Action Now

Our Water is Being Destroyed: the Fracking Industry will cost the taxpayers.

We need YOU to do something - people can no longer look the other way to what is happening to our precious freshwater. We need your action, and have provided information here you need to know because there are immediate actions that need to be taken before it's too late.

Hoses left near a small stream in which a brine truck was illegally rinsing out contents which settle and concentrate contaminants

Chemical Species	Median Flowback Concentration (mg/L)	Median Initial Concentration (mg/L)
Na	1100 – 44,100	80
K	8 – 1,010	< 50
Sr	46 – 5350	0.82
Ca	204 – 14,800	32
Ba	76 – 13,600	0.6
NH_4	4 – 359	16
Fe	14 – 59	0.68
Li	4 – 202	0.04
Mn	1.2 – 8.4	0.074
Mg	22 – 1,800	3.7
Zn	0.07 – 0.14	0.08
Cl	1,070 – 151,000	82
Br	16 – 1,190	< 10
B	2.7 – 3,880	0.5
SO_4	0.8 – 89	59
Total Dissolved Solids	3010 – 228,000	735
Ra-226 / Ra-228	73 – 6540 pCi/L	

Table: Geochemical data for flowback water and initial injected water in the Pennsylvania Marcellus Shale formation. Data from Hayes (2008) and Haluszczak (2013).

Surface and Groundwater Contamination

Any time development of petroleum resources occurs, there will be concern about impacts on surface and groundwater. For UOGD, the use and production of brines can lead to specific impacts, including salinization, exposure to toxic metals and organic contaminants, and pollution of shallow aquifers and groundwater resources. **(Photo left: Hoses left near a small stream in which a brine truck was illegally rinsing out contents which settle and concentrate contaminants).** While the exact composition of brines used for UOGD does not have to be disclosed, some common components are known: chloride, bromide, sulfate, barium, and strontium, among others (Table 1). In other countries (e.g., Poland), manganese has also been found at elevated levels in UOGD brines (Montcoudiol et al. 2017). These major ions can be used to trace intrusion of UOGD brines into water sources (USGS Scientific Investigations Report 2009-5086) and have been associated with salinization of freshwaters. "Freshwater salinization syndrome" is a widespread phenomenon stemming from increased salt levels in freshwater, leading to negative ecological impacts as well as detrimental impacts to needed infrastructure. High salt levels can degrade concrete and increase corrosion of steel, as well as render current drinking water sources unusable.

While some components of UOGD fluid and produced water are relatively innocuous at typical concentrations (e.g., Na, K, Cl), others such as the heavy metal radium pose particular risks. While barium is toxic, it would be expected to be rendered relatively benign by precipitation with sulfate (forming barium sulfate). However, co-precipitation of radium will also occur. Radium is a naturally occurring radioactive element that is extracted from rocks by the presence of acidic sulfate. Natural radium has two main isotopes, radium-226 and radium-228. Of these, radium-226 is generally of higher concern, as its decay product is radon-222. Radon is the second leading cause of lung cancer. Both isotopes of radium, however, contribute to increased radiation in exposed populations. Radium does occur naturally, but UOGD produced water concentrates natural levels and transports radium to the surface. US EPA sets maximum levels of radium-226 and radium-228 at 5 pCi/L for each isotope (Safe Drinking Water Act 1986 Amendments) for drinking water and follows the Nuclear Regulatory Commission's limit of 600 pCi/L for discharges to sewer. Produced water from UOGD has been found to exceed this level by over 3000 times (Columbus Dispatch, 3 Sept 2012). This becomes a particular concern as produced water from UOGD in the Marcellus and Utica Shale formations is often sent to municipal wastewater treatment plants for treatment and discharge into surface waters. Radium-226/228 are not routinely monitored in such discharges, however.

Radium from UOGD can also be released into the environment intentionally. Recently, produced waters have been purchased by Ohio Department of Transportation as a cheaper alternative to rock salt and brines for road treatment during winter. High levels of dissolved salts in brine fluid act in a similar fashion to rock salt by melting ice and snow. However, as noted above, brine fluids have been shown to have high levels of radium. Dispersal of brine fluids on roadways enables migration of radium into surface waters. Radium can also be put into an inhalable form either through small droplets or dust in the air. Radium-226 decays by a process known as alpha decay, the radiation from which is easily stopped by the skin without harm. However, upon inhalation, the radiation is much more damaging. As previously mentioned, the decay product of radium-226 is radon gas, which is then given a direct route to the lungs. A lack of regulation by the state of Ohio has allowed significant release of radioactive material into the environment, putting human health at substantially increased risk.

Although many of the chemical species present in UOGD brines are toxic, the presence of bromide in particular presents a problem, as bromide can react with free chlorine during water treatment. The end result of this reaction can be the formation of compounds such as bromoform ($CHBr_3$) and chloroform ($CHCl_3$), part of a class of compounds known as trihalomethanes or THMs. THMs are regulated under the Safe Drinking Water Act and US EPA limits total THMs to 80 parts per billion (80 micrograms per liter). Chloroform is a suspected carcinogen and has the potential to form phosgene, a toxic chlorinated compound. Bromoform is similarly classified as a probable human carcinogen and can impair liver function.

Other markers for intrusion by UOGD fluids include isotopic signatures. While water is comprised of two hydrogens and one oxygen, small variations in the isotopes of each element can and do occur. The amount of deuterium (^{2}H) and oxygen-18 (^{18}O) can be used to trace water infiltrating an aquifer from rain, as well as distinguish when the aquifer is receiving water from other sources (Montcoudiol et al. 2019, Warner et al. 2012).

Although hydraulic fracturing occurs at significant depth (> 6500 ft), there is still cause for concern about fluids escaping the fractured formations and migrating upward into shallow aquifers. Isotopic shifts indicative of mixing between UOGD fluids and groundwater have been found in shallow wells (Warner et al. 2012). This mixing is believed to occur through natural fractures in rock overlying the shale play. One study in the Horn River Basin (British Columbia, Canada) found that UOGD wells were hydraulically connected through pathways resembling fractures up to 1 km (3280 ft) horizontally and 130 m (426 ft) vertically (Fu and Dehghanpour 2020). In Wyoming (Pavillion Field), organic contaminants and changes in ion chemistry in EPA monitoring wells indicated upward migration of UOGD fluids in that formation, threatening aquifers used as drinking water sources (DiGiulio and Jackson 2016). Fugitive gases – gases related to UOGD such as methane (CH_4) or ethane (C_2H_6) that have escaped from a well or other facility – contaminated drinking water wells in the Marcellus Shale and closely related to distance from the nearest producing UOGD well (Jackson et al. 2013b). The authors note that homeowners living less than 1 km (3280 ft) from a UOGD well had gases contaminating their potable water supplies. It should be noted that fugitive gases have the potential to build up in buildings, creating a significant safety hazard. One such incident was reported in Dimock, Pennsylvania, in 2009. In that instance, a concrete slab was overturned and split into multiple pieces due to an apparent methane explosion inside a water well. While one study did not find sufficient evidence to conclusively link methane buildup to the Dimock explosion, the authors do indicate at least eight other instances of methane explosions of various origins in wells and basements (Engelder and Zevenbergen) .

Additional threats to groundwater resources exist due to casement failure at shallower depths. Typically, a UOGD well has a multi-layer cement casement designed to protect shallow aquifers and groundwater (see Figure). Loss of containment within this stage can lead to direct release of UOGD fluids into shallow aquifers, potentially contaminating groundwater. Darrah et al. (2014) found that fugitive gases were present in drinking water wells in Pennsylvania (Marcellus Shale) and in Texas (Barnett Shale). These gases were linked to cement failure in the production casing and seepage into the annular space between the production and surface casings at intermediate depth. In another incident in the Pennsylvania Marcellus Shale, foaming agents and organic contaminants were found to have migrated 1 – 3 km horizontally through shallow or intermediate depth fractures, polluting several drinking water wells (Llewellyn et al. 2015).

Other organic contaminants also pose a potential risk to human health due to UOGD. Clark et al. (2022) studied drinking water wells in Monroe and Belmont Counties, Ohio, and Bradford County, Pennsylvania, finding that certain compounds associated with UOGD were more likely to be detected in proximity to UOGD wells. Benzene (a known carcinogen; Snyder 2012) and 1,2-dichloroethane were detected in 24% of Ohio homes, compared to 7% detection in a prior study (Elliott et al. 2018). It should be noted, however, that concentrations were below both WHO and USEPA maximum contaminant levels for drinking water and similar to background levels. This does not rule out chronic exposure to organic contaminants causing long-term negative impacts.

Taken together, it is clear that there is a risk for migration of UOGD-related contaminants into shallow aquifers and drinking water wells. The extent to which groundwater sources are at risk will depend on a number of factors, including the underlying geology and presence of fractures or faults, the wellhead pressure, and well casement construction.

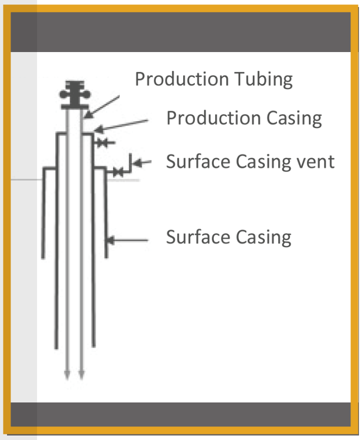

Figure: Schematic of UOGD well head construction. Image from Jackson et al. (2013a).

In December, 2022, Cabot Oil and Gas pled no contest to 15 criminal charges related to the explosion and UOGD development in and around Dimock.

Case Study: Redbird Injection Well

In 2019, an increase in flowback at the Redbird Injection Well site in Washington County, Ohio, led to an investigation into potential groundwater contamination. The Class II disposal well Redbird #4 was suspected of having cross-linkage with production wells in the same area. A survey of groundwater chloride (Cl) and bromide (Br) levels was subsequently launched. A total of 48 private water wells were identified, of which a private contractor was able to sample nine. Based on a threshold value of 250 mg/L Cl and measurable Br, the contractor concluded that no contamination of shallow aquifers had occurred.

USGS mixing models indicate, however, that leachate from waste disposal can be identified using the Cl:Br ratio along with the absolute amount of Cl. In this case, groundwater contamination can be suspected when Cl concentrations exceed 12 mg/L and Cl:Br ratios are between 100 and 300. From the contractor's data, four of the nine sampled wells exceed the Cl threshold, all of which have Cl:Br ratios within the range indicating leachate. This suggests the despite assurances by the private contractor, contamination of shallow aquifers may have occurred and may still be occurring. Given that there is no way to decontaminate an aquifer, greater care must be taken to ensure contamination does not occur.

Water Quantity and Environmental Flow

UOGD is an inherently water-intensive industry. A typical UOG well in the Marcellus and Utica-Point Pleasant formations such as are found in southeastern Ohio can use over 3.4 million gallons of water throughout its useful life (Kondash and Vengosh, 2015). For the state of Ohio, however, one study found that UOG wells average 6.7 million gallons of water use (Chen 2015), while other estimates place this number over 10 million gallons (Ted Auch, fractracker.org). With low water recycling rates, most of the water used for UOGD is so-called "blue" water, or water that is taken directly from surface sources. **(Photo top left: A large compressor removes water from a small stream near Leesville Reservoir in Ohio.)** Blue water is replenished by precipitation, although excessive withdrawals can lead to reduced availability. A minimum amount of water in e.g., rivers and streams, is required to maintain habitat and preserve ecosystem services in that area. This minimum amount of water is known as environmental flow (King et al., 2008).

When water levels drop too low, the total wet area decreases and the depth of the remaining water is lower. **(Photo top right: Water is removed from Wills Creek in Southeast Ohio, which is showing evidence of the loss of environmental flow This can result in increased temperatures and reduced vegetation.)** Because insects and fish depend on maintaining preferred temperature zones for spawning, decreasing flow can impact populations of these critical species. Invasive species can move into impacted areas, putting further pressure on native fish, plants, and invertebrates (Paillex et al., 2017). There is, however, no commonly agreed upon standard to determine the minimum flow required to maintain ecosystem health.

Several jurisdictions and agencies have specific metrics that are used to measure low flow events. US Geologic Survey utilizes 7Q10, or the lowest 7-day average flow with a 10-year recurrence; US Environmental Protection Agency uses a biologically-characterized 4-day lowest flow with 3-year recurrence (4B3). Recently, the Nature Conservancy examined the Susquehanna River and suggested thresholds at 10% reduction of flow and 20% reduction, as well as other limitations based on season and biological requirements (TNC Report). **(Box: The Nature Conservancy also supported the removal of water from reservoirs in SE Ohio to support the Muskingum Watershed Conservancy District's plans to engage in the industry, stating that it would protect smaller streams, which was not the case. A complaint about this policy was filed to TNC headquarters without a response.)** Regardless of the metric used, there will be gaps especially for intermittent flow reductions. A recent study by Harmon et al. (2023) found that UOGD in the Ohio River Basin caused reductions in excess of 10% in a large number of streams. Smaller watersheds were at especially high risk.

Water for UOGD must come from somewhere. In Ohio, water withdrawals are almost exclusively from surface sources rather than groundwater. Entities are required to obtain a withdrawal permit if the facility has the capacity to withdraw 100,000 gallons per day or more, regardless of actual usage (ORC 1521.16). Enforcement is minimal, with Ohio Department of Natural Resources relying on self-reporting of actual water use. The Ohio statute stands in contrast to surrounding states with UOGD. West Virginia requires permitting when the facility is able to withdraw 210,000 gallons over a 30-day period (7,000 gallons per day) (WVC §22-6A). Pennsylvania does not set a fixed standard for water withdrawals, instead relying on a rule that the withdrawal cannot "adversely affect" downstream users (§3211(m)(2)). The threshold for adverse effect is established by various interstate commissions such the Susquehanna River Basin Commission and the Delaware River and Bay Authority. For the Ohio River, however, there is no established regulatory authority and thus the standard is set by Pennsylvania Department of Environmental Protection. Michigan requires an assessment of the effects of water withdrawals that takes into account biological and ecological effects if the withdrawal exceeds 100,000 gallons per day average in any 30-day period.

Case Study: Austin Masters, Martins Ferry OH

Situated along the Ohio River in Belmont County, the Austin Masters facility processes UOGD wastes, including radioactive materials. Dating as far back as 2017, there have been reports and photographs of alleged violations of ODNR regulations. A 2019 inspection report revealed a violation regarding shredding of materials containing radioactive substances.

Local citizens have raised concerns about the operations at the Martins Ferry facility, which is located in close proximity to both a local hospital and the high school football field and less than 1,000 feet from a set of municipal drinking water wells. In January, 2022, ODNR issued a new rule governing waste treatment facilities such as Austin Masters, but as of February, 2022, radium levels in nearby soils exceeded EPA limits.

Because UOGD water use is self-reported in Ohio, there is little incentive to report accurately water withdrawals. Within the state of Ohio, some 3,648 UOGD wells have been drilled since 2010. Of these, only 2,935 have reported water use (FracTracker.org) – a difference of 713 (19.5%) wells. This mirrors trends found in Pennsylvania (26.4% of wells not reporting) and West Virginia (62.3% of wells not reporting). Given the average water use reported, the lack of reporting represents a gap of some 9.5 billion gallons of water (24% of total reported water use). Reporting gaps represent not only real water that is not being accounted for, but economic losses when these withdrawals occur under water sale agreements with, e.g., Muskingum Watershed Conservancy District. Based on typical sales agreements, the reporting gap could reach over $85 million of revenue that is not being collected. This number could be higher if water sales reflected national averages instead of artificially low pricing found in areas of southeast Ohio

(Photo top: Pipes are installed to take water to and from frack pads.)

In addition to relatively lax regulations in the state of Ohio, low water costs incentivize the use of new water for UOGD rather than recycling of flowback. In Ohio, the cost of water was estimated to be around $8 per 1,000 gallons compared to a national average of nearly $22 – 35 per 1,000 gallons (cite?). The discounted rate for water consumption shows up in a lower recycling rate (< 5%) versus other UOGD plays (up to 95%).

(Photo bottom: A huge impoundment pond used to pipe water to and from frack pads. This pond has subsequently been covered up, and we do not know what happened to the contaminated residue and plastic liner).

Recent sales agreements between the Muskingum Watershed Conservancy District and UOGD companies have prices ranging from $3 to $9 per 1,000 gallons, with a weighted average of $4.40 per 1,000 gallons – well below state and national averages. Much of the withdrawals for UOGD in the Muskingum River watershed are allocated from reservoirs such as Wills Creek Reservoir, Clendening Lake, Piedmont Reservoir, and Tappan Lake. Tappan Lake is part of an Ohio EPA source water protection area, as it is a drinking water source for Cadiz, Ohio, a town of about 3,300 residents.

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Regulatory Environment

Note that this overview is not intended to be comprehensive of regulations at the state or federal level and may not include all pertinent statutes and rules.

(Photo: Brine trucks unloading at a major injection well site in Cambridge, not far from Wills Creek, a drinking water source for the city and surrounding area. Without monitoring wells hazardous fracking fluids laced with "proprietary" chemicals could leak and go undetected, polluting ground and surface water).

The regulatory framework surrounding UOGD has been a topic of international concern. While the United States generally has a more robust set of regulations, a lack of enforcement has blunted their impact significantly. At the Federal level, UOGD is exempted from regulations pertaining to underground injection of fluids under the Safe Drinking Water Act (SWDA). UOGD is also exempted from regulations regarding pollutant discharges under the Clean Water Act (CWA), as the CWA does not view materials injected underground as pollutants. UOGD as an industry does not need to disclose the composition of fracking fluids under the Energy Policy Act of 2005, and does not need to comply with the Comprehensive Environmental Response, Compensation, and Liability Act (CERCLA, also known as Superfund). States are permitted to regulate UOGD within their borders provided that minimum Federal standards are met.

In Ohio, disposal of UOGD fluids is governed under OAC 1509, with oversight and rule-making authority delegated to the Department of Natural Resources Division of Oil and Gas. Permitting of Class II injection wells is likewise delegated from OEPA to ODNR DOG under OAC 3745-34-12(A). Authority over Class I disposal is still held by OEPA as part of Ohio's Underground Injection Control program (UIC) (OAC 3745-34-12).

In 1983, US EPA granted Ohio primacy for UIC for Class II injection wells in the state (ODNR UIC; Program Approval, 48 Fed Reg 38238 (1983); 40 CFR 147). Thus, the legislature should be able to reclassify UOGD flowback as hazardous under Ohio law. This would require operators to dispose of UOGD flowback under more stringent standards in Class I wells or establish a stricter framework for disposal of fluids. Under Federal law, Class I wells require injection into a separate formation beneath the lowermost formation containing drinking water. This carries with it a quarter mile (1320 ft) radius for establishing drinking water sources. By contrast, a Class II well requires a 50 ft exclusion zone beneath drinking water sources. Given the vertical migration observed in other parts of the Marcellus Shale, this separation is insufficient to protect drinking water sources (Fu and Dehghanpour 2020). A bill was introduced in 2012 (HB474 129th General Assembly) that would revise OAC 1501 to revise the procedures and requirements for permitting UOGD fluid disposal, effectively treating it as Class I waste. However, the bill did not advance and died at the end of the General Assembly.

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Recommendations

Water Quality

- **Classify UOGD waste as hazardous and require Class I disposal.** While the ideal would be to ban disposal of UOGD waste within the state of Ohio, a reasonable step would be to reclassify UOGD waste to require disposal in more stringently regulated Class I wells. This would place these wastes at a lower formation than existing drinking water wells, rather than the 50-foot vertical buffer required for Class II wells. It could also prohibit municipal water treatment systems from accepting UOGD waste, raising the cost of disposal and encouraging flowback recycling. Short of fully reclassifying UOGD wastes as hazardous, implementing a waste management plan requirement prior to permitting may serve a similar purpose, if the waste management plans are sufficiently stringent.

- **Mandate UOGD waste recycling as the preferred method of disposal.** Currently, Ohio does not mandate recycling of UOGD flowback or other brine waste. Thus, the operator is free to dispose of wastes using any method that complies with state and federal law. Mandating recycling of UOGD wastes diverts those fluids from injection wells or municipal systems to new UOGD wells, reducing not only the risk to shallower aquifers but also reducing demand for new freshwater resources.

- **Baseline groundwater monitoring prior to UOGD.** Because of the sensitivity of groundwater resources and the inability to mitigate contamination of aquifers, additional protections need to be implemented. Prior to development, a baseline needs to be established in order to determine future contamination. At a minimum, a series of groundwater wells should be sampled over a period of time and major ions (Na, K, Ca, Mg, Cl, sulfate) be determined. To better detect intrusions, isotopic markers can be measured such as δ2H and δ18O. Background organic contaminants should be measured to determine natural levels of e.g., benzene and toluene.

- **Groundwater monitoring wells at injection well sites to identify migration of fracking fluids.** While this measure may not prevent contamination of groundwater resources, identifying when these leaks occur can be an important public health measure, mitigating the impact of intrusions when they do occur. Coupled with baseline measurements, routine monitoring will better enable detection of UOGD intrusions. Electrochemical detection of major ions such as chloride and overall conductivity can be implemented for real-time monitoring at specific sites. Organic contaminants (benzene, toluene, etc.) can be monitored as well, particularly with passive integrating samplers to assess long-term exposure.

- **Establish routine monitoring for trihalomethanes in surface waters.** While trihalomethanes are routinely monitored in drinking water, monitoring has not been established for surface waters or wastewater discharges. Accepting UOGD waste into municipal water treatment systems increases the potential for trihalomethanes to be released into surface waters.

- A**dd testing of wastewater prior to discharge for radium-226/228.** Radium is currently tested in drinking water sources, where it falls under EPA regulations. Radium is one of the priority pollutants present in fracking waste that is not currently routinely testing in wastewater discharges, however. Measuring radium-226/228 in discharges will protect aquatic ecosystems, especially when coupled with enforcement of limits similar to the NRC limit (600 pCi/L).

Water Quantity

- **Limit total water withdrawals based on recharge. Water is a finite resource.** With multiple users within a watershed, each party must take care not to over-use water resources, whether groundwater or surface. For each watershed, the total amount of water extracted by all users (including natural losses such as evapotranspiration and groundwater recharge) should not exceed the total amount of water entering the watershed from all sources. Placing these limits ensures long-term sustainability for all users, including natural processes.

- **Establish cumulative water withdrawal limits for surface waters.** Each new UOGD well removes surface water, and more wells lead to additive withdrawals. The more intensively a water body is used for UOGD, the greater the potential for low flow events. Establishment of limits for cumulative withdrawals will be one more tool to protect Ohio waters.

- **Lower thresholds for water withdrawal permitting.** Ohio watersheds are at disproportionate risk of low flow events due to UOGD, primarily due to the higher threshold for withdrawal permitting. Establishing a lower volume threshold or placing a "no adverse effect" standard will help to prevent excessive withdrawals before they happen.

- **Require water withdrawal metering for UOGD wells.** The gap in water withdrawal reporting represents not only missing water, but missing money. Metering withdrawals will force operators to report their use and properly compensate for water withdrawals.

- **Install gauging stations in headwater streams potentially impacted by UOGD.** Small streams are more likely to have significant negative impacts when water withdrawals occur. However, the USGS does not typically have gauge stations installed on these rivers and so monitoring requires modelling of flow in these watersheds, creating a time lag and potentially introducing errors. Installation of gauging stations to monitor water depth and flow will close a significant knowledge gap. Monitoring prior to withdrawals or UOGD will enable a better estimation of the potential impacts on any particular stream reach.

- **Charge operators for water withdrawals according costs of water replacement.** Although the Ohio River Basin is relatively water-rich, the cost of water is significantly below national average and has consistently declined over the past decade. The price of water does not account for future projections due to climate, nor does it account for the costs associated with disposal and treatment of UOGD waste.

RADIOACTIVE POLLUTION

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