A., "Impacts of shale gas wastewater disposal on water quality in western Pennsylvania." Environmental Science Technology, October 2015.

[191] "Sources of Radium Accumulation in Stream Sediments Near Disposal Sites in Pennsylvania: Implications for Disposal of Conventional Oil and Gas Wastewater," N. Lauer, N. Warner, A. Vengosh, Environmental Science and Technology, Jan 4, 2018, DOI: 10.1021/acs.est.7b04952

[192] J. Harkness, G. Dwyer, N.R. Warner, et al. "Iodide, Bromide, and Ammonium in Hydraulic Fracturing and Oil and Gas Wastewaters: Environmental Implications." *Environmental Science & Technology*. 2015.

[193] "Sources of Radium Accumulation in Stream Sediments Near Disposal Sites in Pennsylvania: Implications for Disposal of Conventional Oil and Gas Wastewater," N. Lauer, N. Warner, A. Vengosh, Environmental Science and Technology, Jan 4, 2018, DOI: 10.1021/acs.est.7b04952

[194] Belcher, M., Resnikoff, M., Hydraulic Fracturing Radiological Concerns for Ohio. Fact Sheet prepared for FreshWater Accountability Project Ohio. Radioactive Waste Management Associations, June 13, 2013.

[195] US EPA, "Detailed Study of the Centralized Waste Treatment Point Source Category for Facilities Managing Oil and Gas Extraction Wastes." EPA-821-R-18-004, page 9-20, May 2018.

[196] Sharon Kelly, "How Trump's EPA Is Moving to Undo Fracking Wastewater Protections." DeSmog Blog, May 11, 2018.

[197] Field, R.A., et al., "Influence of oil and gas field operations on spatial and temporal distributions of atmospheric non-methane hydrocarbons and their effect on ozone formation in winter." Atmospheric Chemistry and Physics, March 31, 2015.

[198] US EPA, "Detailed Study of the Centralized Waste Treatment Point Source Category for Facilities Managing Oil and Gas Extraction Wastes." EPA-821-R-18-004, page 9-35, May 2018.

[199] US EPA, "Detailed Study of the Centralized Waste Treatment Point Source Category for Facilities Managing Oil and Gas Extraction Wastes." EPA-821-R-18-004, page 9-26, May 2018.

[200] PA DEP, Aquatic Biology Investigation. Report, January 2013.

[201] Patnode, K.A., et al., "Effects of high salinity wastewater discharges on unionid mussels in the Allegheny River, Pennsylvania." *Journal of Fish and Wildlife Management*, vol. 6, issue 1, 2015.

[202] Maloney, K.O., et al., "Unconventional oil and gas spills: Materials, volumes, and risks to surface waters in four states of the U.S." *Science of the Total Environment*, volumes 581-582, March 1, 2017.

[203] Lauer, N.E., et al., "Brine spills associated with unconventional oil and gas development in North Dakota." Environmental Science Technology, volume 50, issue 10, 2016.

[204] Grant, C.J., et al., "Fracked ecology: Response of aquatic trophic structure and mercury biomagnification dynamics in the Marcellus Shale formation." *Ecotoxicology*, vol. 25, issue 10, 2016.

[205] Earthworks public records request, April 2018: Eureka Resources & PA DEP "Consent of Civil Penalty" records from 2014 – 2018.

[206] US EPA, "Detailed Study of the Centralized Waste Treatment Point Source Category for Facilities Managing Oil and Gas Extraction Wastes." EPA-821-R-18-004, page 9-26, May 2018.

[207] US EPA, "Detailed Study of the Centralized Waste Treatment Point Source Category for Facilities Managing Oil and Gas Extraction Wastes." EPA-821-R-18-004, page 9-15, May 2018

[208] US EPA, "Detailed Study of the Centralized Waste Treatment Point Source Category for Facilities Managing Oil and Gas Extraction Wastes." EPA-821-R-18-004, page 9-5, May 2018

[209] Abrahm Lustgarten, "Injections Wells: The Poison Beneath Us," *Propublica*. June 21, 2012.

[210] EPA. "Water, Underground Injection Control, Classes of Wells." http://water.epa.gov/type/groundwater/uic/wells.cfm

[211] EPA. "Class II wells—Oil and Gas Related Injection Wells." http://water.epa.gov/type/groundwater/uic/class2/index.cfm

[212] US GAO. *EPA Program to Protect Underground Sources from Injection of Fluids Associated with Oil and Gas Production Needs Improvement.* 2014. This report also notes a third emerging trend, diesel injection, which is important but beyond the scope of this report to discuss in detail. It should be noted that diesel can be present in hydraulic fracturing fluids that later become waste products; the underground injection of diesel is illegal unless permitted by EPA—a rule that the agency views as also applicable to the UIC program.

[213] EPA. "Water: Underground Injection Control, UIC Program Primacy. "http://water.epa.gov/type/groundwater/uic/Primacy.cfm

[214] Clean Water Action. Aquifer Exemptions; A first-ever look at the regulatory program that writes off drinking water resources for oil, gas, and uranium profits. 2015. See also the federal guidance for state programs under the US Safe Drinking Water Act: http://www.epa.gov/ogwdw/uic/pdfs/guidance/guide_uic_guidance-19_primacy_app.pdf.

[215] GAO. *EPA Program to Protect Underground Sources from Injection of Fluids Associated with Oil and Gas Production Needs Improvement.* 2014. This report also notes a third emerging trend, diesel injection, which is important but beyond the scope of this report to discuss in detail. It should be noted that diesel can be present in hydraulic fracturing fluids that later become waste products; the underground injection of diesel is illegal unless permitted by EPA—which the agency views as also applying to the UIC program.

[216] Ibid

[217] Akob, D.M., et al., "Wastewater Disposal from Unconventional Oil and Gas Development Degrades Stream Quality at a West Virginia Injection Facility," Environmental Science Technology, (2016), 50 (11), 5517-5525.

[218] Colin Deppen, "Feds knock down Highland Township injection well appeals." Bradford Era, June 13, 2014.

[219] David DeWitt, "Dozens heap scorn on local injection well proposal." *Athens News*, January 4, 2015.

[220] Jessica Lilly, "DEP postpones public hearing concerning Lochgelly waste site." West Virginia Public Broadcasting, January 7, 2015.

[221] Dan McGraw, "Ohio: Land of injection wells." Crain's Cleveland Business. August 16, 2013.

[222] US GAO. EPA Program to Protect Underground Sources from Injection of Fluids Associated with Oil and Gas Production Needs Improvement. 2014.

[223] National Research Council, Division on Earth and Life Studies, Board on Earth Sciences and Resources *Induced Seismicity Potential in Energy Technologies.* National Academies Press. 2013.

[224] Ibid.

[225] Code of Federal Regulations §146.22.

[226] EPA Office of Water, UIC National Technical Worksgroup. Minimizing and managing potential impacts of injection-induced seismicity from Class II disposal wells: practical approaches. 2015.

[227] Ryan Collins and David Wethe, "Earthquakes in Heart of Texas Oil Country Spur Water Crackdown." *Bloomberg*, December 5, 2018.

[228] EPA Office of Water, UIC National Technical Worksgroup. Minimizing and managing potential impacts of injection-induced seismicity from Class II disposal wells: practical approaches. 2015.

[229] Ibid.

[230] Rick Steelhammer, "Small earthquake rattles Braxton near quake cluster recorded in 2010." *West Virginia Gazette*, January 11, 2012.

[231] Kiah Collier, "Expect Fewer Man-made Earthquakes in Texas, Federal Agency Says," Texas Tribune. March 1, 2017.

[232] Won-Young Kim. "Induced seismicity associated with fluid injection into a deep well in Youngstown, Ohio." *Journal of Geophysical Research,* Vol. 118, Issue 7, July 2013.

[233] ODNR Emergency Action, Ohio Administrative Code, Chapter 1501, Section 9-3-06. July 2012. The rules apply to injection wells in Pre-Cambrian and Cambrian formations; see ODNR GeoFacts Issue #13 and #20.

[234] Julie Carr Smyth, "Ohio halts injections at two wells for fracking wastewater after quake." Associated Press, September 6, 2014.

[235] Dan Elliot, "CU Study: More evidence links earthquakes to energy waste wells along Colorado-New Mexico border." Associated Press, October 25, 2017.

[236] U.S. EPA, Fact Sheet on Aquifer Exemption Data, January 2017.

[237] E. Hansen, D. Mulvaney, and M. Betcher. Water Resource Reporting and Water Footprint from Marcellus Shale Development in West Virginia and Pennsylvania. Downstream Strategies and San Jose State University, 2013.

[238] Figures calculated using "injection well" (as disposal method) data from PADEP's Oil & Gas Reporting website, "State data downloads, waste." https://www.paoilandgasreporting.state.pa.us/publicreports/Modules/Welcome/Welcome.aspx

[239] National Research Council, Division on Earth and Life Studies, Board on Earth Sciences and Resources *Induced Seismicity Potential in Energy Technologies.* National Academies Press. 2013.

[240] Abraham Lustgarten, "Injection wells: The poison beneath us." *ProPublica*, June 21, 2012.

[241] Abraham Lustgarten, "The trillion-gallon loophole: lax rules for drillers that inject pollutants into the Earth." *ProPublica*, September 20, 2012.

[242] Center for Health, Environment, and Justice, Buckeye Forest Council, and others. Letter to Susan Hedman, Regional Administrator, EPA. March 14, 2013.

[243] ODNR inspection reports and documentation on the Ginsburg wells, posted by Appalachia Resist! https://appalachiaresist.wordpress.com/injection-wells/shut-down-the-ginsburg-well/

[244] Bradley Kennan, Natural Resources Defense Council, WV Surface Owners' Rights Organization, Plateau Action Network v. Director, Division of Water and Waste Management, WVDEP. Appellant brief, WV Environmental Quality Board, September 4, 2014.

[245] Ibid.; see included Affidavit from Dr. Avner Vengosh, Nicholas School of Environment, Duke University.

[246] US GAO, Characterization of Injected Fluids Associated with Oil and Gas Production. 2014.

[247] Ibid.

[248] Ibid.

[249] New York Environmental Conservation Law §360-1.15 and beneficial use program, http://www.dec.ny.gov/chemical/8821.html; Ohio Revised Code §1509.226 and beneficial use program, http://www.epa.ohio.gov/dmwm/Home/BeneficialUse.aspx; and Pennsylvania Code §287.611, Subchapter H and beneficial use program, http://www.portal.state.pa.us/portal/server.pt/community/beneficial_use/14094; Colorado Regulations Pertaining to Solid Waste Sites and Facilities, 6 CCR 1007-2, PART 1: https://drive.google.com/file/d/1vgAs0py17puoBf3fmXaiVYRTT7djOsjA/view; 16 Texas Administrative Code (TAC), Chapter 4, Subchapter B, https://texreg.sos.state.tx.us/public/readtac$ext.ViewTAC?tac_view=5&ti=16&pt=1&ch=4&sch=B.

[250] WVDEP Handbook, Series 18. "Utilization of coal ash, tires, sludge, and other items."

[251] Rebecca Peitsch, "New Mexico seeks new uses for fracking waste water." *Stateline*, November 30, 2018.

[252] Don Hopey, "DEP revokes permission to dump wastewater brine from drilling on dirt roads." *Pittsburgh Post-Gazette*, May 22, 2018.

[253] PADEP, "Roadspreading of brine for dust suppression and road stabilization." Fact sheet, revised 2013.

[254] E. Scott Bair and Robert K. Digel. "Subsurface transport of inorganic and organic solutes from experimental road-spreading of oil-field brine." *Groundwater Monitoring and Remediation.* Summer 1990.

[255] ODNR. Spreading oil-field brine for dust and ice control in Ohio: A guide for local authorities. Revised 2004.

[256] PermaFix Environmental Services for PADEP. Technologically Enhanced Naturally Occurring Radioactive Materials (TENORM) Study Report. 2015.

[257] Karla Lant "Toxic Potential: Oil and Gas Wastewater on Roads." Environmental Monitor, August 30, 2018.

258 Earthworks, Letter to PADEP regarding the potential rule making allowing road spreading of oil and gas wastewater, July 31, 2018: https://earthworks.org/publications/letter-potential-rulemaking-allowing-road-spreading-of-oil-and-gas-wastewater/

[259] Argonne National Laboratory, Drilling Waste Management Information System. "Beneficial reuse of drilling wastes." Fact Sheet, http://web.ead.anl.gov/dwm/techdesc/reuse/.

[260] Ibid.

[261] Railroad Commission of Texas, Guidance Document: Permit Application for Reusable Product. Accessed online March 15, 2019: https://www.rrc.state.tx.us/media/31565/reusable-product-372016.pdf.

[262] Clean Earth and Penn State Extension. "Recycling and reuse of Marcellus Shale drill cuttings." Presentation, December 2013. http://extension.psu.edu/natural-resources/natural-gas/webinars/drilling-and-pipeline-cuttings-reclamation/drilling-and-pipeline-cuttings-reclamation-powerpoint-december-19-2013

[263] Ibid.

[264] The Delaware Riverkeeper Network, Maya Van Rossum, The Delaware Riverkeeper, Earthworks, and Stewards of the Lower Susquehanna, Apellants v. Commonwealth of Pennsylvania, Department of Environmental Protection, Appellee, and Range Resources, Appalachia, LLC and LaFarge North America Inc., Pemittees. Filed with the Environmental Hearing Board, September 15, 2014.

[265] enerGREEN360 company website, http://energreen360.com/.

[266] Food and Water Watch and Freshwater Accountability Project vs. State of Ohio, Governor John R Kasich, and James Zehringer, Chief, ODNR. Verified Complaint for Writ of Mandamus, Court of Appeals of Franklin County. November 2014. Due to public outcry

over the lack of public notification, EnerGreen 360 withdrew its permit request to lease land in an industrial park for a facility in July 2014.

[267] Buckeye Forest Council and Freshwater Accountability Project. “Toxic waste sites enter Ohio communities without oversight.” Press Release, May 4, 2014.

[268] Ohio Revised Code §3734.125.

[269] Ohio Revised Code §3734.01(V)(2); Jennifer Parker and Megan Cummiskey. Final Analysis, Am. Sub. HB59. Ohio Legislative Service Commission, 2013.

[270] Joshua Pribanic, “Clorox Selling Pool Salt Made From Fracking Wastewater.” Public Herald, February 11, 2019.

[271] Melissa Troutman, “Is drilling & fracking waste in your pool or on your sidewalk?” Earthworks Earthblog, March 5, 2019.

[272] Yixin Yao, Thomas Kluz, et al., “Malignant human cell transformation of Marcellus Shale gas drilling flow back water.” Toxicology and Applied Pharmacology, October 1, 2015.

[273] Don Hopey, “Radium found in commercial roadway de-icing, dust suppression brine.” *Pittsburgh Post-Gazette*, July 2, 2018.

[274] Melissa Troutman, “Is Drilling and Fracking Waste On Your Sidewalk or in Your Pool?” Truthout, February 21, 2019.

[275] Energy In Depth, “Hydraulic Fracturing and Water Use: Get the Facts.” July 16, 2013.

[276] Samuel J. Maguire-Bond and Andrew R. Barron. “Organic compounds in produced waters from shale gas wells.” *Environmental Science: Processes and Impacts.* 2014.

[277] PermaFix Environmental Services for PADEP. Technologically Enhanced Naturally Occurring Radioactive Materials (TENORM) Study Report. 2015.

[278] Vidic, R.D., Brantley, S.L., Vandenbossche, M., Yoxtheimer, D. and Abad, J.D. “Impact of Shale Gas Development on Regional Water Quality.” *Science*. 2013.

[279] David Wethe and Peter Ward, “Fracking bonanza eludes wastewater recycling investors.” *Bloomberg Business News*. November 25, 2013.

[280] US EPA, Study of Oil & Gas Extraction Wastewater Management: https://www.epa.gov/eg/study-oil-and-gas-extraction-wastewater-management. Accessed August 29, 2018.

[281] US EPA, “Memorandum of Understanding; EPA and State of New Mexico; Produced Water from Oil and Gas Extraction Activities,” July 16, 2018.

[282] Don Hopey, “Gas drillers recycling more water, using fewer chemicals.” Pittsburgh Post Gazette, March 1, 2011; Ellen M. Gilmer, “Wastewater concerns persist despite rise in reuse.” *E&E News*, September 6, 2012.

[283] E. Hansen, D. Mulvaney, and M. Betcher. Water Resource Reporting and Water Footprint from Marcellus Shale Development in West Virginia and Pennsylvania. Downstream Strategies and San Jose State University, 2013.

[284] Independent Petroleum Association of America, “Oil and Natural Gas RCRA Exemption Under Attack,” September 24, 2010.

[285] Notes from IOGCC’s Environmental Affairs Committee meeting June 18, 1979 in Lexington, Kentucky, obtained by investigators at DeSmog Blog. https://www.documentcloud.org/documents/2798893-Legal-Basis-of-IOCC-Subcommittee.html#document/p7/a288314

[286] Paul Davidson, “Exxon’s record $11.7B profit still disappoints, stock falls.” ABC News, August 2, 2008.

[287] CNN Money, Global 500 ranking of world’s largest corporations (2010-2012). Accessed September 10, 2018.

[288] CNN Money, Global 500 ranking of world’s largest corporations (2012). Accessed September 10, 2018.