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WASTING AWAY:
Four states' failure to manage gas and oil field waste from the Marcellus and Utica Shale

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For 25 years, Earthworks has been protecting communities and the environment from the impacts of irresponsible mineral and energy development while seeking sustainable solutions.

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Acronyms

E&P waste: Exploration, development, and production waste

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

Introduction

Nearly 30 years ago, before the shale boom was even a gleam in the oil and gas industry's eye, the United States Environmental Protection Agency (EPA) considered whether oil and gas development waste should be regulated under the Resource Conservation and Recovery Act (RCRA). Among the agency's many conclusions in a report to Congress were:

- Such 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."[1]

Despite these conclusions, EPA decided to exempt oil and gas development waste from the definition of "hazardous" under RCRA.

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) and the average rate of oil production had gone up nearly 40%.[2] Today, there are more than 1.1 million active oil and gas wells nationwide.[3] Most are hydraulically fractured and all of them produce large quantities of liquid and solid waste. Yet RCRA still does not apply to oil and gas development waste. Consequently, it is categorized as non-hazardous and its management is largely subject to state discretion.

Many policymakers and advocates have started to ask: as drilling continues, where is all the waste going and what happens as a result?

At the same time, many of the questions asked about oil and gas field waste decades ago persist, including what it contains and how it is, and 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.

A series of high-profile events has drawn public attention to the limitations and risks of current disposal facilities and methods. (See box below.) In addition, research studies and investigations have begun to document the contaminants present in oil and gas field waste and the pathways through which they enter the environment—and can ultimately impact human health. **As more problems with waste storage and disposal capacity have grown alongside the number of wells and scale of operations, many policymakers and advocates have started to ask: as drilling continues, where is all the waste going and what happens as a result?**

More than 1.1 million active oil and gas wells nationwide.
Photo by Frank Finan.

This report examines how oil and gas field waste is tracked, regulated, and managed in the Marcellus and Utica Shale region, which is one of the centers of the current expansion of domestic natural gas production. Waste is frequently transported across the borders of New York, Ohio, Pennsylvania, and West Virginia, creating a complex web of waste management both within states and regionally. **The following pages also consider current information gaps pertaining to the oil and gas waste stream in the region, as well as necessary steps that states and the federal government can take to prevent widespread environmental harm that may result from an ever-growing volume of drilling waste.**

Industry and its supporters have touted natural gas as a clean energy source and marketed it as an environmentally friendly "alternative" to other fossil fuels like coal and oil. However, the weight of scientific research and documentation of actual impacts increasingly show that this assumption doesn't hold true if the entire process of gas development—not just its burning and end-use—is considered.[4] With time, awareness has grown about other long-term environmental and health risks, including those posed by the generation of large volumes of liquid and solid waste.

Oil and gas waste is often referred to as the "Achilles Heel" of the industry, a vulnerability that carries with it great risk and cannot be ignored indefinitely. 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 none of the Marcellus and Utica shale states can say for sure how much waste is being produced, where it ends up, and what happens when it gets there.

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.[5]

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.[6]

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.[7] 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.[8]

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.[9]

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.[10]

2012 and 2014

A bipartisan majority in the New Jersey legislature passed bills to ban the treatment and disposal of oil and gas waste in the state. Governor Christie vetoed both bills.

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.[11]

2013
The US 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.[12] The Pennsylvania Attorney General also filed criminal charges against XTO for the spill.[13]

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.[14]

2013
Sierra Club and partners launched a campaign to prohibit New York landfills from accepting drilling waste from Pennsylvania. [15]

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.[16]

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.[17]

2014
A West Virginia landfill rejected waste from centralized impoundments in Pennsylvania because of high radioactivity levels—signaling a reversal of past practices.[18] 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.[19]

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.[20]

2014
A study by the US 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.[21]

2014
Court depositions revealed that Pennsylvania regulators had omitted measurements of harmful contaminants near a waste impoundment from a report on air quality.[22]

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.[23]

Types of Waste

Oil and gas waste can generally be classified as either liquid or solid. Sometimes wastes fall along the line between the two or become mixed with other wastes as they are generated and managed. From the perspective of operators, waste facilities, and agencies, however, waste management practices and regulations are based on definitions of several key oil and gas field wastes established by the industry and researchers.

Brine

This broad term refers to water resulting from oil and gas drilling and production that has a high saline content. Regulators generally use "brine" to mean produced water, but the term can also encompass flowback—especially because as produced water flows to the surface it mixes with the fluids and chemicals used in hydraulic fracturing.

Brine storage tank. Photo by Nadia Steinzor.

Produced water

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 (also called "brine" and "formation 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. Estimates range from 80-1,200 gallons per day for shale gas wells.[24]

Studies indicate that produced water from the Marcellus Shale is the second saltiest and most radioactive of all sedimentary basins in the US where large-scale oil and gas development is underway.[25] 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.[26] Produced water may continue to flow over the entire life of a well. However, the proportion of water relative to hydrocarbon increases with time, posing increasing treatment and disposal challenges for operators and waste facilities.[27]

Flowback

The advent of horizontal drilling has vastly increased the volume of water required for oil and gas production, with 2-5 million gallons typically used to hydraulically fracture a shale well.[28] Once fracturing is completed and drilling pressure is released, the injected water and 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. A recent study suggests about 10-30% of injected fracturing fluid is recovered,[29] while a recent review of data reported by operators put recovery at 8% in West Virginia and 6% in Pennsylvania.[30]

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.[31] In addition, flowback can contain substances originating from the fractured formation, such as hydrogen sulfide and various volatile organic compounds.[32]

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Drill cuttings

After a hole is drilled into shale 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;[33] to 600 tons for a Utica Shale well;[34] to 750 tons for an average Marcellus well;[35] to 1000 tons for an average Marcellus well in West Virginia.[36]

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.[37]

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.[38]

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 kept 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.

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.[39]

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

The RCRA Loophole

Sensible waste management begins with 'good housekeeping'… Although they 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 if improperly managed.

—United States Environmental Protection Agency, 2002

In an effort to enact more comprehensive waste disposal standards nationwide, the US Congress passed the Resource Conservation and Recovery Act (RCRA) in 1976 as an amendment to the Solid Waste Disposal Act of 1965. Through RCRA, Congress declared that the "disposal of solid waste…without careful planning and management [was] a danger to human health and the environment."[40] Over time, however, Congress would also act to create a special exemption in RCRA for oil and gas waste.

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 classifications of waste. Congress defined hazardous waste in RCRA, but left it up to EPA to decide through a Regulatory Determination the specific characteristics of hazardous waste and to promulgate lists of wastes meeting those characteristics.[41] The definition of a hazardous waste under RCRA is:

[A] solid waste, or combination of solid wastes, which because of its quantity, concentration, or physical, chemical, or infectious characteristics may-

> (A) cause, or significantly contribute to an increase in mortality or an increase in serious irreversible, or incapacitating reversible, illness; or
>
> (B) pose a substantial present or potential hazard to human health or the environment when improperly treated, stored, transported, or disposed of, or otherwise managed.[42]

Under RCRA, "characteristic" wastes are those that exhibit measurable properties that indicate whether a waste poses enough of a threat to warrant regulation as a hazardous waste. The four technical criteria EPA uses to determine if a waste is a characteristic waste are ignitability, corrosivity, reactivity, and toxicity; waste will be considered hazardous if it exhibits *any* of the four characteristics.[43]

In 1978, EPA proposed hazardous waste management standards that included reduced requirements for several types of large volume wastes, believing that these "special wastes" were lower in toxicity than other wastes being regulated as hazardous waste under RCRA.[44] Congress then amended RCRA with the Solid Waste Disposal Act Amendments of 1980.[45] One of the amendments, the so-called Bentsen Amendment,

The so-called Bentsen Amendment, temporarily exempted drilling fluids, produced waters, and other wastes associated with the exploration, development, or production of crude oil or natural gas (collectively called E&P wastes) from regulation under RCRA temporarily exempted "drilling fluids, produced waters, and other wastes associated with the exploration, development, or production of crude oil or natural gas" (collectively called E&P wastes) from regulation under RCRA.[46]

Duplicating the loophole: RCRA in the states

Ohio does not specifically exempt oil and gas field waste from being defined as hazardous, but its 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.[47]

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, stating that "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.[48] 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…"[49]

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…"[50] 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 US Congress.[51]

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."[52] 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.[53] 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.[54]

Under the Bentsen Amendment, Congress directed EPA to conduct a study to determine whether or not E&P wastes should be regulated as hazardous wastes under RCRA.[55] In 1982, EPA missed the statutory deadline for submitting the oil and gas exploration and production wastes 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 to Congress. EPA then entered into a consent order obligating it to complete and submit the Report to Congress by August 31, 1987.[56]

EPA met the 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*.[57] Shortly after, in 1988, EPA issued its Regulatory Determination for Oil, Gas, and Geothermal Exploration, Development, and Production Wastes, in which it decided that regulation of E&P wastes under Subtitle C of RCRA was unwarranted.[58]

In addition, the Regulatory Determination clarified the meaning of the RCRA exemption for "other wastes associated with the exploration, development, or production of crude oil or natural gas" by stating that such "other wastes" 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."[59]

In the Regulatory Determination, EPA emphasized that it was exempting oil and natural gas E&P 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.[60]

EPA therefore declined to define E&P wastes as hazardous—despite simultaneously finding that E&P 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 E&P wastes were of major concern and present at "levels that exceed 100 times EPA's health based standards."[61]

EPA declined to define E&P wastes as hazardous despite finding contaminants "levels that exceed 100 times EPA's health based standards."

In addition, the EPA study used to determine the waste exemption concluded that between 10 and 70 percent of the oil and gas wastes sampled "could potentially exhibit RCRA hazardous waste characteristics," leading the agency to state that, "It is clear that some portions of both the large-volume and associated waste would have to be treated as hazardous if the Subtitle C exemption were lifted."[62] Notably, this conclusion was reached long before the advent of high-volume horizontal hydraulic fracturing in deep shale formations, which can generate waste containing even higher levels of salt, chemicals, and radioactive material than the E&P wastes of the 1980s.

Although the Regulatory Determination was based on the EPA's assessment that existing state and federal regulations were generally sufficient to manage E&P waste, the agency had also found that regulatory gaps existed and that 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, 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.

In discussing necessary improvements to state regulatory programs, EPA identified collaboration with the Interstate Oil and Gas Compact Commission (IOGCC) as the way to encourage states to fill specific gaps:

- Regulations for road-spreading and land-spreading of waste.
- Surface impoundment (i.e., pit) location, design, and maintenance.
- Regulations for wastes associated with E&P wastes.
- Plugging abandoned oil and gas wells.[63]

To improve states' regulatory and enforcement programs going forward, the IOGCC assisted EPA in realizing a state regulatory review process. In 1989, it created the Council on Regulatory Needs, which brought together state, environmental, and industry representatives to develop national guidelines for state oil and gas programs. In early 1990, the Council released a report titled *EPA/IOCC Study of State Regulation of Oil and Gas Exploration and Production Waste*, which established guidelines for the integration of recommended criteria into regulatory programs. The Council also proposed to implement a process by which state oil and gas programs were reviewed in comparison with those guidelines.[64]

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

In 1999, this resulted in the formation of a multi-stakeholder organization, called the State Review of Oil and Natural Gas Environmental Regulations, Inc. (STRONGER), to educate state regulators and compare various state oil and gas regulatory programs against established guidelines. To date, STRONGER has reviewed 22 states and conducted 12 follow-up reviews of some of those states, as well as conducting six reviews focused on regulations specifically for hydraulic fracturing operations.[65] In recent years, however, states have been reluctant to have their programs reviewed—in part because they consider it unlikely that the US Congress will take action to overturn the RCRA exemption and reinstate federal oversight of state oil and gas waste programs.

In the nearly 30 years that have passed since EPA issued its Regulatory Determination, both the oil and gas industry and the risks associated with E&P wastes have expanded dramatically. Yet the continued existence of the RCRA exemption has made it possible for states to define and manage E&P wastes as "solid" or "residual" regardless of whether they might in fact 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.

Drilling waste pit in Pennsylvania. Photo by Frank Finan.

Pivotal Challenges

The relatively recent focus on E&P waste reflects a general trend in oil and gas development: states have not established the regulations and policies or dedicated the oversight and enforcement resources needed to protect the environment and human health *before* proceeding with a rapid expansion of drilling. As with many other aspects of the industry, states are now struggling to catch up with ever-growing volumes of both liquid and solid waste.

In the process, they are meeting several pivotal challenges to improving waste management. As detailed in this section of the report, these issues range from identifying the content and contamination potential of waste to addressing the limitations of current storage and disposal practices. With emerging research and documentation on these aspects in hand, regulators and policymakers on both the state and federal levels have ample opportunities to face, and potentially reduce, the significant problems related to oil and gas waste.

Pits and impoundments

For decades, oil and gas operators nationwide have relied on open pits to store waste products at well sites until they evaporate or are trucked away for disposal. With the expansion of shale gas and oil development, operators have increasingly relied on raised impoundments to store the large amount of freshwater needed for high-volume hydraulic fracturing (HVHF), as well as the waste fluids that result. **As volumes of waste grow and drilling expands into more densely populated areas, concerns have increased over the risks to groundwater posed by leaking or overflowing pits and impoundments, as well as the odors and air contaminants that emanate off their surfaces as contents settle and evaporate.**

The record of such problems includes:

- A review of inspection reports showed that between January 2010 and August 2013, PADEP issued notices of violations for the improper management and disposal of drill cuttings in pits for at least 48 well sites statewide. Such problems included structural instability; improper encapsulation; liner holes and tears; leakage of fluid into springs, ponds, and streams; seepage of contaminated fluids to the surface; and erosion and runoff at pit sites.[66]
- 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.[67]
- A 2012 study commissioned by the WVDEP 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."[68]
- A 2010 PADEP 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.[69]

- In 2014, researchers in West Virginia launched a focused study of air emissions at waste storage and disposal sites, the first nationwide.[70]
- In 2014, PADEP 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).[71]

Waste bubbling into a municipal water supply from a drilling pit, Pennsylvania. Photo by PADEP.

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.[72] Such systems would help prevent spills, contain volatile materials and wastes, 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."[73] The American Petroleum Institute states that, "Consideration should be given to the use of tanks or lined pits to protect soil and groundwater, especially for brines and oil-based fluids."[74] 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."[75]

Production pits

Production or reserve pits are located at well sites and are either dug directly into the earth or constructed above ground with embankments. They are 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 pits are often included in well permits, so operators do not have to submit information about their construction and use. Yet the land disturbance associated with these "accessory" structures can be significant, especially if there are several on one site. In reviews of permit applications in Pennsylvania, which sometimes include information on whether pits will be used in operations, Earthworks documented pits ranging in size from 100x100x12 feet with a capacity of 800,000 gallons to 220x120x14 feet with a capacity of 2.5 million gallons.

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

The four states in the Marcellus and Utica Shale region continue to allow pits to be constructed and used according to very limited standards. New York requires watertight pit liners only if the underlying soil is deemed to be "porous."[76] Ohio does not have specific standards for pits, requiring only that they "prevent the escape" of waste substances.[77] Both Pennsylvania and West Virginia require only single synthetic liners for production pits.[78] Despite the water-rich nature of the entire region—and the reliance of many residents on underground aquifers and springs for drinking water—only Pennsylvania has an established distance from the bottom of production pits to the seasonal high groundwater table, although even this is only 20 inches.[79]

In a sign of growing awareness of problems related to pits, New York, before deciding to generally prohibit HVHF, had proposed new regulations that would have limited the size of pits and required pit liners and the use of closed-loop systems for containment of certain liquids and cuttings.[80] Pennsylvania's recently proposed revisions to its oil and gas regulations would prohibit the storage of waste in open pits at unconventional well sites (although they would still be allowed at conventional sites).[81] In addition, Maryland's proposed drilling regulations would prohibit open pits and impoundments for waste storage and treatment—the only state nationwide to attempt to do so.[82]

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, 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.**

Nor do any of the states 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.[83]

Ohio law allows for the use of pits to store waste, but prohibits the use of reserve pits for the "ultimate disposal" of brine or other liquid waste, implying that pits used for this purpose may not be buried on site.[84] At the same time, operators are required to "fill all pits for containing brine and other waste substances" as part of well site reclamation."[85] Whether "filling" includes burial of the wastes and waste liner that were in the pit is not clear. In addition, a new law passed in 2013 (HB59) directs ODNR to adopt rules, procedures, and requirements related to the storage and disposal of oil and gas waste fluids—but current state regulations do not address the burial of pits that are used for solid waste (e.g., drill cuttings or muds) or contain specific requirements such as pit liner thickness or distance of a buried pit from seasonal high groundwater.[86]

Pennsylvania has 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).[87] PADEP has also confirmed that it doesn't always require operators to perform chemical analysis of waste prior to burial, despite regulatory limits on the chemical content of the leachate coming from pits.[88]

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

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 became the destination for contaminated waste from over 190 wells in a dozen townships.[89]

Centralized impoundments in Pennsylvania. Photo by Robert Donnan.

None of the states covered in this report maintains 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).[90]

Unlike production pits, the construction and operation of impoundments is generally subject to additional permits (i.e., separately from well permits), including with regard to earth disturbance and erosion and sedimentation control. In addition, because of their sheer size and complexity of their construction, operators generally intend for impoundments to be in use for years. To ensure that they are properly maintained and continue to be utilized for the purpose originally permitted (e.g., for freshwater and not waste fluid storage), a high degree of oversight by regulators is necessary.

In Pennsylvania, waste impoundments are supposed to be constructed according to specific design standards, including double 40 mil liners and leak detection and groundwater monitoring systems.[91] As with production pits, impoundments can be constructed only 20 inches above the seasonal high groundwater table.[92] Impoundments also require a special permit pursuant to the Dam Safety and Encroachment Act.[93] Proposed revisions to the state's oil and gas regulations would require operators of centralized waste impoundments to either close them in three years or apply for a new permit based on residual waste permitting requirements.[94] Pennsylvania operators processing (as opposed to just storing) waste using impoundments, pits, or tanks are also supposed to obtain a Waste Management General Recycling 123 (WMGR123) permit, which covers "Processing, transfer and beneficial use of oil and gas liquid waste to develop or hydraulically fracture an oil or gas well."[95]

West Virginia allows the use of impoundments for the temporary storage of freshwater and liquid wastes from single or multiple well sites. Since the passage of the Horizontal Well Control Act in 2011, impoundments with a capacity of more than 5,000 barrels (210,000 gallons) require a special permit and have to be constructed according to specific standards, including leak detection and groundwater monitoring systems and double 60 mil liners.[96] The standards allow for impoundments to be only a minimum of 20 inches above the seasonal high groundwater table (in contrast to the four foot distance required for septic tanks).[97]

In addition, a special dam permit is required for particularly high and large impoundments.[98] In 2013, WVDEP stated that the agency would assign identification numbers to all impoundments and enter permit information into the agency's centralized database; as of the time of writing, this information was not included in the publicly accessible database of permits for oil and gas operations that have been issued by WVDEP.[99]

The only current regulations for impoundments in Ohio are waste containment laws for the coal mining industry, which indicate that impoundments can be used for freshwater, but ostensibly not waste fluids. However, these do not include any specific or binding standards, stating only that impoundments should "be so designed as to achieve necessary stability with an adequate margin of safety."[100] Since the passage of HB59, Ohio has required oil and gas operators to have a permit to store, recycle, treat, process, or dispose of oil and gas waste.[101] Currently, however, Ohio has not enacted regulations for impoundments or production pits used for the purposes spelled out in the new law.

> The only current regulations for impoundments in Ohio are waste containment laws for the coal mining industry, which indicate that impoundments can be used for freshwater, but ostensibly not waste fluids.

In 2013, ODNR drafted such rules but has not moved them forward for public review and adoption. The draft rules do not include any specific standards or methods for the construction and use of waste management facilities; instead, ODNR simply requests that, "sound engineering design and construction, and commonly accepted industry practices, shall be used."[102] The absence of specific standards would in effect leave inspectors with nothing to enforce, and would make it difficult for regulators to define and subsequently issue violations.

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 to which exposure is known to increase the risk of developing several types of cancer. Under various conditions, radium (a decay product of uranium and thorium) can be soluble in water or settle out and stick to materials (such as clay); because Ra-226 and Ra-228 have long half-lives (about 1,600 and 5.75 years, respectively), they can be persistent environmental contaminants that can accumulate gradually over time.[103]

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 and 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.[104] 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.

Naturally occurring radioactive material (NORM) wastes are those that contain radioactivity at concentrations considered to be "background," or a natural state.

Levels of radioactivity can vary across shale formations 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.[105]

The potentially high levels of radioactivity in drilling waste have been primarily documented with regard to produced water and flowback.[106] According to a 2011 review of sampling data by the US Geological Survey, the median total radium activity for produced water from the Marcellus Shale 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).[107] **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.[108]**

NORM vs. TENORM

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 defined as those in which the radioactivity has become concentrated because of human activities.

The EPA defines NORM to be materials that are "undisturbed," and TENORM as "materials that have been concentrated or exposed to the accessible environment as a result of human activities."[109] STRONGER does not distinguish between NORM and TENORM, defining both as materials "whose radionuclide concentrations have been enhanced by human activities" and recommending that states establish "risk-based numerical action levels above which NORM is regulated."[110]

EPA has set radioactivity standards for the clean-up of toxic waste sites under the Comprehensive Environmental Response, Compensation, and Liability Act (CERCLA, commonly known as the Superfund Law), with a limit of 5 picocuries per gram (pCi/g) of Ra-226 for surface soil and 15 pCi/g for subsurface soil.[111] The American National Standards Institute sets a guideline of 3pCi/g for the control and release of TENORM in solids.[112] Industrial solid waste landfills nationwide generally follow a limit of 3 piC/g of radium.[113]

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 may choose to define waste products differently in order to have greater latitude and flexibility to determine whether they are regulated as NORM versus TENORM**. 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.[114] None of the states in the Marcellus and Utica Shale region have consistent requirements for the testing of Ra-226 and Ra-228 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."[115] 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."[116] As a result, state laws governing the disposal of low-level radioactive waste do not apply to drill cuttings.

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.[117] 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.[118]

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.[119] In 2013, HB59 specifically excluded drill cuttings from the definition of TENORM.[120] 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."[121]

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.[122] 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.[123]

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.[124] 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.[125]

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."[126]

Detecting radioactivity

A recent report on TENORM in drilling wastes by PADEP (discussed below) 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."[127] 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 Ra-226 and Ra-228 that exceeded the federal Maximum Contaminant Level (MCL).[128]

However, wastewater treatment plants where landfill leachate is sent for disposal do not generally monitor for Ra-226 and Ra-228 prior to release into rivers and streams because federal National Pollutant Discharge Elimination System (NPDES) permits don't require them to.[129] Nor is radium on the federal list of substances that landfills are required to test for as part of routine groundwater monitoring.[130]

In January 2015, the PADEP released a comprehensive study on TENORM in materials associated with Marcellus Shale gas development, including drill cuttings, flowback, produced water, drilling mud, sludge, and filter cakes from landfills and wastewater treatment plants (as well as natural gas).[131]

Issued just before former Governor Corbett left office, official statements on the TENORM study concluded that, "There is little potential for radiation exposure to workers and the public" from natural gas development.[132] However, the report also concluded that there are "potential radiological environmental impacts" if drilling fluids and filter cakes are spilled; such impacts "should be studied at all facilities in Pennsylvania that treat wastes to determine if any areas require remediation;" there is a "potential long-term disposal issue" with filter cake from treatment facilities; and some waste facilities may need to require the use of "protective equipment by workers or other controls."[133]

Radiation detector at a New York landfill. Photo by Matt Richmond/WSKG.

The data contained in the PADEP report indicate significant levels of radioactivity associated with gas field waste management, including:

- Samples of produced water from unconventional well sites had concentrations of Ra-226 more than 20 times as high and Ra-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 Ra-226 concentrations about 100-5,000 times higher than the EPA drinking water standard for combined radium (551-25,500 pCi/L); concentrations of Ra-228 were 50-350 times as high (248-1,740 pCi/L).

Flowback samples had Ra-226 concentrations about 100-5,000 times higher than the EPA drinking water standard.

- Samples of produced water had Ra-226 concentrations 8-5,300 times higher than the EPA drinking water standard for combined radium (40-26,600 pCi/L); Ra-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.[134]

With regard to the last point, the high concentration of radiation in filter cakes indicates filtration systems are working; however, it also underscore 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.[135] Notably, the PADEP 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.[136]

This conclusion about potential exposure to surface radiation did not apply to POTWs, where levels were found to be much lower. It is not clear why, although one possibility is the fact that volumes of gas field wastewater going to POTWs overall has been declining—the result of numerous letters and administrative orders to facilities by the EPA, high-profile lawsuits following the contamination of drinking water, and a request by PADEP that operators voluntarily stop sending Marcellus wastewater to POTWs.[137] Another possible explanation is that, according to new rules adopted in 2011, drilling wastewater has to be pre-treated at CWTs before being discharged through POTWs.[138]

The PADEP 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 test for radiation. New York and Ohio do not do not require detectors at solid waste facilities, although some may choose to install them. A 2007 survey; a 2007 survey found that neither state considered radiation a problem or a priority.[139] Despite the acceleration of shale gas development, officials in Ohio appear to still maintain this view.[140]

All Pennsylvania landfills have had radiation detectors in place since 2002, a response to concerns over improper disposal of medical waste. However, they are generally set to detect radiation coming off the waste at levels that would be hazardous for people nearby who are directly exposed. This can mean that significant volumes of waste "pass the test" for disposal but could still contaminate water and soil, especially over time. For example, in 2012, only 4% of the waste setting off radiation alarms at Pennsylvania landfills was considered too "hot" to handle and had to be shipped out of state to specialized facilities.[141]

Waste pits under construction in Pennsylvania. Photo by Frank Finan.

West Virginia has also installed radiation detectors at landfills that accept drilling waste.[142] Facility employees would have to use both stationary and handheld devices to measure radiation levels; however, no such devices appear to exist to actually test at the low levels stipulated in the associated regulation.[143]

In addition, waste facilities and regulatory agencies may not always use the appropriate testing methods to detect radiation. Gamma radiation is used to measure Ra-226 and Ra-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.[144] 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.[145] Recognizing that concentrations of naturally-occurring radionuclides in wastewater may be 1,000-10,000 times as high as in water samples, EPA has begun to consider how to develop a new method to test radiation specifically in flowback and produced water from hydraulic fracturing operations.[146]

Waste being transferred for transport in Pennsylvania. Photo by Riverkeeper.

Characterizing waste

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.[147] However, EPA does not require states to integrate these criteria into regulation as part of their Subtitle D programs, which would make them enforceable on the state level—even though landfills have to follow them to be classified as legal facilities.[148] **In practice, 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.**

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."[149]

Similar concerns exist with regard to the wastewater treatment plants that accept both drilling wastewater and the leachate collected (and sometimes pre-treated) by licensed landfills.[150] Although facilities that treat and discharge wastewater are required to obtain a federal National Pollution Discharge Elimination System (NPDES) permit, as well as applicable state permits, testing parameters under these permits may only partially correspond with the actual contaminants with leachate from landfills that accept oil and gas waste, or in drilling wastewater.

This can result in facilities not testing or monitoring for—and therefore not taking steps to sufficiently remove—certain contaminants (such as radium, benzene, and toluene). A 2014 study by researchers at Duke University found that oil and gas wastewater being discharged into streams and rivers in Pennsylvania and 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.[151] Similar concerns exist when bromides in oil and gas wastewater combine with chlorine used for disinfection and form trihalomethanes and haloacetic acids, which can harm human health.[152] Researchers concluded that identification and removal of the by-products may require specific processes, which are not currently in place at wastewater treatment plants.[153]

Testing waste

Waste characterization forms are used by generators of waste in all the states considered in this report. In general, they allow for basic descriptions and operator latitude in whether or not 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 cover many loads or tons of waste from different locations over the course of several months or more.

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

In November 2014, OEPA, ODNR, and the Ohio Department of Health issued a recommendation to managers of landfills accepting shale field waste generated through horizontal drilling that, "facility personnel who approve special wastes discuss recognized sampling and analysis methods with their oil and gas customers."[154] Ohio's regulatory agencies do not appear to require waste generators to complete waste characterization forms that indicate the type of waste being disposed and potentially the substances it contains. However, solid waste management districts generally require customers to complete waste profile forms, on which they declare whether a waste is hazardous or not and may have to provide data on the chemical constituents and characteristics of waste.[155]

West Virginia requires generators of special wastes, which include "treatments like solidification," to complete a waste characterization form (WCF) with estimates of the volume of waste disposed.

On the WCF, operators have to declare the "anticipated" weight of waste delivered within a certain timeframe, though not specific volumes or distinctions between wastes (e.g., drill cuttings versus drilling muds). Operators have to provide a "common sense description" of the content and consistency of the waste (i.e., whether it is solid, liquid, slush, or slurry), choosing whether to make this decision "visually, by best judgment, or by a laboratory test."[156] They can also simply check boxes for whether the waste is hazardous and contains toxic or radioactive material.

Landfills seeking a minor permit modification (i.e., without having to go through a new permitting process) to accept the waste sign the form and submit it to WVDEP. Proposed changes to regulations on solid waste management—which have yet to be formally enacted but are currently in force under an emergency rule—require landfills to obtain from oil and gas operators a comprehensive analysis of the contaminants of waste (though not including radioactivity) from the lateral or horizontal portion of each well bore.[157]

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.[158] 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.[159]

Landfills in Pennsylvania are required to provide determination of whether the waste they accept is liquid or solid, based on the EPA paint filter test; color and odor; and certification from the generator of the waste that it's not hazardous.[160] If waste generators don't provide the landfill with "a detailed physical, chemical and radiological characterization of the waste and its leachate," the landfill can state that "generator knowledge" is sufficient.

In New York, generators of solid waste are required to complete waste characterization forms for the facilities where disposal will occur. Although a state form exists, waste disposal facilities often develop their own to match the wastes they accept, which may or may not include solidified/bulked drill cuttings.[161] These generally include proof of laboratory testing for toxicity, although it is up to each NYDEC regional office to determine whether the characterization guidelines of the landfills they oversee are sufficient and such testing is necessary—resulting in variability statewide.

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 in turn, for soil and water quality. As long as comprehensive chemical testing is not required, and landfills instead rely on such factors as appearance, passing the paint filter test (discussed below), and the general declarations of waste generators to determine how waste is managed and disposed, the actual content of waste and its potential impacts will remain largely unknown.

Solid vs. liquid

When it comes time for disposal, oil and gas field waste can blur the line between "solid" and "liquid." 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. For example, between 2012 and 2014, operators in Pennsylvania reported sending over 260,000 barrels of "drilling fluid waste," "fracing fluid waste," "produced fluid," and "servicing fluid" to landfills.[162]

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

This happens because oil and gas operators and waste facilities can process sludges and liquids using large volumes of other materials in order to solidify and stabilize them so that their toxic contents are less likely to leach out. 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. Materials used to blend waste can include wood chips, sawdust, and cement, or other waste products such as lime kiln dust, the by-products of coal combustion, or the shredded remnants of automobiles and tires.

Dilution makes it much more likely that a load of waste will 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.[163] Downblending is also frequently used to decrease the concentration of radioactivity in a given volume of waste enough to meet landfill disposal standards.

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.[164] In 2014, a company in Ohio applied for a permit to operate a disposal facility to store and process brine, drilling muds, drill cuttings, and tank bottom sediment, stating that operations would "involve 'blending' of waste material that exceeds the regulatory limit of 6.99 pCi/g Ra-226/228."[165]

Shakers separating drilling muds and cuttings. Photo by Cowgirl Jules.

In 2013, the passage of HB59 in Ohio specifically allowed for downblending with dry materials in order to lower radioactivity thresholds in the waste so that it could meet landfill standards.[166] In 2014, ODNR issued authorizations for 23 waste facilities to process oil and gas field waste, including through solidification; however, the agency did so using "Chief's Orders" that circumvent public notification requirements and local government review, and Ohio does not have any regulations in place to govern the blending process.[167]

The same year, OEPA sent a memo to landfill operators signaling the possibility that drillers could send liquid waste to landfills after solidifying it at the well site.[168] Landfill operators have stated that this isn't happening yet because of the state's brine disposal rules.[169] However, what the future holds may depend on the volume of brine produced and the capacity limitations of underground injection wells that take much of Ohio's waste fluids.

Blending wastes

In January 2015, PADEP adopted a new policy on the formula for diluting sludges prior to disposal at landfills, changing annual limits on radioactive content to monthly caps—in effect requiring facilities to ensure that enough dilution material is used based on tonnage and radium concentrations.[170] It is too soon to tell whether this requirement could cause landfills to exceed their capacity and disposal limits, or if operators will respond to the additional cost of obtaining materials for blending by sending more waste out of state or seeking other methods of disposal.

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.[171]

The possibility of this happening is a particular concern when drilling wastes are mixed with materials that already contain toxic and/or radioactive substances. 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.[172] New draft rules in West Virginia on the management of oil and gas solid waste do not specify which materials are acceptable for use in solidification, or how and where the process of blending and stabilization should occur.[173] However, WVDEP permits landfills to use coal ash as a solidification agent for other wastes, a process defined in regulations as a "beneficial use" of coal combustion by-products.[174]

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.[175]

> 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.

In a 2002 publication about the RCRA exemption for oil and gas waste, EPA warned operators that they could face regulatory complications if they mixed their wastes with other products: "Whenever possible, avoid mixing non-exempt wastes with exempt wastes…The resulting mixture might become a non-exempt waste and require management under RCRA Subtitle C regulation."[176] The publication provides examples of how this could happen, including if after mixing, the resulting waste becomes more corrosive or contains excessive levels of toxic substances (such as benzene).

Just like oil and gas field waste, some key blending materials are exempt from RCRA. In late 2014, EPA declined to designate coal ash as a hazardous waste, instead classifying it as "solid waste"—a move that supports the expansion of efforts to repurpose coal ash.[177] 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 US Environmental Protection Agency (EPA) Toxicity Characteristic Leaching Procedure (TCLP)."[178]

In addition, as sludges and liquids are blended with other wastes, levels of contaminated and potentially hazardous contents may also 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.

Underground injection

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). 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.[179] Designated specifically for the oil and gas industry, most of the estimated 170,000 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 (about 100 are used for hydrocarbon storage).[180]

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

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) from 2005 to 2012.[181] EPA can grant approval for states (as well as US territories and tribes) to hold primary enforcement responsibility for UIC activities, a status known as "primacy."[182] 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).[183]

In managing UIC programs, states with primacy have responsibility for issuing permits, inspecting wells, enforcing regulations, and collecting and reporting data to EPA. For the states covered in this report, Ohio and West Virginia have primacy, while EPA retains authority over Pennsylvania's and New York's UIC programs.

UIC program quality

Ohio has the largest number of active waste disposal UIC wells in the region, about 200, mostly in the eastern and central parts of the state; at the time of writing, nearly 40 others were in the process of being permitted or drilled.[184] As of mid-2014, eight private and two commercial facilities in Pennsylvania were actively accepting waste.[185] There are about 60 active waste disposal UIC wells in West Virginia; 14 are commercial wells that accept fluid from numerous operations, while the rest are owned by drillers and used only for their own operations.[186] New York's UIC program is limited, with only six wells owned by conventional drilling companies being used for produced water disposal and natural gas storage; no new wells have been permitted since the 1990s and since 2012, injection has occurred at only three of the wells.[187]

A 2009 assessment of state wastewater management programs by the Argonne National Laboratory found that while regulatory agencies in all of the Marcellus and Utica Shale region states maintain data on total volumes produced, only Ohio tracks how much waste is injected underground at licensed facilities (over 95% at the time).[188] The only source of related information in the region is data reported by operators on the method used for waste disposal (i.e., injection underground); in Pennsylvania, this includes several types of waste, while in West Virginia the information is available only for flowback.

In a 2014 report on the federal UIC program, the **US 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" and that EPA is not consistently conducting key oversight and enforcement duties for Class II wells** to ensure that requirements are being upheld.[189] 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.[190]

These two trends are closely associated with the rapid growth in the quantity of waste produced by the oil and gas industry. 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 Pennsylvania, EPA recently issued an injection well permit despite widespread opposition by residents and county officials.[191] Opposition to new injection wells in eastern Ohio is on the rise,[192] while West Virginia residents have enlisted state and national environmental groups to fight the renewal of a permit for an older injection well.[193]

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 ODNR 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.[194] 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 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.[195]

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.[196] 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.[197] 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, 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).[198] EPA's UIC National Technical Workgroup recently issued recommendations to minimize the risk of injection-induced seismicity, including assessment of sites for the likelihood of activating faults, reduction of pressure, and seismic monitoring.[199] However, the agency is clear that these are non-regulatory "practical steps" for states and operators to consider and are also "within the Class II Director's discretion to apply."

Federal regulations do not currently address seismic risk from underground waste injection

West Virginia's current regulations for its UIC program date to 2002.[200] Existing construction standards for oil and gas wells are presumed to apply to Class II wells, which require operators drilling in porous formations to test for the location of faults; however, they do not include measures to safeguard against seismic activity, in contrast to the extensive regulations (e.g., related to pressure, mechanical integrity, and monitoring) for the Class I wells used for hazardous waste injection in the state.[201]

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.[202] 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.[203] 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.[204]

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.[205] 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.[206] In 2014, two more injection wells were shut down following another earthquake.[207]

In the aftermath of the earthquakes in Ohio (as well as several in Arkansas, Colorado, New Mexico, Oklahoma, and Texas), questions were raised about the likelihood of similar events occurring in Pennsylvania.[208] EPA has recently issued several permits for UIC wells in the state, with others likely to follow; in doing so, the agency has indicated that the wells would be unlikely to cause seismic activity due to the pumping pressure and well depth that operators included in their permit applications.[209]

Pressure and leaks

Even as oil and gas companies set their sights on new injection wells 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 has increased significantly in recent years—raising the question of whether capacity can ultimately keep pace with the volumes of waste being produced. The same trend has been seen for an earlier period in West Virginia; in 2010, 12% of flowback fluid (the only waste systematically reported by operators) was disposed of in UIC wells, this increased to 26% in 2011 and 35% in 2012.[210] According to data available from Pennsylvania, the proportion of injected waste coming from Marcellus Shale wells has also increased, from 79% in 2011 to 93% in 2014.[211]

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

	Year				% Change
Ohio	2011	2012	2013	2014	2011-2014
	12.6 million	14.1 million	16.4 million	22 million	+75%
Pennsylvania	2011	2012	2013	2014	2011-2014
	2.8 million	4.3 million	3.5 million	4 million	+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. 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.[212]

With such risks at play, construction standards and testing requirements in the UIC program aim to protect groundwater by preventing leaks and the migration of injected fluids. Federal criteria include frequent monitoring for injection pressures and rates; in addition, Class II wells should be monitored for "mechanical integrity" at the time of construction and then at least once every five years.[213] New York, Pennsylvania, and West Virginia adhere to this standard; Ohio recommends monthly monitoring unless doing so is "not feasible" for operators.[214] ``

However, the rapid increase in waste injection raises the question of whether these testing requirements and oversight of injection wells by regulatory agencies are still sufficient—resulting in problems going undetected or unaddressed for long periods of time. 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.[215] 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.[216]

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

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.[217] 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."[218] 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.

In West Virginia, only two Class II injection well permit applications are currently pending—but they are for the renewal of permits at a facility that has been leaking and likely causing damage to water quality for several years. 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.[219] 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."[220]

According to the 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.[221] 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."[222]

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.[223]

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

Both trends are particularly concerning because of a loophole in the Safe Drinking Water Act that allows the injection of oil and gas waste into UIC wells even if they are drilled directly into aquifers, as long as the aquifers are deemed to contain water of too low-quality and "will not reasonably be expected to serve as a source of drinking water."[224] In mid-2014, EPA stated that over 1,250 such exemptions have been issued for Class II waste disposal wells; however, the agency does not provide state-by-state breakdowns.[225]

Repurposing waste

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 New York, Ohio, and Pennsylvania.[226] West Virginia does not have a BUD program, but has adopted regulations for the beneficial use of specific wastes (such as coal combustion products, scrap tires, and sewage sludge).[227] 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.

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 the practice is the high levels of salt, chloride, and chemical contaminants (e.g., benzene and toluene) in the brine, which can harm human health, aquatic life, and vegetation. This happens when melting snow and rain carry the brine into soil, streams, rivers, and groundwater.

All four states considered in this report allow road-spreading of brine, which in this context appears to be limited to produced water (i.e., not flowback or other fluids from oil and gas operations). The states have varying requirements for the road-spreading of brine, including those related to the testing of chemical content; allowable limits of total dissolved solids, calcium, chloride, and other contaminants; and the methods used and rate of application (i.e., the allowable volume of waste spread on a given area of road). However, key gaps remain, including the exclusion of radionuclides in testing requirements and the testing of only "representative samples" of waste submitted by operators and waste haulers.

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

In its 2012 comments on New York's draft environmental impact statement on HVHF, the EPA stated that, "produced water may still contain some of the chemicals used in the hydraulic fracturing fluids if not all the fluids returned in the initial flowback period. Moreover, the 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 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.[228] 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.[229] 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.[230]

State-specific considerations around the road-spreading of brine include:

Ohio regulates the hauling and spreading of brine through its UIC waste disposal program, but actual permitting for road-spreading for purposes of dust suppression and de-icing is done through municipal or county governments. It is not an approved BUD process, over which OEPA would have regulatory authority. Instead, local jurisdictions adopt resolutions on brine-spreading, which have to comply with standards (e.g., restrictions on how and when the brine can be applied) that are contained in state law and a guidance document from ODNR.[231] It is not clear how ODNR ensures that only produced water is used on roads, since the state defines brine as "all saline geological formation water resulting from, obtained from, or produced in connection with the exploration, drilling, or production of oil or gas…The definition of brine includes flowback water from hydraulic fracturing."[232]

Pennsylvania currently allows brines from conventional gas wells to be used as a dust suppressant and stabilizer on unpaved roads, practices guided by specific requirements and plan approvals developed on the basis of the state's Clean Streams Law, Solid Waste Management Act, and oil and gas regulations.[233] However, PADEP has yet to legally approve of road-spreading as a BUD process. In 2011, PADEP issued a notice for public comment on a beneficial use general permit (known as WMGR064) to allow gas well brines to be used both for dust suppression and de-icing; however, following challenges to the permit, PADEP withdrew it.

PADEP has included road-spreading of brine from conventional wells for dust suppression, anti-icing, and de-icing of roads in proposed revisions to its Chapter 78 oil and gas regulations.[234] However, this process may be an illegal circumvention of the state's permitting and rulemaking procedures for residual waste management.[235] Earthworks and its partners have recommended that Pennsylvania prohibit road-spreading of brine in Chapter 78, emphasizing that until the scientific data is provided that demonstrates the treatments in use meet federal and state drinking water standards, it cannot be considered safe.[236]

West Virginia does not have specific beneficial use regulations for the road-spreading of oil and gas brine, but allows it for de-icing and road pre-wetting purposes. According to a 2011 agreement between WVDEP's Division of Water and Waste Management and the West Virginia Division of Highways, only produced water (not "hydraulic fracturing return fluids," i.e., flowback), can be used, and limits have been placed on the allowable concentrations of total dissolved solids, chloride, benzene, and other contaminants that can be present in brine spread on roads.[237]

New York allows brine from oil and gas production and gas storage to be spread on roads, requiring waste transporters to obtain a BUD for the practice.[238] The state policy regarding the radioactivity risk of oil and gas waste is based on a study conducted in 1999 and predicated on wells generally drilled 1,500-3,000 feet deep; even so, the study concluded that "Of these wastes, the highest concentrations of radium were found in brines." [239] In the meantime, waste transportation records from Pennsylvania indicate that production brine from conventional wells in that state was sent to Allegany and Chautaqua Counties, New York, for road-spreading.[240] To date, 15 New York counties have enacted bans on the road-spreading of oil and gas waste.[241]

Creating new materials

Oil and gas operators are increasingly interested in finding ways to repurpose drill cuttings 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.[242] 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."[243]

In 2011, CleanEarth, a company that handles contaminated soils and materials for disposal and reuse, opened a Research and Development (R&D) facility in Williamsport, Pennsylvania, exclusively for the development of methods to reprocess Marcellus Shale drilling and pipeline cuttings.[244] Under approval by PADEP, the facility had 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.[245] 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.[246]

In December 2013, the Pennsylvania DEP received an application from Range Resources to conduct R&D on the use of drill cuttings in the creation of construction materials at gas well sites. The company sought a beneficial use permit (WMGR097) that PADEP had developed specifically for R&D on municipal and residual waste—even though the new permit didn't go into effect until three months after the application submission.[247] Earthworks and its partners recommended to PADEP 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. In particular, PADEP has not yet proven the safety of the process being proposed and that the end-product wouldn't be more hazardous and potentially harmful to water, soil, and health than the plain cement it would replace.[248] In addition, PADEP failed to analyze and address the long-term and cumulative impacts of the project on water resources and the surrounding community.

PADEP granted the permit anyway, which Delaware Riverkeeper, Earthworks, and Lower Susquehanna Riverkeeper then appealed through the state's Environmental Hearing Board.[249]

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.[250] 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."[251] However, ODNR approved the project through a "Chief's Order" that circumvents public notification requirements and local government review.[252]

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.[253] 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—the definition of which in HB59 specifically excludes drill cuttings.[254] 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.

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 clean and treat the waste has been driven largely by the need to reduce the use of freshwater, particularly in arid regions. But it has also been touted by industry as a way to reduce waste transport and disposal.[255]

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.[256] 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.[257]

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.

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.

Table 2: Reuse and recycling of liquid waste, Pennsylvania, 2011-2014				
Unconventional wells				
	Total barrels waste	Total barrels reused & recycled	% of all waste that is reused	% of all waste that is recycled
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, fracing, and produced fluids.				

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).[258] 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.[259] (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."[260]

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.[261] Currently, the prospects for recycling appear limited, while more information from operators and regulators would be needed to determine what and how reuse is being applied and where the final waste products ultimately end up.

Empty waste pit showing discolored soil in West Virginia. Photo by Marc Glass.

The State of the States

If the heterogeneity we observed reflects different conditions across states that lead to different levels of environmental risks, then that heterogeneity is a good thing. On the other hand, if the heterogeneity does not depend on environmental risks but is, perhaps, more dependent on politics, regulatory capture, economic concerns about jobs, or simply historical evolution or unexamined assumptions, we might question whether this heterogeneity is justified.

—Resources for the Future[262]

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.** The following pages review regulatory structures, oversight processes, and tracking and reporting specific to each of the four states in the Marcellus and Utica shale region.

In fall 2014, Matthew Cartwright, a member of the US House of Representatives from Pennsylvania, wrote to regulatory agencies in Ohio, Pennsylvania, and West Virginia requesting information on the states' policies, regulations, and monitoring systems related to waste from hydraulic fracturing operations. His letter stated that "if not handled properly, these fracking wastes can contaminate nearby lands and waters and cause harm to human health and the environment." At the time of this report, agencies in Pennsylvania and West Virginia had responded to the request with short general letters outlining established regulations and assuring Congressman Cartwright that the waste stream is being properly managed.[263] Ohio has not yet responded.

Waste Management at a Glance

Waste Management Table Key	N = No	Y = Yes	\ = Partial, with exceptions

	Ohio		Pennsylvania		West Virginia		New York	
Type of waste management	**Current**	**Proposed**	**Current**	**Proposed**	**Current**	**Proposed**	**Current**	**Proposed***
REGULATORY AGENCY OVERSIGHT								
Agency verifies data submitted by operators	N	N	N	N	N	N	N	N
DATA TRACKING								
Operators document origin and destination of flowback	Y	Y	Y	Y	Y	Y	N	Y
Operators document origin and destination of produced water	Y	Y	Y	Y	Y	Y	N	Y
Operators document origin and destination of solid waste	N	N	Y	Y	N	Y	N	Y
Operators report waste data to regulatory agency	\	\	Y	Y	\	\	Y	Y
Data publicly available online or in files	\	\	Y	Y	N	N	N	\
Data publicly available upon request or through FOIA/RTKL	\	\	Y	Y	\	\	\	\
VOLUME REPORTING								
Operators report volume of flowback	Y	Y	Y	Y	Y	Y	Y	Y
Operators report volume of produced water	Y	Y	Y	Y	N	N	Y	Y
Operators report volume of solid waste	N	N	Y	Y	N	N	Y	Y
Disposal facility records volumes accepted	Y	\	Y	Y	Y	Y	Y	Y
Data publicly available online or in files	\	\	Y	Y	N	N	N	N
Data publicly available through FOIA/RTKL	Y	Y	Y	Y	Y	Y	Y	Y
STORAGE PRACTICES								
Production/reserve pits allowed	Y	Y	Y	\	Y	Y	Y	Y
Centralized impoundments for waste allowed	Y	Y	Y	Y	Y	Y	Y	\
Closed-loop and tank systems required	N	N	N	\	N	N	N	N
DISPOSAL PRACTICES								
Onsite waste pit burial allowed	Y	Y	Y	\	Y	Y	Y	\
Land application of solid waste allowed	Y	Y	Y	Y	Y	Y	Y	Y
Road-spreading of liquid waste allowed **	\	\	\	\	\	\	\	\

	Ohio		Pennsylvania		West Virginia		New York	
Type of waste management	**Current**	**Proposed**	**Current**	**Proposed**	**Current**	**Proposed**	**Current**	**Proposed***
Solid waste disposal at municipal landfills allowed	Y	Y	Y	Y	Y	Y	Y	Y
Solid waste disposal at specialized landfills/facilities required	N	N	N	N	N	N	N	\
Wastewater disposal at municipal treatment plants allowed	Y	Y	Y	Y	Y	Y	Y	Y
Wastewater disposal at specialized or industrial plants required	N	N	\	\	N	N	N	N
Liquid waste can be injected underground	Y	Y	Y	Y	Y	Y	Y	Y
Financial assurance (bonding) for oil and gas wells covers waste removal	N	N	N	N	N	N	N	N
CHARACTERIZATION REQUIREMENTS								
Operators test and report chemical composition of liquid waste	N	N	\	\	\	\	\	\
Operators test and report chemical composition of solid waste	\	\	\	\	\	\	\	\
Treatment plants and/or injection wells test and set limits on chemical composition and radioactivity	\	\	\	\	\	\	\	\
Landfills test and set limits on chemical composition and radioactivity	\	\	\	\	\	\	\	\
Oil & gas waste may be classified as industrial	N	N	N	N	N	N	N	N
Oil & gas waste may be classified as hazardous	N	N	N	N	N	N	N	N

* New York's proposed regulatory changes only would have applied to unconventional, high-volume wells had the state decided to move forward with such drilling.

** All four states allow road-spreading of brine for de-icing and dust suppression. In New York, Ohio, and Pennsylvania, regulations specify that only brine from conventional wells, not high-volume shale wells, can be used. West Virginia hasn't specified such a prohibition, although the state has set limits on the allowable concentrations of total dissolved solids, chloride, benzene, and other contaminants in the brine.

Ohio

Ohio's oil and gas industry dates back to the mid-1800s; since then, nearly 280,000 wells have been drilled, primarily using vertical drilling and low-volume hydraulic fracturing in sandstone and limestone formations.[264] After steady declines in recent decades, production has picked up in the last few years due to HVHF in the Utica and Marcellus shale formations.

As of 2013, most of Ohio's 38,000 active oil and gas wells were classified as conventional; only about 350 were shale gas wells—yet these accounted for 46% of oil and 59% of gas produced in the state in 2013.[265] When production volumes doubled between 2012 and 2013, the industry began to use the term "boom," while the Ohio Department of Natural Resources (ODNR) claimed the state was on its way toward energy independence.[266] As of early 2015, nearly 1,800 horizontal well permits had been issued and over 1,350 Utica or Marcellus shale wells were producing or being drilled.[267]

In 2011, STRONGER released a positive report on Ohio's hydraulic fracturing regulations—but emphasized that it only considered "currently anticipated volumes of waste" and that regulators had yet to address "anticipated development of the Marcellus and Utica Shale."[268] In 2013, ODNR stated that proposed changes in waste management reflected a "proactive" approach.[269]

Yet in the last few years, it's become increasingly clear that when it comes to waste management, Ohio is already having a hard time keeping up with expanded drilling. **Rapid shale drilling both in-state and in neighboring Pennsylvania and West Virginia has led to a surge in the volume of waste fluids being disposed of in Ohio and the number of facilities receiving permits to handle it.** [270] An analysis by the FracTracker Alliance of data from a single solid waste management district in Ohio indicates that the volume of oil and gas field waste accepted there increased by about 13,000-19,000 tons annually during 2011-2014.[271]

As indicated in Table 3, shale gas wells have accounted for a rapidly increasing proportion of the brine produced in Ohio in recent years. By 2014, horizontal wells generated 7.4 million barrels of brine—more than the volume generated by *all* wells just one year earlier.

Table 3: Brine production from Ohio oil and gas drilling, 2011-2013 (in barrels)

	All producing wells	Horizontal only	% of all brine from horizontal wells
2011	4.8 million	76,000	1.6%
2012	5.6 million	682,000	12%
2013	7.3 million	2.7 million	37%
% Change (2011-2013)	+52%	+3,450%	N/A

Figures calculated using data reported by operators to ODNR and available on the Oil and Gas Production website. Note that in 2011, "horizontal" meant Utica Shale wells; in 2012 and 2013, it meant both Utica and Marcellus Shale wells.

In Ohio, common sense may mean less regulation

In 2011, Governor John Kasich issued an Executive Order creating the "Common Sense Initiative" (CSI), through which Lieutenant Governor Mary Taylor and members of the CSI can direct state agencies to review and change their regulations "to create a more jobs-friendly regulatory climate in Ohio."[272] Two guiding principles are that "regulations should facilitate, not hinder, economic growth" and "Compliance should be as easy and inexpensive as possible," and in 2012 CSI boasted of 44% fewer regulatory filings than usual.[273]

Under the CSI, agencies must complete a "Business Impact Analysis" that answers why a regulation more stringent than federal requirements is necessary; whether regulatory compliance will have a cost for businesses (e.g., fees or fines); and whether regulations include exemptions and waivers for businesses.[274] Among the many rulemakings currently subject to CSI review are those pertaining to horizontal well site construction and facilities (e.g., pits and tanks); spills and containment; underground injection control; solid waste fees; and waste transfer facility rules.

It is difficult to clearly identify the influence of CSI on these and other rulemakings—or on ODNR as it decides whether to issue new rules and how to enforce existing regulations. However, it is clear that the State of Ohio is investing considerable resources to ensure that regulations do not "burden" any industry, including oil and gas.

Oversight

Ohio's oil and gas regulations, including those pertaining to waste management, are found in Chapter 1501:9 of the Ohio Administrative Code (OAC), with additional information in Rule 1509 of the Ohio Revised Code.[275] In 2010, Ohio revised its oil and gas laws for the first time in 25 years through Senate Bill 165 (SB165) and in 2012 added additional changes through Senate Bill 315 (SB315), which focused specifically on shale development.[276] In 2013, House Bill 59 (HB59) clarified the oversight authority and coordination of state agencies, in particular with regard to oil and gas field waste classification and disposal.[277]

The Division of Oil and Gas Resources Management (DOGRM) within ODNR is responsible for oil and gas permitting and regulatory enforcement. **When it comes to the management of oil and gas waste, however, the question of regulatory authority becomes much more complicated, leading three state agencies to develop an extensive chart** as "a starting point to help companies identify the correct agency to contact regarding regulatory requirements."[278]

Ohio drilling site, with flame near a pit. it. Photo by Kari Matsko.

In sum, ODNR holds authority over any management of oil and gas field waste that is generated, stored, or processed onsite (i.e., at well sites), as well as disposal and the "beneficial use" of brine and the processing of solid waste landfills and transfer facilities. ODNR has also managed and regulated the state's Underground Injection Control (UIC) program since 1982, when the agency received approval to do so from EPA, a status known as primacy.[279]

The Ohio Environmental Protection Agency (OEPA) holds authority over several aspects of off-site waste management, in particular with regard to solid waste (e.g., drill cuttings, muds, and sand). OEPA's Division of Materials and Waste Management oversees waste disposal facilities, which are coordinated through solid waste management districts (SWMDs).[280] The Ohio Department of Health (ODH) holds authority for the disposal of any waste with radioactive content.

Two or all three of the agencies share authority for several types of waste and stages of management, as well as oversight and enforcement related to permits, waste facilities, and the illegal transport or disposal of waste. This split regulatory picture can clearly pose challenges for operators trying to follow regulations, for advocates promoting stronger protections, and for the public needing information on waste-related pollution and action by public agencies.

Tracking and reporting

Brine is the only type of oil and gas field waste tracked by state agencies in Ohio. Operators report the volume generated at producing wells to ODNR both quarterly and annually; this information is publicly available online.[281] ODNR defines brine as "all saline geological formation water resulting from, obtained from, or produced in connection with the exploration, drilling, or production of oil or gas," i.e., both flowback and produced water.[282]

In addition, licensed haulers that transport brine for disposal in injection wells are required to track and record origin, destination, and volume and report the data to ODNR's UIC program.[283] Since the passage of SB315 in 2012, injection well owners are required to submit quarterly reports on brine volumes to ODNR.[284] Although this information is not online, it may be made available upon request.[285]

Utica Shale well site in Ohio. Photo courtesy of Penn State.

When it comes to solid waste (e.g., drill cuttings, muds, and frac sand), Ohio does not require tracking or reporting, nor does the agency maintain a database or other centralized system of information on the types and volumes of waste. Operators, haulers, and disposal facilities generally track and record solid waste in order to calculate handling and disposal charges, but these records are not available to the public and ODNR does not require that they be submitted.

The FracTracker Alliance has found that only one SWMD (out of more than 50 across Ohio) tracks the volume of solid waste received in such a way to know what was received specifically from oil and gas operations, as opposed to all customers.[286] According to a statement by that SWMD, drilling muds make up nearly 80% of the volume of solid waste disposed of at landfills in the district.[287]

Current practices

Nearly all (98%) of Ohio's produced water and fluid waste is disposed of in the state's underground injection wells.[288] Such wells are classified by EPA as Class II, into which brine and other oil and gas field wastes are injected or through which residual oil and gas can be recovered.[289] (See section on underground injection for more information.) Ohio has become a key destination for the disposal of waste generated at shale gas well sites in neighboring states. In recognition of the popularity of Ohio's geology for drilling waste disposal in UIC wells, in 2010, legislators used SB165 to increase fees for both injection well permits and brine disposal—setting fees for waste coming from outside a UIC district four times as high as for waste generated within it (20 cents per barrel vs. 5 cents).[290]

Figures compiled by ODNR show that in 2012, 14.2 million barrels of waste were disposed of in UICs, with the amount of waste coming from other states rising 19% from 2011 to 2012.[291] An analysis of operator filings by Downstream Strategies indicates that in 2010-2012, Ohio received

21% of the flowback fluid produced in West Virginia for underground injection, as well as 9% of all liquid waste produced in Pennsylvania for underground injection, industrial waste treatment, and other uses.[292] According to PADEP, operators in Pennsylvania have shipped drill cuttings, fracturing sand, produced fluid, flowback, and drilling fluids to 25 waste facilities in Ohio.[293]

Road-spreading of brine has long been allowed in Ohio for de-icing and dust suppression, but since the passage of SB165 in 2010, this practice is permitted only if the brine consists of produced water, not flowback or other fluids used in well development.[294] At the same time, ODNR's definition of "brine" appears to encompass both types of liquid waste.[295] Ohio law allows for the use of pits and centralized impoundments for both waste and freshwater, though the regulations for both are somewhat vague and have not yet been updated to address the types and volumes of waste generated by shale gas and oil development.

Drill cuttings illustrate the potential confusion over how to define, process, and dispose of oil and gas field waste, as well as the discretion that both operators and waste facilities have in making decisions. ODNR regulations apply to drill cuttings that are water- or clay-based and produced prior to the cementing of casing; such cuttings are considered to be "earthen material" and can be disposed of at the well site or in a landfill. However, if drill cuttings become contaminated through contact with oil or polymer-based muds, then OEPA's rules on solid waste govern their disposal at approved facilities.[296]

Drilling muds at a holding facility in Ohio. Photo by Amanda Kiger.

This regulatory distinction may not play out in practice, however, as Ohio doesn't require operators to conduct chemical testing to determine whether cuttings managed and disposed of onsite are in fact "uncontaminated." State agencies have recommended, but not required, that "landfill operators request written documentation from its customers" to determine whether drill cuttings are earthen material or solid waste.[297]

Making matters more complicated, only if drill cuttings contain radioactive components (such as Radium 226 and 228) above a level greater than what is found in a "natural state" would they be defined as TENORM and subject to ODH rules.[298] But in 2013, lawmakers who passed HB59 declined to give ODH—the state agency experienced with radioactive material—the authority to test oil and gas field waste, and instead put ODNR in charge.[299] At the same time, responsibility for actually determining if the waste is TENORM was put in the hands of solid waste landfills and transfer facilities, which are required to obtain representative samples and ensure that they adhere to the regulatory threshold for radioactivity.[300] (See section on radioactivity for more information.)

Looking ahead

Since the passage of SB165 in 2010, ODNR has been required by law to "adopt rules and issue orders regarding storage and disposal of brine and other waste substances."[301] In 2013, it seemed that Ohio would finally address the management of oil and gas field waste, beyond the piecemeal, incremental revisions made in SB165 and SB315 (discussed above). Yet HB59—a wide-ranging budget bill in which oil and gas regulations were addressed—left many gaps untouched. In particular, legislators abandoned proposed requirements for chemical standards and testing of both liquid and solid waste prior to disposal.[302]

In early 2014, ODNR created a preliminary draft of revisions to regulations on the construction of facilities at horizontal drilling (shale) well sites (contained in Chapter 1501:9-1-10 of the OAC). Among the changes contemplated by ODNR were requirements that drilling permit applicants and operators of well sites provide information on how both liquid and solid waste would be stored, treated, processed, reused, and recycled; develop a radiation protection plan; and track waste as it enters and leaves well sites.

However, the draft regulatory revisions do not include any standards or limits related to waste storage and treatment methods, volumes, or chemical parameters, nor specify any practices (e.g., reserve pit burial or brine evaporation) that would be prohibited. **ODNR's approach appears to be one of allowing operators to submit information of their own choosing, and agency staff to use their own discretion when issuing permits or determining regulatory violations.**

At the time of writing, ODNR had not included any information related to waste management in the current regulatory proposals posted on its website, and it is unclear when the agency plans to draft revisions or make them available for public comment.[303] At a meeting of the Common Sense Initiative (see box) in June 2014, DOGRM/ODNR distributed a list of "rulemaking topics that the Division is working to address." This list included several topics related to waste, including processing, recycling, storage, and treatment; impoundments; alternative disposal technologies; secondary containment at well sites; discharge reporting; disposal/treatment of oily and saline solid wastes; and brine tracking and disposal fees.[304]

Pennsylvania

Pennsylvania has a long history of oil and gas development and boasts of being home to the first commercial well drilled in the United States, in 1859. Today, there are more than 137,000 permitted wells across the state, most of which have been developed using vertical drilling and low-volume hydraulic fracturing in sandstone and limestone formations.[305] Yet the pace of drilling in the Marcellus Shale and other unconventional formations has been rapid, with the number of such wells considered "active" numbering nearly 10,000 and accounting for 55% of all wells drilled since 2010.[306]

Along with the shale gas boom has come a flood of waste. According to a recent comprehensive analysis of state data, between 2004 and 2011, the volume of liquid waste disposed of in Pennsylvania increased by 570%.[307] As indicated in Table 4 below, by 2014, volumes of waste reported by Marcellus drillers reached over 41 million barrels and 1.6 million tons and accounted for an increasing proportion of all waste generated.[308]

Centralized impoundment under construction in Pennsylvania. Photo by Frank Finan.

In light of such trends, elected officials, advocates, and the public have voiced growing concerns about Pennsylvania's ability to track and manage oil and gas waste—in part because of documented cases of damage to drinking water and soil from waste storage and treatment. For example, in 2012, the Pennsylvania Department of Environmental Protection (PADEP) found elevated levels of chloride, bromide, lithium, strontium, Ra-226, and Ra-228 just downstream of a treatment plant that accepts drilling waste and discharges it to the Allegheny River, concluding that the wastewater is "harmful to the water uses and aquatic life..."[309]

In 2013, a shipment of highly radioactive waste produced in Pennsylvania had to be trucked to a specialized facility in Idaho, since the operator failed to find a proper disposal option anywhere in the state or surrounding region.[310] In 2014, PADEP issued a record $4.15 million fine to Range Resources for several violations of five state laws, following investigations that confirmed soil and groundwater contamination at eight centralized waste impoundments in Washington County.[311]

Table 4: Waste production, Pennsylvania oil and gas wells, 2011-2014

BARRELS	CONVENTIONAL	MARCELLUS	TONS	CONVENTIONAL	MARCELLUS
2011	5.7 million	20.2 million	2011	4,800	842,000
2012	7.1 million	29.1 million	2012	5,000	1.5 million
2013	4.3 million	32.3 million	2013	3,200	1.3 million
2014	4 million	41.3 million	2014	500	1.6 million
Total volume (2011-2014)	21.1 million	122.9 million	Total volume (2011-2014)	13,500	5.2 million
% Change (2011-2014)	-30%	+104%	% Change (2011-2014)	-90%	+516%

Figures calculated using operator data submitted to PADEP, "State data downloads, waste" spreadsheets. The types of waste reported in barrels include produced fluid, fracing fluid, drilling fluid, lubricant, servicing fluid, and basic sediment; types of waste reported in tons include drill cuttings and fracturing sand. Note that PADEP maintains data for conventional and Marcellus waste separately.

Oversight

In 2012, more than six years after the first Marcellus well was drilled in Pennsylvania, the General Assembly developed and passed Act 13, the Oil and Gas Act. (Most of the state's previous oil and gas law dated from 1984.) Act 13 provides for the collection of an impact fee from unconventional wells and contains additional requirements, including some related to waste containment at well sites and reporting by waste haulers, for all types of wells.[312] The Solid Waste Management Act, passed in 1980 and most recently amended in 1997, covers the planning and regulation of solid waste, including storage, processing, transportation, and disposal.[313]

Pennsylvania's oil and gas regulations are found in Title 25 of the Pennsylvania Code. Article I (Land Resources), Chapter 78 includes key provisions related to the storage, processing, and treatment of waste at well sites. Chapter 287 contains the DEP's general regulations for residual waste management away from well sites. Article II (Water Resources), Chapter 91 contains general guidelines for wastewater impoundments, different aspects of which are also regulated under Chapter 102 (Erosion and Sedimentation Control) and Chapter 105 (Dam Safety and Waterway Management); for impoundments not located on well sites, Chapter 299 (Storage and Transportation of Residual Waste) also applies.

The Office of Oil and Gas Management at PADEP oversees and regulates most aspects of oil and gas development permitting and operations. This includes monitoring of waste as long as it is generated, stored, treated, or disposed of at a well site. However, when operators move the waste off of the well site (e.g., to a landfill), the Bureau of Waste Management at PADEP assumes regulatory authority over waste-related processes.

Tracking and reporting

PADEP compiles more data on the oil and gas waste stream and makes it publicly available to a greater degree than regulatory agencies in several other states, including those discussed in this report. However, questions have been raised by researchers about the accuracy of current information due to the self-reported nature of the information, the possibility that operators repeatedly report data for the same wells, and the absence of data quality oversight by PADEP—making the true volumes of wastes produced and their ultimate disposal destination difficult to assess.[314]

In a recent review of PADEP's performance on protecting water quality from shale gas development, Pennsylvania's Auditor General summed up concerns with oversight of the waste stream: "DEP has little reliable documentation to prove to the public that waste is generated, stored, transported, and disposed of properly and that water quality is protected from this potentially dangerous waste."[315] Another key finding was that PADEP lacks—but should develop and implement—a uniform "cradle to grave" system to track waste from the site where it is created all the way through transport, treatment, and disposal.[316]

Drilling waste storage on a Pennsylvania farm. Photo by Joshua Pribanic.

PADEP has asserted that current laws and the self-reported records developed and kept by operators provide sufficient documentation of waste volumes, types, and management practices.[317] However, PADEP staff have also indicated the intention to expand the electronic reporting of production and waste data by operators, which would presumably improve accuracy and availability of the information.[318]

PADEP has mechanisms available to ensure that oil and gas operators make plans for the management of the waste they create, including:

- Provisions in the Pennsylvania Code require operators to develop and implement an emergency plan on the "control and disposal of fluids, residual waste and drill cuttings…from the drilling, alteration, production, plugging or other activity associated with oil and gas wells."[319] In turn, operators submit a Preparedness, Prevention, and Contingency (PPC) Plan "for the operator to review his operations and identify all the pollutional substance and wastes, both solid and liquid, that will be used or generated, and identifying the methods for control and disposal of those substances or wastes."[320] PPC plans should contain the name of the disposal facilities and waste haulers used by the operator, and are submitted to the agency and kept at the well site.[321]
- Act 13 requires operators of unconventional oil and gas wells to prepare and submit to PADEP site containment plans, which should include information on the systems and practices used "to provide adequate containment for drilling muds, hydraulic oil, diesel fuel, drilling mud additives, hydraulic fracturing additives and hydraulic fracturing flowback."[322] Notably, Act 13 only requires PADEP to review—not approve or disapprove—the plans.

These documents are available through review of hard copy files at regional PADEP offices. Oil and gas operators in Pennsylvania are also required to report the liquid and solid wastes they generate annually for conventional wells and, since 2009, bi-annually for unconventional wells, using PADEP's Oil and Gas Reporting Website.[323] This information is publicly accessible online, with waste types and volumes viewable according to operator, county, or waste facility; statewide datasets are also available going back to 2000, with separate records for Marcellus Shale wells starting in 2009. In addition, the Susquehanna River Basin Commission requires operators with wells in that region to report the volumes of flowback and fluids produced and where they are disposed.[324] This information is not publicly available, although the Commission may provide the data upon request.

Landfills submit spreadsheets on a quarterly basis to PADEP, which include data on the volumes and types of waste they receive. A 2014 analysis of these records by the Pittsburgh Post-Gazette revealed significant discrepancies between the volumes that landfills report receiving and operators report generating; for example, nine facilities in Southwestern Pennsylvania reported accepting 3-4 times as much waste as drillers reported to PADEP. [325] PADEP told the Post-Gazette that data submitted electronically by drillers "are estimates and not necessarily based on real numbers." However, only the electronic data that is self-reported by operators is available to the public, so it is difficult to determine how much waste is actually generated and disposed of.

According to a provision in Act 13, operators of unconventional wells need to maintain records of wastewater transportation for five years, including information on volumes produced during drilling and hydraulic fracturing; the waste hauling company used; and the facility and methods used for disposal. However, operators are not required to submit these records to PADEP, but only to make them available to the agency upon request.[326] Waste transporters are required to complete and maintain daily operational records on forms provided by PADEP, including information on the type and volume of waste transported; the operator that generated it; the facility where it was transferred, processed, or disposed; and any problems while it was being handled.[327]

An additional source of information on oil and gas field waste in Pennsylvania is the well restoration report that operators are required to submit to PADEP within 60 days of restoring a well site; restoration itself must be done within nine months of completing a well.[328] These forms include information on the type and volumes of waste produced, whether it was disposed of onsite or offsite, and the method and destination of disposal.

Wastewater discharge into the Ohio River near Pittsburgh. Photo courtesy of WESA.

However, PADEP has confirmed that this information is not included in the Environment Facility Application Compliance Tracking System (eFACTS), the publicly available database of oil and gas well information. Previous research by Earthworks found that operators of 99 wells reviewed (through hard copy files) should have already submitted a restoration report according to required timeframes for doing so; however, they were missing for 81 of those wells (or 82%)—making it impossible for either PADEP or the public to know whether waste had been removed from the site and where it went.[329]

Current practices

Pennsylvania defines oil and gas field waste as residual waste, which includes "any garbage, refuse, other discarded material or other waste including solid, liquid, semisolid, or contained gaseous materials resulting from industrial, mining, or agricultural operations…provided that it is not hazardous."[330] In 1986, the Pennsylvania legislature amended the state's solid waste management law to specifically exclude drill cuttings from the definition of "solid waste."[331] This exclusion allows operators to dispose of cuttings at the well site (see section on pits and impoundments).

PADEP's Oil and Gas Reporting website includes search options for data on the volume and types of waste that operators report having transported to disposal facilities both across Pennsylvania and to eight other states. Ohio and West Virginia are key destinations for brine and fluids, while landfills in both states, as well as in New York, accept drill cuttings and drilling muds. Maryland has accepted drilling fluid waste and New Jersey takes both drilling fluid waste and drill cuttings. Shipments of used fracturing sand have made it as far as Michigan and Idaho, and one operator appears to have taken produced fluid from its Pennsylvania operations all the way to Texas.

A comprehensive analysis by Downstream Strategies (which took into consideration problems with data quality) found that during 2008-2011, oil and gas operators in Pennsylvania reported disposing of most (88%) of the waste they produced in-state, while nearly 12% was shipped out of state to Ohio and West Virginia.[332] Disposal methods included 39% of waste going to brine or industrial waste treatment plants and 15% to municipal sewage treatment plants; an additional 5% was disposed of through underground injection (mostly in Ohio) and 32% was reused for other purposes (the remaining 9% was recorded as disposed using "other" methods).[333] Downstream Strategies also found that, between 2008 and 2011, more than 50 percent of liquid waste generated by Marcellus Shale drilling operations in Pennsylvania is discharged to surface waters after treatment.[334]

PADEP has acknowledged the environmental risks posed by current drilling wastewater treatment practices. In 2010, the agency issued more stringent standards for the treatment of Total Dissolved Solids (TDS), including by sewage treatment plants, in part to reduce bromide loads in surface waters.[335] One requirement is that Publicly Owned Treatment Works (POTWs) are not allowed to discharge wastewater from natural gas wells unless it is pre-treated first at a centralized wastewater treatment facility.[336] In addition, the state's wastewater treatment regulations require "a complete characterization of the operator's wastewater stream including chemical analyses, TDS concentrations and monthly generation rate of flowback and production fluid at each natural gas well."[337]

However, these binding standards only apply to new sewage treatment plants, not ones "grandfathered in" prior to 2010. Perhaps because of this—or because the limits set are insufficient, or because of a lack of regulatory enforcement—evidence of contamination by drilling wastewater discharged into rivers and streams continued to surface.[338] In 2011, PADEP issued a voluntary request to oil and gas operators to not take wastewater to municipal treatment plants. However, to date PADEP has not prohibited operators outright from using municipal wastewater treatment plants for oil and gas field waste disposal.

In early 2013, PADEP launched a comprehensive study of radiation in Marcellus Shale wastewater, production fluids, drill cuttings, and other materials, indicating that the results could lead to new regulations and oversight requirements for both drillers and waste facilities.[339] (See section on radioactivity for more on the study results, which were released in January 2015.)

As far back as 2001, PADEP stated that because of risks to water resources, "Disposal wells or injection wells are the preferred disposal method for brines because it returns the fluids produced from the well to the geologic strata that approximate their point of origin and there is no discharge of the produced fluids to surface or ground water."[340] Pennsylvania is one of ten states nationwide that does not have primacy over its Underground Injection Control (UIC) program, which is instead managed by the EPA.[341] (See section on underground injection for more information.)

When it comes to solid waste, operators in Pennsylvania often take advantage of another disposal option: the burial of production pits at well sites. While common practice in many other states, pit burial in Pennsylvania has come under increased scrutiny because of problems at well sites. In 2013, STRONGER concluded that, "PADEP's experience with pits has shown that, although their use is decreasing, many liner failures still occur with pits and other types of waste are being dumped into pits" and recommended that PADEP "consider adopting regulations or incentives for alternatives to pits used for unconventional wells in order to prevent the threat of pollution to the waters of the Commonwealth."[342] (See section on pits and impoundments for more information.)

Pennsylvania also allows for the disposal of residual waste and drill cuttings through land application (i.e., spraying or spreading on the ground); a related regulation includes criteria to prevent runoff and contamination of soil and groundwater.[343] However, the waste is not subject to chemical analysis nor limits on the concentration of contaminants prior to land application, and Earthworks and partner organizations have raised concerns that runoff is inevitable in a state with frequent rain, and a sloped and hilly landscape. As in other states, Pennsylvania allows brine from conventional oil and gas wells to be spread on roads as a dust suppressant; this process is also allowed under the state's "beneficial use" regulations.[344] (See section on repurposing waste for more information.)

Operators can seek a waiver (known as form OG71) from PADEP to use different practices to manage waste than what is set out in regulation, including when burying residual waste, spreading drill cuttings on land, and treating and re-using fluids onsite.[345] Although the waiver requires operators to demonstrate that the alternative method provides "equivalent or superior protection" to established regulations, previous research by Earthworks found no indication in PADEP records that this regulation is being followed or enforced.[346]

Looking ahead

At the end of 2013, PADEP issued proposed updates to the Chapter 78 oil and gas regulations for public comment, and hearings were held in several locations in early 2014. PADEP reviewed an unprecedented number of comments (about 25,000) received from the public, environmental advocates, technical experts, operators, and industry representatives.[347] Many of these comments focused on the prohibition and storage of waste in open pits and centralized impoundments and practices such as the burial, road spreading, and land application of waste.[348]

In summer 2014, the Chapter 78 revision process was delayed and became more complicated when the legislature passed a budget bill containing a requirement that PADEP distinguish between conventional wells and shale wells when issuing oil and gas regulations. PADEP later decided to issue two sets of regulations, one for conventional drillers focusing on the original Chapter 78 and a set explicitly for unconventional operators, now called Chapter 78a.[349] A final draft of both sets of rules will be issued for public comment in early 2015, with final rules expected by early 2016.

Centralized waste impoundment, Pennsylvania. Photo by Robert Donnan.

West Virginia

In any discussion about US energy resources, West Virginia is synonymous with coal. But as with other Appalachian states, West Virginia has seen a steady decline in coal production in recent years due to rising costs and depletion of the most prolific reserves.[350] As the reign of "King Coal" begins to fade, policymakers and energy industry analysts are setting their sights on the rise of natural gas to replace jobs and revenue.[351]

Oil and gas development has been underway in West Virginia since the mid-1800s, with extensive development now stretching across most of the state.[352] West Virginia currently has about 56,000 active oil and gas wells, most of which have been developed using vertical drilling and low-volume hydraulic fracturing in limestone and sandstone formations; the state also have over 700 coal bed methane wells.[353] There are currently about 1,400 active shale gas and oil wells in West Virginia, which have been drilled using both vertical and horizontal hydraulic fracturing.[354]

In 2010, the National Energy Technology Laboratory estimated that West Virginia could see 900 new shale gas wells per year by 2020, most of them high-volume, horizontal drilling operations.[355] **In 2011, production from the Marcellus Shale began to outpace all other types of gas production in the state for the first time.**[356] Companies are also beginning to pursue gas production in the even deeper Utica and Point Pleasant shale formations.[357]

In 2010, the National Energy Technology Laboratory estimated that West Virginia could see 900 new shale gas wells per year by 2020, most of them high-volume, horizontal drilling operations.

The West Virginia Department of Environmental Protection (WVDEP) has acknowledged that a shale boom would inevitably mean growing volumes of oil and gas field waste. In a 2010 guidance document issued to Marcellus Shale drillers, the agency emphasized that, "Perhaps the greatest challenge faced by these operations is the disposal of the drilling or frac fluids. The operator must thoroughly plan for this situation...Currently there are limited options, all of which may involve some time constraints for authorization or implementation."[358]

Available data indicate that on average, a horizontal Marcellus Shale well in West Virginia results in about 1,000 tons of solid waste,[359] as well as nearly 400,000 gallons of flowback fluid.[360] In the last few years, officials, advocates, and the public across West Virginia have increasingly focused on problems associated with waste, and attempts have been made by regulators and legislators to strengthen regulations, disposal procedures, and reporting.

Oversight

West Virginia's oil and gas field waste is managed through a combination of regulations and guidance documents. Key among these are Title 35 of the Code of State Rules (35CSR), which contains regulations related to waste storage and disposal in Series 1 on water pollution controls; Series 4 on oil and gas wells and injection wells; and Series 8 on horizontal well development.[361]

The Office of Oil and Gas (OOG) within the WVDEP holds the authority for issuing permits, monitoring activities, and enforcing regulations related to the state's oil, natural gas, and coalbed methane industry. Also within WVDEP, the Solid Waste Program oversees landfills and related regulations and the Division of Water and Waste Management administers programs and rules related to groundwater and surface water protection. EPA granted West Virginia primacy in 1983 to manage and regulate the state's Underground Injection Control (UIC) program for waste disposal and enhanced oil and gas recovery. [362](See section on underground injection for more information.)

Waste trucks at a landfill in West Virginia. Photo by Bill Hughes.

Tracking and reporting

The only type of oil and gas field waste consistently tracked in West Virginia is flowback. Operators using more than 300,000 gallons to hydraulically fracture a well in any formation in West Virginia are required to report either 50% of the original water that was injected and returned, or the exact volume of water recovered during the first 30 days of the flowback process, whichever occurs first.[363]

Since 2010, oil and gas operators have used WVDEP's Frac Water Reporting website to submit information on volumes of water withdrawals, fluid injections, flowback recovery, and the type and location of disposal.[364] The Natural Gas Horizontal Well Control Act requires operators to keep records of the information reported on the website for three years, but does not mandate that operators actually report data. Downstream Strategies has found that operators of only 35% of the wells permitted in 2010-2011 reported data to the Frac Water Reporting site—an indication that volumes of waste generated and disposed are much higher and waste destinations more numerous than what available records show.[365]

West Virginia regulations also require operators to maintain records on produced water and the method and location of its disposal, although not specific volumes; however, this information is only made available to WVDEP if the agency requests it.[366]

UIC facility operators are required to file a monthly "Report for Waste Disposal Wells" with WVDEP, which includes data on the volumes of waste injected each day, and maintain manifest records with information on the quantity, source, and transportation method of wastes delivered; however, this information is made available to WVDEP only if the agency requests it.[367] The permit application for a UIC facility in West Virginia requires information on the source, type, and physical and chemical characteristic of wastes destined for injection (which applicants include in a list of all the oil and gas wells that will be serviced by the particular facility).[368]

Wastewater treatment plant in West Virginia. Photo courtesy of Chesapeake Bay Program.

Generators that wish to dispose of solid waste in West Virginia, including oil and gas operators, are required to complete a Waste Characterization Form and submit it to WVDEP; this enables the agency to issue permits and permit modifications for landfills.[369] The form requires operators to document which "special wastes" they produce, provide chemical sampling results, and certify that the waste is not hazardous. (See section on waste characterization for more information.)

None of the data, transportation manifests, forms completed by operators, or reports from drillers, waste facility operators, or WVDEP are available online or otherwise publicly accessible. However, WVDEP may provide information upon request or through a Freedom of Information Act filing.

Current practices

In 2013, Downstream Strategies analyzed how drillers in West Virginia dispose of flowback fluid, the only type of oil and gas waste that the state tracks comprehensively. More than 40% was transported out of state in 2012, about half to Ohio for disposal in UIC wells and half to Pennsylvania for reuse in Marcellus Shale operations.[370] In addition, UIC wells within West Virginia have seen increasing use, with the percentage of flowback disposed of in this way tripling from 12% in 2010 to 35% in 2012.[371]

West Virginia drillers report reusing a significant proportion of flowback for hydraulic fracturing at the same well site where it was generated or at other sites; this practice accounted for 65% of disposal in 2012, a lower level than in previous years.[372] Disposal of flowback through municipal sewage treatment plants appears to be a limited practice in West Virginia, accounting for only about 1% of total volume in 2010 and 2011.[373] Road-spreading of brine (produced water only) is allowed in West Virginia for de-icing and road pre-wetting, in accordance with a 2011 agreement between WVDEP's Division of Water and Waste Management and the West Virginia Division of Highways.[374]

Operators may also choose to dispose of brine through "land application," by spreading or spraying waste on the ground at the well site. Doing so requires a General Water Pollution Control Permit, developed by WVDEP in 2005 to govern "the direct disposal of treated industrial wastes (i.e., wastewaters generated during exploratory/developmental drilling, well treatment operations, plugging operations and reworking of wells) by land application."[375] This permit includes limits on chlorides, pH, solids, and iron in the waste stored and treated in reserve pits at well sites destined for land application; it also requires operators to monitor for oil and grease, but only for undefined "steps to be taken" if levels are exceeded.

The definition of "industrial wastes" in the West Virginia Code appears to potentially apply to oil and gas field waste, with this category including "from or incidental to the development, processing, or recovery of any natural resources…"[376] At the same time, West Virginia's definition of solid waste includes "oil and gas and other mineral resources placed or disposed of at a facility" regulated under the state code.[377] The 2011 Natural Gas Horizontal Well Control Act requires operators to dispose of drilling waste (i.e., drill cuttings and drilling muds) in approved solid waste facilities, which are managed by Solid Waste Authorities throughout the state.

WVDEP has not required oil and gas operators to seek permits for disposal at specialized facilities, allowing them to instead take drilling waste to municipal landfills. According to figures reported in the media, WVDEP has indicated that West Virginia landfills accepted more than 720,000 tons of drilling waste in 2013, and monthly tonnage levels tripled between July 2012 and December 2013.[378] **In an analysis of landfill records, Downstream Strategies found that many municipal solid waste facilities accepting drilling wastes routinely exceed their permitted monthly disposal limits.[379]**

The only exception to the state's solid waste disposal requirements is if operators have the written consent of owners of the land to solidify and bury waste kept in reserve pits at well sites.[380] This landowner consent restriction does not apply to operators of conventional wells, who are allowed to bury drill cuttings onsite as long as they are solidified first. WVDEP has a set of forms for drilling permit applicants; the "Fluid/Cuttings Disposal and Reclamation Plan" form asks operators to state the method of disposal they will use for wastes that have been stored and treated onsite in reserve pits (choices include land application, underground injection, reuse, off-site disposal, or "other"), as well as whether drill cuttings will be taken to a landfill or left onsite.[381]

West Virginia allows the use of centralized impoundments for the temporary storage of freshwater and liquid wastes from multiple well sites. Since 2011, these require special permits and have to be constructed according to specific standards.[382] (See section on pits and impoundments for more information.)

Looking ahead

As noted above, nearly half of the liquid waste generated at West Virginia well sites is shipped out of state and much of the remainder is injected underground through the state's UIC program. WVDEP and legislators are not currently working to revise rules or practices related to how brine and drilling fluids are managed or disposed of, even though volumes are on the rise.

In contrast, changes to West Virginia's management of solid waste are on the horizon. In 2013, WVDEP issued a memo to clarify the options of solid waste facilities in managing drilling waste: either apply for a permit modification to increase tonnage limits—which are frequently being exceeded due to the shale gas boom—or develop separate areas of landfills (called "monofills") solely for the disposal of drilling waste.[383] In the latter case, no tonnage limits would apply.

In 2011, the West Virginia Legislature passed the Natural Gas Horizontal Well Control Act to in part to address the large volumes of water used and waste created through shale gas development.[384] In 2014, House Bill 107 (HB107) was passed in part to amend portions of the Solid Waste Management Act. This includes the requirement that WVDEP develop new regulations to establish limits on contaminants associated with drilling waste, including heavy metals, chlorides, petroleum-related substances (such as benzene, toluene, and xylene), and other chemicals, as well as radium and radon.[385]

The timeline for finalizing these regulations is not clear, nor which procedures (e.g., operator reporting or testing at well sites) would be adopted by WVDEP to implement these standards. However, the draft regulations developed for solid waste management are currently in effect as an emergency rule.[386] In addition, the Division of Water and Waste Management at WVDEP has installed radiation detectors at all landfills that accept drilling waste, following a mandated deadline of January 2015.[387]

Experts have underscored gaps in the draft regulations that need to be addressed in order to prevent ongoing problems for landfills and risks to water and soil. In particular, the rules don't mandate that prior to release into rivers and streams, leachate from landfills must be treated at a specialized facility—rather than run through municipal wastewater treatment plants that lack the testing standards and treatment technologies to handle the potential contaminants (including radioactivity) in drilling waste.[388]

At the same time, HB107 requires that by July 1, 2015, WVDEP must investigate and issue a report on "the hazardous characteristics of leachate collected from solid waste facilities receiving drilling waste" and potential negative impacts on surface water or groundwater resources; potential facilities for disposal other than municipal landfills, which could be funded by oil and gas operators; and alternative methods for management and disposal of drilling waste, such as using it for road fill or construction materials. [389] (See section on repurposing waste for information on this last point.)

New York

New York's drilling history dates back to the late 1800s; today, the state has about 11,000 active oil and gas wells, most of which have been developed using vertical drilling and low-volume hydraulic fracturing in sandstone and limestone formations; in addition, about a dozen deep vertical wells have been developed in the Marcellus Shale.[390] Although the number of active wells has increased slightly in the last few years, New York's gas production declined over 50% between 2008 and 2013, while oil production has remained fairly steady.[391]

A de facto moratorium on HVHF in the Marcellus and Utica Shale formations has been in place since mid-2008. This follows the initiation of a comprehensive environmental review, known as the Supplemental Generic Environmental Impact Statement (SGEIS), in keeping with a mandate under the State Environmental Quality Review Act (SEQRA). In mid-December 2014, Governor Cuomo, the New York Department of Environmental Conservation (NYDEC), and the New York Department of Health (DOH) announced their decision to prohibit the state from moving forward with HVHF. This stance by New York followed the long-awaited issuance of DOH's health impacts review, which considered hundreds of studies and reports from states nationwide.[392]

In recommending a "no" decision on HVHF, the DOH Commissioner became the first top-level state health official to acknowledge the serious risks to air, water, and health posed by oil and gas development. In 2015, NYDEC will integrate the DOH impacts review into a final SGEIS, which is expected to include a legally binding findings statement to prohibit shale gas development using HVHF.

Oversight

Oil and gas regulations are found in Subchapter B on mineral resources in Title 6 of the New York Codes, Rules, and Regulations (6 NYCRR), adopted in 1972, including several aspects related to waste management and disposal.[393] Additional relevant regulations on solid waste are found in 6 NYCRR, Chapter IV; these were adopted in 1988 and the last revisions to sections on waste storage were in 1999.[394]

NYDEC's Division of Mineral Resources holds the authority to promulgate and enforce regulations pertaining to oil and gas field waste management and to issue permits to facilities that accept waste and haulers that transport it.

As in other states, the actual reporting and tracking of waste is currently left up to drillers and the operators of disposal facilities in New York

Tracking and reporting

As in other states, the actual reporting and tracking of waste is currently left up to drillers and the operators of disposal facilities in New York. These private entities record volumes and types of waste they produce and manage, and submit hard copy reports on a quarterly or annual basis (depending on the type of waste) to NYDEC. Oversight of waste facilities (including inspections, facility assessments, and enforcement) is conducted through the NYDEC Materials Management Program, administered through regional offices.[395]

New York's oil and gas law states that, "…for any operation in which the probability exists that brine, salt water or other polluting fluids will be produced or obtained during drilling operations in sufficient quantities to be deleterious to the surrounding environment, the operator must submit and receive approval for a plan for the environmentally safe and proper ultimate disposal of such fluids."[396] However, current regulations do not specify what such disposal plans should include, how NYDEC would determine whether they are sufficient to ensure the safe transport and disposal of waste, and the kind of conditions that would lead the agency to reject a proposed plan.

A landfill in New York that accepts drilling waste. Photo by Roger Downs.

Oil and gas operators do not appear to be required to report the volume, content, disposal process, or destination for waste with any specificity. In a comprehensive review of 100 permit applications from drillers, Environmental Advocates of New York (EANY) found that NYDEC simply asks operators how drilling fluids and waste will be stored, contained, and disposed of—leaving it up to operators to determine the type of information and level of detail to provide.[397] EANY's analysis indicates that responses provided by drillers vary greatly and are often based on generic statement, such as that wastes will be disposed of "at approved facilities" and "in accordance with DEC regulations."

NYDEC does not maintain a centralized database on the oil and gas field waste stream. Therefore, no information on waste production and management is available online or readily available to the public. For example, a Freedom of Information Law (FOIL) request submitted to NYDEC for documents pertaining to oil and gas field waste management yielded spreadsheets with titles of reports that had been submitted by landfill operators, but no actual data. Notably, this is in contrast to production reports, which operators can submit online using the "eReportNY" platform—but are not available to the public.[398]

Current practices

New York excludes all oil and gas field waste from the state's definition of industrial waste, which specifies that "This term does not include oil or gas drilling, production, and treatment wastes (such as brines, oil, and frac fluids)..."[399] As a result, operators can dispose of waste at municipal waste landfills, rather than at specialized landfills permitted to accept industrial waste. As do other states, New York also excludes oil and gas waste from the definition of "hazardous" (see section on the RCRA loophole).

In 2008, NYDEC issued new guidelines for Publicly Owned Treatment Works (POTWs) accepting oil and gas field waste, including requirements for pre-treatment and a "headworks" analysis to determine whether the facility has the capacity to handle the potential flow and pollutants of wastewater.[400] Of particular note is the agency's expressed caution—just as New York began consideration of HVHF—that a "diverse mixture of chemicals and high total dissolved solids could require additional effort by POTWs to ensure adequate treatment."[401]

Conventional drillers in New York may also dispose of waste by injecting it underground in several brine disposal wells regulated by NYDEC and six Class II injection wells overseen by EPA.[402] In addition, operators engage private haulers to spread production brine from conventional wells on roads for dust suppression, de-icing, and road stabilization.[403]

Solid waste is disposed of at Municipal Solid Waste (MSW) facilities, or landfills. New York allows "water-based" drill cuttings to be buried onsite unless they contain oil- and polymer-based mud or lubricant, at which point they are considered to be "industrial non-hazardous waste" and must be removed from the site for disposal in a solid waste landfill.[404] However, the state does not have requirements for chemical testing to ensure that cuttings managed and disposed of onsite are "uncontaminated." Landfills are required to conduct groundwater monitoring and test the leachate from their facilities, but facilities determine the frequency of testing and the parameters considered.[405]

In recent years, New York has become a key destination for gas field waste from Pennsylvania. **Although New York does not track this waste, according to records maintained by the Pennsylvania Department of Environmental Protection, operators in that state sent drill cuttings, wastewater, and used fracturing sand to at least nine waste facilities in New York.**[406] In addition, it appears that two New York counties (Allegany and Chataqua) have accepted brine from Pennsylvania for road-spreading.[407]

Looking ahead

In 2012, NYDEC proposed but never finalized amendments to its oil and gas regulations in order to address the potential for HVHF in the Marcellus and Utica shale formations; however, the date for review of these regulations passed without the agency finalizing them and no new drafts have been issued.[408] Although the state has decided to prohibit such development, updates to oil and gas regulations are needed to improve management of waste that is generated through conventional drilling in New York and imported from other states.

In extensive technical comments to NYDEC on both the proposed HVHF regulations and the SGEIS, Earthworks and other organizations strongly recommended that any strengthening of waste management requirements also apply to conventional oil and gas operations in New York.[409] **Although the volume of waste produced through conventional drilling is much**

smaller than the volume would be from deep shale development using HVHF, it can contain many of the same contaminants and pose similar environmental risks.

The public review of draft HVHF regulations and the SGEIS identified critical gaps that pose risks to the environment, as well as necessary changes to ensure protective waste management practices for all types of oil and gas drilling in the state. Key aspects that were identified include:

- The development of specialized facilities capable of adequately treating wastewater.
- Potential classification of both liquid and solid wastes as industrial or hazardous, thereby subjecting them to additional testing and disposal requirements.
- The use of closed-loop systems to store, process, and transfer liquid and solid waste and clear prohibition of centralized impoundments and open-air reserve pits for these purposes.[410]
- Prohibition of the burial of reserve pits and pit liners.
- Chemical testing by operators of flowback and production water for combined radium (Ra-226 and Ra-228) and other hazardous contaminants.[411]
- Testing of solid waste and clear risk-based numerical standards indicating which levels of NORM in waste would prompt more stringent waste management practices.

In 2011, Eugene Leff, Deputy Commissioner at NYDEC, testified at a New York Senate hearing that under the terms of the SGEIS, all gas field waste would be tracked using a system to "ensure that DEC can monitor the movement of wastes from cradle to grave."[412] In addition, the proposed HVHF regulations would have required operators to complete a Drilling and Production Waste Tracking form.[413] Although NYDEC never specified what information would be included on these forms, such a mechanism through which to record waste type, volume, origin, destination, and transport is just as necessary for existing forms of drilling.

Conclusions

Across the Marcellus and Utica shale region, 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.

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

New York, Ohio, Pennsylvania, and West Virginia have addressed oil and gas field waste management in distinct ways and taken specific steps to improve regulations, operator practices, and data collection. At the same time, all four states have taken essentially the same approach—one that unfortunately has inadvertently created an opaque picture of what's really happening with waste and inadequate efforts to fix problems associated with it. Five 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—rather than developing new ones based on current drilling practices and the specific characteristics of new types of waste. States do not govern the waste based upon its characteristics, i.e., they do not determine if waste is actually hazardous according to RCRA'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 wide 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.

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, persistent regulatory and information gaps remain and practices are underway that call into question the adequacy of state oversight.

EPA's 1988 decision that E&P 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 the four Marcellus and Utica Shale states makes clear that, 30 years later, this assumption was incorrect.

In the meantime, a growing body of science on the chemical and radioactive characteristics of E&P wastes—particularly those derived using HVHF in shale formations—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 the Marcellus and Utica Shale states that are directly supported 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 HVHF in the Marcellus and Utica Shale region, as well as 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, manage, and reduce the volume of 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 both in the Marcellus and Utica Shale regions and nationwide.

Recommendations

To date, states haven't adequately managed oil and gas waste. To stem risks to water, soil, and air quality they should take immediate action to achieve the following. However, if states do not robustly and swiftly pursue these recommendations, then the federal exemption for E&P waste in the Resource Conservation and Recovery Act should be reversed—an action that Earthworks and its partners have called for in the past.

Apply state hazardous waste policies to E&P wastes through new regulations or legislation. This would ensure that oil and gas operators follow the same rules as other 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.

Develop and adopt waste management regulations that address remaining gaps in state oil and gas laws. All states should have detailed regulations in place to ensure that operators maintain responsibility for waste and its potential impacts over time. These should include, but not be limited to:

- 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 E&P 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 E&P 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 oil and gas field wastes.

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 E&P 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, 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 E&P wastes according to more stringent guidelines. The fact that radioactivity is "naturally occurring" should not 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 E&P wastes that contain radioactivity. Existing regulations related to radioactive material should be expanded to include E&P wastes.

Strengthen standards for current and future underground injection control well facilities that accept E&P 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.

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 New York, Ohio, Pennsylvania, and West Virginia, both generally and with regard to the definition, storage, treatment, handling, and disposal of oil and gas 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.
- Calculation of volumes and rates of change for different types of waste.

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 four 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.

Key state data sources include:

- **Pennsylvania Department of Environmental Protection, Oil and Gas Reporting Website:** https://www.paoilandgasreporting.state.pa.us/publicreports/Modules/Welcome/Welcome.aspx.

  This site provides downloadable spreadsheets of statewide production and waste data, including waste generator, waste type, quantity (in barrels and tons), and disposal method, as well as searchable reports by operator, county, and waste facility. This is the most comprehensive source of data on oil and gas waste among the Marcellus and Utica Shale states; as a result, Pennsylvania data were used extensively in the report.
- **Ohio Department of Natural Resources, Oil and Gas Production Website:** http://oilandgas.ohiodnr.gov/production. This site provides downloadable spreadsheets of statewide production, including the volume of brine—the only type of E&P waste that the state requires operators to report (in barrels) and that are available to the public. Data are currently available for combined (all) wells from 1984-2013 and for horizontal wells from 2011-2014.
- **West Virginia Department of Environmental Protection, Frac Water Reporting site:** http://www.dep.wv.gov/WWE/wateruse/Pages/FracWaterReportingForm.aspx. This site is for use by operators only and data are not accessible to the public. However, agency staff provided Earthworks with some data on flowback, the only type of E&P waste that the state requires operators to report.

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