Hydraulic Fracturing
Radiological Concerns for Ohio

Fact Sheet Prepared for

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Fracking Waste: Production and Disposal

Intro

It is a known fact that the Marcellus and Utica shale formations are radioactive, with concentrations of radium-226 that are up to 30 times background[1]. In the process of drilling and fracturing wells (fracking) in shale formations, to produce natural gas, this underground radioactivity is brought to the surface, but where does it go? Oil and gas companies, along with the State agencies they've bamboozled, would have you believe any radioactivity present in waste streams is either within regulatory limits, not within the jurisdiction of State governments to regulate, or non-existent. Translation 1: the radium-226 in Marcellus shale inexplicably disappears when it is brought to the surface. Translation 2: the oil and gas industry does not want to pay the true costs of transporting, managing or disposing the radioactive waste they are producing. In this fact sheet, we want to cut through this murky haze that is settling over Ohio. We will explore the situation at the Patriot water treatment plant in Warren, OH, solid waste disposal in landfills, the potential impact of fracking near public drinking water supplies, specifically near the Muskingum River Watershed, the safety of transporting waste liquids and solids from Pennsylvania and other states to Ohio via trucks, rail and barges and the potential costs of proper disposal.

Background

The process of hydro-fracking, used to obtain natural gas and other related products from underground shale formations, requires a large quantity of water to complete the process- over 3 million gallons of water per treatment[2]. Drillers take water from underground aquifers, or surface water bodies, such as Seneca Lake, which is clearly convenient and also serves to disguise the effects of large water withdrawals (discussed in section: *Are there additional environmental concerns?*). Drilling fluid is used to remove the rock cuttings from horizontal wells in the Marcellus shale formations and to transport the drill cuttings to the well surface[1]. The list of chemicals added to the water throughout the fracking process is extensive and concerning- including diesel, rust inhibitors, proppants and antibacterial agents. Some of the drilling fluid returns to the surface in the form of flowback water once the well is drilled. When the well is producing natural gas, any contained moisture, known as brine, is removed. Brine contains high concentrations of naturally occurring radioactive materials from the shale formation. To add even more concern to an already highly debated process, fracking operations are currently zeroing in on the stretch of Marcellus shale that lies at depths of 4000 to 8500 feet[3] below the Earth's surface and ranges from West Virginia through eastern Ohio across Pennsylvania and into southern New York. The concern for the Muskingum Watershed Conservancy District (MWCD) is that hydraulic pressure often forces drilling fluids through weak sections of well casing or into abandoned wells, thereby contaminating aquifers.

Reports have shown that Marcellus shale deposits, compared to other shale formations in other parts of the country, are much more radioactive. New York DEC sampled flowback water from vertical Marcellus shale wells and found that the liquid contained radioactive concentrations as high as 267 times the limit for discharge into the environment and thousands of times the limit for drinking water[4]. Brine from horizontal drilling, as being done throughout Pennsylvania, will be much more radioactive, quoted by New York DEC as high as 15,000 pCi/L[1]. Fracking not only brings this highly radioactive material to the Earth's surface, but exists in the solid and liquid waste that is created as a result of the process. Radioactivity in oil and gas wastewaters has been found to exceed the U.S. Environmental Protection Agency's drinking water limits by up to 3,600 times, exceeding federal industrial discharge limits set by the Nuclear Regulatory Agency by more than 300 times[5].

We discuss the impact on water treatment facilities, such as the Patriot plant in Warren, Ohio and the proposed GreenHunter facility located on the Ohio River in the section of this report titled: *Treatment Facilities Under Fire*. While Ohio regulations (1509.22) require that releases to surface waters not exceed Safe Drinking Water standards, in our opinion, these waste streams are not being safely managed and regulated in Ohio. Simply allowing waste materials to meet drinking water standards allows mixing at water treatment plants, that is, dilution, without adequate monitoring or measurement for radioactivity before or after discharge.

Ohio law also allows spreading of radioactive brine from wells that are "not horizontal wells" on land and highways – thereby potentially ending up in drinking water sources, or being re-suspended in the air. There is no method to proving or certifying where the brine has actually come from, therefore making it nearly impossible to detect violations from spreading radioactive brine from horizontal wells on roadways.

A management plan to deal with waste material from fracking and natural gas production needs to be put in place immediately and action needs to happen now.

So what does this mean for Ohio?

Even though fracking in Ohio is not yet occurring at intense levels as in other states, the State has been victim to the process especially because the State is making itself available as a dumping ground for the waste from other places, such as Pennsylvania and West Virginia. Both liquid and solid fracking waste, of radioactive nature, is trucked across state lines to Ohio landfills and processed to take to wastewater treatment plants for disposal. There is an estimated 2,000 wells scheduled to be permitted in the near future[58]. Many wells are already drilled, simply awaiting fracking while the infrastructure is being constructed.

If fracking is encouraged throughout Ohio, the state could see more than 4,000 fracking wells drilled over the next ten years. Consider this: it takes between 2 and up to 8 million gallons of water to fracture a single Marcellus shale well one time, and each well may be fractured multiple times. From 5% to 35%[54] of the fluids initially stay underground in the well itself, while the remainder returns to the surface and must be either re-used or disposed of. Immediate issues associated with this process are focused on contamination of water resources, where this radioactive waste should be disposed of and how to properly manage it as well as the irreversible damage it may be contributing to the environment and human health. This will also place an exorbitant demand on the fresh water resource in the State of Ohio. Is it worth it? Below are a few current examples of how waste is currently being treated in the state of Ohio and the issues associated with the process.

What happens to fracking waste?

Solid Waste

How much waste arises from a single hydro-fracked well? To consider the amount of solid waste that a single horizontal drilled well would produce from the drilling/soil removal process, we estimate that the average diameter of the well is one foot and that the horizontal length in which the well is drilled is a mile. This results in approximately 4,147 cubic feet of radioactively contaminated shale rock that needs to be disposed of-somewhere. Now, consider that Pennsylvania has drilled almost 9,000 wells for natural gas to date. This yields over 37 million cubic feet of waste that needs to be relocated to its new home. Ohio takes more than half of Pennsylvania's waste material, indicating that at least 19 million cubic feet of solid material could potentially be sent to Ohio for disposal. Fracking waste is also coming into Ohio from West Virginia.

Where is this solid waste disposed of in Ohio? The gas industry describes water-treatment facilities and injection wells as their methods for disposal for fracking waste. The waste is also being hauled to solid landfills. The solid waste generated throughout the hydro-fracking process is sent to municipal landfills.

Ohio is now experiencing a huge influx of solid waste landfills for disposal and many more are expected. But many of these landfills are not equipped for measuring, managing or storing such contaminated waste. This is evident by the frequent detection of radioactive and hazardous materials from the small amount of landfills that are actually equipped with field sampling equipment at the landfill entrance. In fact, Timothy Puko[7] with the Tribune-Review (located in western Pennsylvania) reported in May of 2013 that "radiation alarms went off 1,325 times in 2012, with more than 1,000 of those alerts just from oil and gas waste", according to data from the Pennsylvania Department of Environmental Protection. One example - in April 2013, a truck carrying a load of solid fracking waste was sent away from the MAX landfill in South Huntingdon, Pennsylvania after the truckload set off an alarm because its contents were so radioactive. The drill cutting materials in the truck had a radiation dose rate of 96 microrems per hour, caused by the radium-226 contents. The limit for radioactive material at the landfill is 10 microrems per hour. The truck was first quarantined at the landfill, and then turned back to the fracking pad in Greene County to be re-directed to a site that can accept higher levels of radiation[8]. And in May 2013, two truckloads of Pennsylvania drilling wastes were turned away from the American Landfill in Waynesburg, Ohio after lab tests showed high levels of radium, 36 times the regulatory limit[9].

Field testing for radioactive materials at landfills is becoming more widespread, but is still not required. It is not known just how many landfills test materials prior to being accepted, and how many shippers have shipping manifests for the landfill operator to review. A proposed Ohio law would require oil and gas companies to conduct radioactivity tests on the tons of waste rock, dirt and drilling lubricants produced at drilling sites before those wastes are dumped in Ohio landfills. Officials with the Ohio Department of Natural Resources, the Ohio Environmental Protection Agency and the Ohio Department of Health say the new proposed requirement is intended to keep radioactive wastes from leaking from landfills[9]. The idea is good in theory, but details of the regulation are a current hot debate. Under the ODNR proposal, drilling waste categorized as technologically enhanced naturally occurring radioactive materials (TENORM) could be disposed of in one of Ohio's 39 licensed municipal solid waste landfills as long as it contains 5 picocuries per gram or less of waste material. TENORM is labeled as naturally occurring radioactive material (NORM) that has been manipulated by man such that its radioactive content is concentrated[10]. If the waste material tests higher than the 5 picocurie per gram threshold, it can be diluted, or essentially "down blended", by mixing it with other materials in an attempt to dilute the radioactive content for disposal[11]. However, because radium is highly soluble in water, rain water percolating throughout the landfill will allow the radioactive constituents of the material to leach out into the environment and potentially into aquifers or surface water for drinking water supplies.

Sampling and testing of materials to be sent to landfills would yield best results if conducted by a third disinterested party or the officials at the receiving landfill, who would be held liable for any radioactive materials present within the facility. The regulatory agency must be able to review the sampling program. Results from some sampling of materials within landfills show radioactive amounts over the restricting limits of 5-10 pCi per gram are often detected, sometimes significantly[12]. The process of field testing for radioactive materials can also be questioned, as details related to where the sample is taken, how many samples need to be taken, the testing method (see Appendix C) and how the trucking container relates to the reading all need further specific field research. There are key criteria that must be constantly and consistently maintained, such as the calibration of the gamma readings taken by the portal monitors with actual laboratory measurements of radium-226.

Disposal Costs at Landfills

There are facilities that specifically manage radioactive solids with the goal of storing the materials in a safe and controlled manner over a long-term period. Traditionally, low-level radioactive waste disposal facilities have charged waste generators a fee for each cubic foot of waste accepted for disposal, at costs far higher than municipal solid waste landfills. This volume-related fee is known as the "per cubic foot charge" [13]. However, facilities may also charge additional fees based on the characteristic of the waste, such as the level of radioactivity and the type of container used for housing.

Regardless of the method of pricing, the cost of low-level waste disposal has increased over the past years. The Barnwell disposal facility in South Carolina, which is no longer operating, had a base disposal price of $13.20 per cubic foot of waste in 1983. In 1994, when the facility closed, the cost per cubic foot for waste disposal had increased to

$220.00, with additional surcharges and fees that were also included[13] such as the type of waste, the weight, dose rate and curies associated with the load of materials to be received. One example of a current low-level waste management facility is the U.S. Ecology waste disposal facility in Richland, Washington. This facility charges $115.50 per cubic foot of low-level radioactive material to be managed[14]. Another example is the waste disposal facility in Clive, Utah, which charges $350.00 per cubic foot of "large component material" and $145.00 per cubic foot for "debris" [14]. Waste at the Utah facility is categorized and priced by size classification of received components.

Compare the costs of properly disposing of the material at one of the proper landfills mentioned above versus sending the toxic material to a regular municipal landfill in Ohio that charges at most a fee of $44.00 per cubic yard of material, or for comparison purposes to the facilities mentioned above, just over $1.60 per cubic foot of material[15]. To dispose of the roughly 4150 cubic feet of waste solids generated from drilling one natural gas well, it would cost $479,000 to send the materials to Washington to be disposed of, $601,000 to send materials to Utah, and $6,775 to send it to the local municipal landfill. When considering the 19 million cubic feet of material that needs to be disposed of referenced previously, it is evident that environmental concerns are trumped by the economics beneficial to the unconventional shale drilling industry.

When Ohio accepts fracking waste from other states, it is then responsible for properly disposing of this radioactive material, which currently is turning up in municipal landfills that are not prepared to handle this material. Ideally, this waste should be sent directly from the site of origination to facilities in the states of Washington, Utah and Texas, licensed to manage naturally occurring radioactive material (NORM) and technologically enhanced naturally occurring radioactive material (TENORM)[16].

Wastewater

The amount of wastewater created throughout the fracking process is astonishing. The problem of what to do with this waste byproduct is growing as the volume of wastewater continues to increase rapidly with the expansion of fracking in the Marcellus shale formation and nationwide[17]. It is estimated that the amount of waste water produced to just drill the vertical shaft of each well for Marcellus shale in Pennsylvania is 80,000 gallons of wastewater[18]. The additional amount of water required for a single hydro-fracking event is as much as 3.8 million gallons per well[18] and others have estimated much more depending on the depth and length of long laterals. It should also be noted that many wells are hydro-fracked more than one time. Ohio also contributes to the amount of wastewater to be disposed of in their own state, as Ohio now has 665 wells permitted for Utica shale, 332 of which are currently drilled[19].

Flowback water is recovered from each well, which includes drilling fluid with added liquids and chemicals and any produced formation brines from the drilled well. Samples of flowback water from vertical Marcellus shale wells show that the liquid contained radioactive concentrations as high as 267 times the limit for discharge into the environment and thousands of times the limit for drinking water[4]. Once the well is producing, brine that is separated from natural gas will be much more radioactive, quoted by New York DEC as high as 15,000 pCi/L[1]. The flowback water is often sent across state lines to Ohio for injection well disposal or to waste water treatment facilities to be processed for eventual release back into the environment.

Despite the hazardous and radioactive components of this waste fluid, Ohio law allows county commissioners, a board of township trustees, or the legislative authority of a municipal corporation to approve the spraying of brine fluids on public roads to control dust or ice. Some states, such as Texas, even go as far as spreading this radioactive material on farmlands. Also known as "landfarming", this process is a method of treatment of disposal of low toxicity wastes in which the wastes are spread upon, and mixed within soils[20]. All of this can be done without first even testing the hazardous or radioactive contents of the material. These materials go on to contaminate drinking water sources and soils in the surrounding areas, resulting in a threat to human health that is very serious and widespread. During the summer months, when the roads and the fields are dry, radium can become airborne and be inhaled. . Ohio has an opt-out provision regarding the spraying of waste water on road ways, where a locale can vote as a policy matter to prohibit brine spraying. However, the spreading of this material on roadways is explicitly legal unless community members and individuals mobilize and convince their elected officials not to do it

Radium concentrations in bones can give rise to leukemia, and the actual symptoms from radiological exposure may not occur for years to come. With these materials persisting in place for decades, due to being spread on roadways, crop fields and surrounding areas, land contaminated by radium in produced water from Marcellus shale drilling can pose a threat to people working or living nearby for thousands of years[21].

http://truckfax.blogspot.com/2012_01_01_archive.html

Another solution to get rid of the polluted waste-water is to create deep injection wells to essentially use as storage tanks to pump this water right back down underneath the ground. Over the past two decades, Ohio approved an average of four new storage wells a year. In 2011, that number jumped to 29[22]. As of 2012, Ohio had 178 active injection wells that had accepted almost 14 million barrels of brine and liquid waste[5]. And if those numbers don't cause concern, then consider that 98% of Pennsylvania's 94.2 million gallons of drilling wastewater in 2011 was sent to, and stored in, Ohio[22]. And just a year later in 2012, Ohio injection wells handled 588 million gallons of wastewater, the majority of which was received from Pennsylvania[23].

Currently, Ohio has 179 injection wells used for storage of waste materials from the fracking process. The injection wells are different sizes, with a range of diameters and depths below the Earth's surface. The Ohio Department of Natural Resources states that the wells "range to be 13,000 feet in depth"[6], while it is known that the Northstar I Class II injection well in Youngstown, the cause for the seismic activity that occurred in the area late 2011, is approximately 9,000 feet deep[6]. Estimating an average injection well depth of 10,000 feet and a diameter of one foot, vertical storage of a single injection well can hold just over 59,000 gallons of wastewater material. With the 179 current injection wells, that's a total storage capacity of 10.5 million gallons of wastewater, a concerning value when acknowledging that in 2012 alone, Ohio's injection wells handled 588 million gallons of wastewater. The excess wastewater exits the injection well at the underground base into the substrate below surface. It remains unknown just how much water can be pumped into a single injection well over time.

These wells are also classified as "Class II wells", in which "Class IV" wells are the only wells designated for receiving any kind of radiological material[6]. It is also interesting to note that while Class I, IV and V wells are regulated by Ohio EPA, Class II and III injection wells are regulated by the ODNR[24]. It remains to be known just how much waste a single injection well can handle. It is established that injection wells were the contributing cause of a series of earthquakes occurring in the Youngstown area[25]. Seismic activity linked to injection well sites across the country as wells as fears that injection well could leak toxins that would seep into drinking water sources necessitate a more serious investigation of deep well disposal[26].

A third option for wastewater treatment is to send the liquid and sludge to wastewater facilities to be treated and properly managed. However, sometimes the gas producers dispose of the contaminated water by sending it to wastewater treatment plants that deal with sewage and water from other industrial sources[27]. Studies[28] and documents obtained by the Environmental Protection Agency (EPA) reveal that wastewater, which is sometimes hauled to sewage plants not designed to treat it and then discharged into rivers that supply drinking water, contains radioactivity at concentrations far higher than the level that federal regulators say is safe for these treatment plants to handle[29]. Most of these facilities cannot remove enough of the radioactive material to meet federal drinking-water standards before discharged into rivers, sometimes just miles upstream from drinking-water intake plants. The municipal wastewater facilities often release water directly into public drinking water sources after merely diluting the toxic materials, rather than removing it. Not only are these water treatment facilities producing water that is illegally passed as drinking water for the public, but these same water treatment facilities are also not equipped to properly handle radioactive and otherwise hazardous material. Sometimes, a wastewater treatment plant is bypassed altogether and the radioactive materials are simply just dumped down the sewer[30]. Unfortunately, "there are business pressures" on companies to "cut corners", said John Hanger, who stepped down as secretary of the Pennsylvania Department of Environmental Protection in January of 2011. "It's cheaper to dump wastewater than to treat it," he added[29].

A main concern is that radium is in soluble form in landfills and can leach out and into water supplies. This leachate is also sometimes processed at wastewater treatment plants, again, without removing the radioactive or other hazardous components.

It also should be noted that drilling contamination is entering the environment in areas directly connected to the drilling site through spills, too. In the past three years, at least 16 wells whose records showed high levels of radioactivity in their wastewater also reported spills, leaks or failures of pits where hydro-fracking fluid or waste is stored, according to State records[29].

This toxic wastewater should be processed at a specific facility that can properly treat and manage the wastewater, which can then be released to a municipal wastewater treatment plant for further treatment and release. Even with waste treatment facilities that have been designed to specifically treat the wastewater from the fracking process, radiological components, chemicals and toxins have been released and later detected in freshwater sources[28]. Proper sampling methodology needs to be put into place and strictly enforced to ensure that water quality is minimally affected by the treatment and release of this wastewater.

As far as pre-treatment, the proper disposal of filter cakes and other by-products that would be involved in such a process to remove radioactive components is of vital importance. There must be a full chain of custody and cradle-to-grave tracking of these radioactive waste materials with proper disposal in a licensed site to handle it.

Disposal Costs of Wastewater

Current estimates say that the cost to dispose of Marcellus shale fracking fluids at a proper wastewater management facility are roughly \$3.00 per barrel to dispose of it, and \$7.00 to \$10.00 for it to be hauled away[31]. That equals between \$10.00 and \$13.00 for the disposal of a single barrel, which holds 42 gallons of wastewater. Now considering that it requires 4 million gallons of water to hydro-frack a well (and a minimum of 60% of the liquid will return to the surface as flowback/brine), costs to dispose of wastewater from a single well (more than 57,000 barrels) could be as high as \$740,000 apiece. Sending wastewater to an injection well for disposal is less expensive, as Ohio charges an injection well disposal fee of five cents per barrel on Ohio brine, and twenty cents per barrel for waste originating out-of-state[49]. In 2012, new energy policy proposals were put forth[49] that would raise brine disposal fees from five to ten cents on in-state waste, and from twenty cents to \$1.00 on out-of-state waste. Under new proposed costs, disposing of liquid waste from a single well in this manner would cost \$5,700 for in-state waste and \$57,000 for out-of-state disposal. When looking at these numbers, it becomes clearer why a natural gas company may try to dispose of water through the local environment and wastewater treatment facility rather than sending it directly to a specialized treatment plant or an injection well.

The Situation in Ohio

Treatment Facilities Under Fire:

Patriot Waste Water Management Facility

The Patriot Waste Management facility in Warren, Ohio has been at the center of controversy since operations were permitted in 2010[50]. A private facility that processes wastewater from natural gas drilling operations, the management and processing methods associated with handling of the radioactive waste has been questioned. Patriot accepts "low-salinity" brine wastewater from shale gas extraction activities, which the oil and gas industry defines as containing less than 50,000 mg/L of total dissolved solids (TDS) [32]. The facility treats the wastewater to remove heavy metals and other constituents before the treated, still-salty, wastewater is sent to Warren's wastewater treatment plant. There, it is handled just like any other sewage and is "treated" and then discharged into the Mahoning River.

The proper treatment of wastewater at the Patriot facility is a question of ongoing debate. In 2011, the Ohio Environmental Protection Agency (OEPA) opted not to renew Patriot's brine water treatment permit due to suspicions that water was not being properly decontaminated, and it ordered the company to not send its treated water to the City of Warren's wastewater treatment plant. Opposing the cessation of operations, Patriot appealed the decision and overturned the original decision, following a ruling by the Environmental Review Appeals Commission of Ohio that Patriot be able to continue their operation of water treatment for fracking fluid.

Now operating again, the Patriot waste management facility is required to present samples to the City on a monthly basis to satisfy the industrial user pretreatment permit. The permit regulates the wastewater discharge from the facility to the City's sanitary sewer system. The City provides Patriot with the sampling equipment to conduct their sampling; Patriot conducts the sampling and then submits the samples to a lab and sends a copy of the lab results to the City[32]. However, the methodology behind the collection of these samples is unclear. The level of confidence in the sampling process should be high, but having a facility take its own tests, without greater regulatory oversight, greatly reduces the confidence of results in a sampling scenario.

We question several aspects of Patriot's testing program for radioactivity:

- Patriot has conducted specific background tests for total alpha, total beta, total uranium and total thorium. In February 2010, Patriot did do a gamma spec, which should identify specific radionuclides in the uranium decay chain, such as bismuth-214 and lead-214, and actinium-228 and thallium-208, but surprisingly, these were below the lowest detection limit. Patriot did not specifically test for radium-226, a radionuclide that is expected in flowback water from the Marcellus shale formation.
- Patriot did initial and follow-up tests for total dissolved solids (TDS) and chloride, which are expected to be high.
- On a daily basis, Patriot tested for TDS and chlorides, but, as far as we can tell, not for gamma emitting radionuclides and not for radium-226.
- Random sampling protocol is not outlined so it is difficult to know how samples are chosen.

Aside from the debate about whether or not the wastewater being disposed into the waterways is properly treated and thus decontaminated, another question arises from the treatment of the toxic water filled with drilling fluid chemicals, sediments and radioactive materials. When brine water returns to the Earth's surface after the fracturing process, small pieces of radioactive sedimentation are concentrated throughout the water. These total dissolved solids (TDS) are soaked in the radioactive liquid waste-water. Throughout the treatment process at the wastewater facility, sediment and sludge is accumulated from the water from a separation process, however most separation technologies fail to remove all of the radioactive liquid from the solid contents. This material, along with filters, is removed from the wastewater at the Patriot waste treatment plant, and then needs to be disposed of. The solid waste, still coated with radioactive waste-water, is then sent to the municipal landfill.

Long after any current landfill is filled and covered at the completion of production, the waste cuttings will emit radiation for thousands of years. "We're removing the metals like strontium, barium, iron, lead and other toxic heavy metals and organics as well as a little bit of oil," said Tom Weber, owner of Wastewater Management in Cleveland, who designed the Patriot plant[33]. But we question whether Patriot and Warren treatment plants are able to remove radium in solution, and neither facility describes how this is done.

GreenHunter Waste Water Management Facility

GreenHunter waste management facility in Wheeling, West Virginia is not currently operating its full facility, but hopes to do so in the near future. This wastewater processing facility would treat 10,000 barrels of waste fluids a day and has as much as 19,000 barrels of tank storage. Similar to Patriot, the goal is to remove suspended solids from gas-field flowback that returns to the surface during fracking, and produced water that comes up during gas production. This waste would be disposed of in one of three ways. According to Green Hunter, clean brine, estimated to be 80% of the waste volume, would be placed on tanker trucks for re-use in other fracking operations. Dehydrated solid waste, estimated to be 10% of the incoming volume, would be sent to landfills. And concentrated liquid waste, estimated to be 10% of waste volume, would go to permitted injection wells via transportation by barge[34]. This waste would be transported by barge to different locations along the Ohio River, in which the waste would then be stored on-site at a second facility or further transported via trucks to underground injection wells acquired by Green Hunter Waste Facility in Kentucky, Ohio and West Virginia.

GreenHunter has already obtained supplemental sites, in addition to the waste management facility in Wheeling, two of which are located in New Matamoras and Racine, Ohio. Both sites have been described as storage sites and access points for the barge to unload materials being transported down the Ohio River that are coming from the Wheeling, West Virginia facility. The primary role of the GreenHunter facility in Racine is to store radioactive waste from the barge in injection wells on-site[55]. The GreenHunter website states[55] that the riverside saltwater disposal facility in Racine, Ohio has the potential to inject more than 3,000 barrels per day of oil field brine and also allow for a barge receiving terminal to be installed on the river so material can be piped directly to the disposal well from the barge cells. The facility in New Matamoras, Ohio is capable of holding 75,000 barrels on-site for bulk storage. At both sites, the close proximity of the storage tanks and injection wells to the Ohio River introduces an even greater risk to the Ohio River watershed of seepage and pollution from radioactive brine materials. President of GreenHunter, Jonathan Hoopes, stated that[56], "One of our primary goals at GreenHunter Water is to never have to turn down a customer's load of brine water for disposal." In a current situation where public health and the local environment are at risk, GreenHunter has made it clear that its priorities are focused on its income and business desires.

John Jack, vice president of business development for GreenHunter points out holding tanks on-site that store radioactive water in May 2013[35].

Community concerns are focused on the potential for spill or seepage at the site during all of the loading/unloading of materials that will be occurring, as well as the potential for the facility to be flooded as it lies on the banks of the Ohio River that frequently experience high water incidents throughout the year. The idea of putting the most radioactive material from the treatment process, the flowback and brine material en route to injection wells, on barges in the river system that is a drinking water source for numerous States is also of serious concern. If an accident were to occur and the material leaked into the Ohio River, the effects on the fresh water system could be extremely serious to both the environment and its role as a main source for drinking water. And accidents do happen. In April 2013, believed to be a result of high water, 100 barges broke free from moorings in the Mississippi River, 11 of which sank to the bottom of the river[36]. And in June 2012, a barge sank in the Ohio River, again as a result of high water conditions[37]. There are numerous other examples, many due to floods causing barges to sink. On a waterway such as the Ohio River, which experiences high water events numerous times throughout a given calendar year and random floods, putting such toxic and dangerous materials on a barge for transport is asking for trouble. Transportation of the toxic materials via barge is currently in limbo; the Green Hunter waste management facility first needs approval from the U.S. Coast Guard, which has not yet occurred.

Transportation Adds to the Risk

GreenHunter waste management facility in Wheeling, West Virginia is of great interest to those living in Ohio, as the treatment plant is located on the banks of the Ohio River with goal of transporting radioactive materials via barge. This waste-water processing facility would treat 10,000 barrels of waste fluids a day and have as much as 19,000 barrels of tank storage. The goal is to remove suspended solids from gas-field flowback that returns to the surface during fracking, and produced water that comes up during gas production. This waste would be disposed of in one of three ways. Clean brine, estimated to be 80% of the waste volume, would be placed on tanker trucks for re-use in other fracking operations. Dehydrated solid waste, estimated to be 10% of the incoming volume, would be sent to landfills. And concentrated liquid waste, estimated to be 10% of waste volume, would go to permitted injection wells via transportation of barge[34]. This waste would be transported by barge to locations, in which the waste would be further transported via trucks to underground injection wells acquired by Green Hunter Waste Facility in Kentucky, Ohio and West Virginia.

Community concerns are focused on the potential for spill or seepage at the site during all of the loading/unloading of materials that will be occurring, as well as the potential for the facility to be flooded as it lies on the banks of the Ohio River that frequently experience high water incidents throughout the year. The idea of putting the most radioactive material from the treatment process, the flowback material en route to injection wells, on barges in the river system that is a drinking water source for numerous states is also extremely risky. If an accident was to occur and the material was leaked into the Ohio River, the effects on the fresh water system could be devastating to both the environment and its role as a main source for drinking water as outlined previously. Such toxic and dangerous materials on a barge for transport is problematic. Transportation of the toxic materials via barge is currently in limbo, as the Green Hunter waste management facility first needs approval from the U.S. Coast Guard, which has not yet occurred.

Transportation of fracking waste via rail has been proposed, but is currently not occurring in Ohio. There is a 5,000 acre facility next to the CSX railyard in North Baltimore, Maryland that was purchased by a drilling company to provide either injection well storage or horizontal drilling at the location. If it weren't for the citizen's in Mansfield, Ohio passing a charter amendment, there would have been rail transport from Ohio to the planned injection wells there.

Are there additional transportation concerns?

Radioactive waste from hydro-fracking is currently transported by trucks, but the transportation of materials by barge and rail (as mentioned above) has also been proposed and is being considered. Both of these alternative modes of transport are encouraged by the oil and gas industry, as the options offer transport of more materials at one time for a less expensive shipping price. This increases the risk of public health and environmental exposure to toxic chemicals if an accident was to occur. The total activity in brine truck shipments requires that it be classified as Class 7 waste by the U.S. Department of Transportation (DOT). Class 7 shipments have had accidents. DOT statistics show that vehicles transporting class 7 in the last ten years, have had 78 rail, highway and water incidents[57]. No matter how this material is moved from one location to another, strict rules and regulations are required.

If material that is transported is hazardous or radioactive, specific Federal rules, that relate to container construction, placarding and insurance, apply. Our investigation of Federal and State regulations show that the State of Ohio regulations are far less protective of public safety. Shipments involved in crossing State boundaries are unequivocally regulated by the Federal Department of Transportation (DOT) under title 49 of the Code of Federal Regulations[47]; these rules may also apply to intrastate regulations as well.

Under Federal DOT rules, transported material that exceeds a total activity, in terms of total Curies of radioactivity, is classed as a radioactive material. The specific limit for Radium-226 is 2.7×10^{-7} Curies[47]. Below this total activity, the material is not classed as radioactive by DOT; above this amount, specific Federal regulations apply regarding design, packaging and labeling of transportation vehicles. For placarding, the NRC has even stricter limits 1×10^{-7} Curies (10CFR20, App. C).

To compare the levels of Ra-226 in brine, we assumed radioactivity ranging from 10,000 to 15,000 pico curies per liter, according to NY Department of Environmental Conservation[38]. Conditions described by Green Hunter waste management facility[39] state that a truck transporting materials from the facility will transport 100 barrels of waste at a time, with each barrel holding 42 gallons of material. They expect 100 truck loads per day to move the 10,000 barrels per day (420,000 gallons per day) capacity of toxic waste[39]. Trucks transporting brine on Pennsylvania highways are in the form of a single container, not individual barrels. At 10,000 to 15,000 pico curies per liter of Ra-226 for brine, this results in a total radium-226 activity content of 1.589×10^{-4} to 2.3835×10^{-4} curies per truckload, greatly exceeding the federally defining limit of 2.7×10^{-7} curies. Transportation by barge is estimated to carry 10,000 barrels of brine at a time, resulting in a total radium-226 activity content as high as 2.3835×10^{-2} Curies in a single barge load. Both transportation methods, by truck and by barge, result in a DOT classification as radioactive that requires adherence to regulations and limitations described for transportation of hazardous materials.

These transportation shipping regulations can be found in chapter 49 of the Code of Federal Regulations in sections 173.410 and 173.411 (shown in Appendix A and B). Generally speaking, the regulations in place state that any package used for the transportation of radioactive materials must be easily handled and properly secured with a structurally sound lifting attachment, will have an external surface free from protruding features that can be easily decontaminated, all valves through which the package contents could escape will be protected against unauthorized operation and the behavior of the packaging and contents under irradiation will be taken into account. Additionally, the materials qualify as a Low Specific Activity II waste, must be properly packaged in Industrial Packaging Type 2 (IP-2) or Industrial Packaging Type 3 (IP-3) enclosures. The descriptions for each of these packages are listed in Appendix B. The State of Ohio does not have comparable regulations for radioactive brine.

Insurance is another requirement under DOT regulations. Under Federal regulations vehicles transporting hazardous substances, such as brine, must hold an insurance policy with a minimum level of financial responsibility of $5,000,000. The state of Ohio requires each transporter of brine to hold a liability insurance policy that would cover both bodily injury and property damage caused by processing associated with brine for $600,000. Most insurance policies for private cars have liability coverage greater than $1 million. State of Ohio regulations are clearly inadequate for a hazardous material, and possibly illegal.

Finally, federal DOT regulations require that hazardous and radioactive shipments be properly placarded. Specifically, federal DOT regulations require this notice: “RADIOACTIVE—LSA” or “RADIOACTIVE—SCO.” Instead, trucks we have seen on Pennsylvania highways are simply labeled “brine.”

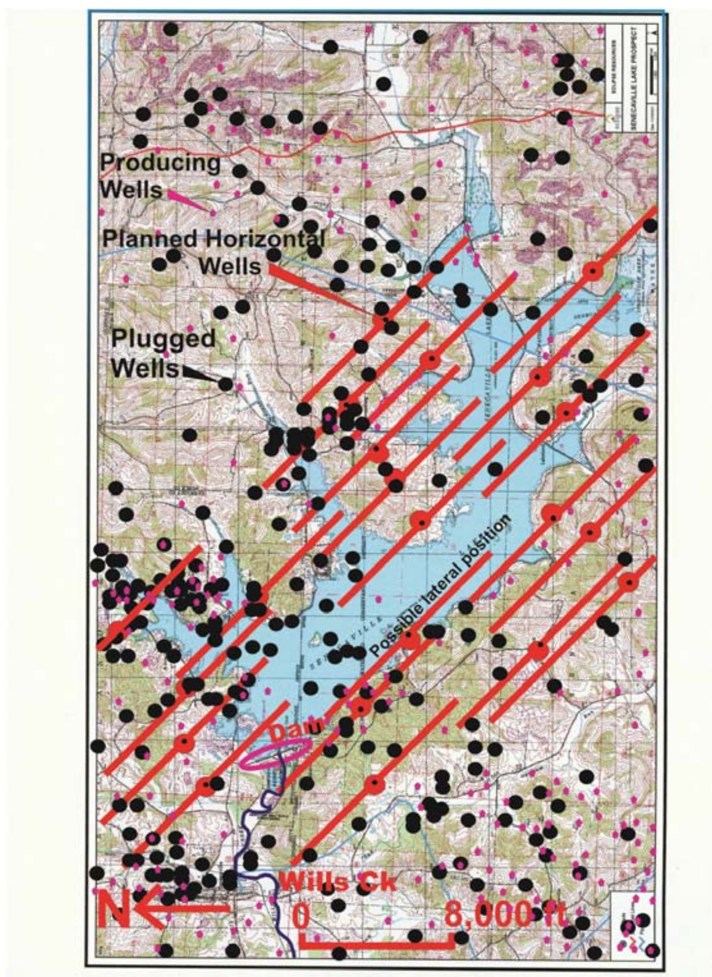
A truck marked as “radioactive” traveling on a highway near Golden, Colorado.
(Source: http://colorspray.blogspot.com from June 2010)

Are there additional environmental concerns?

Muskingum River Watershed

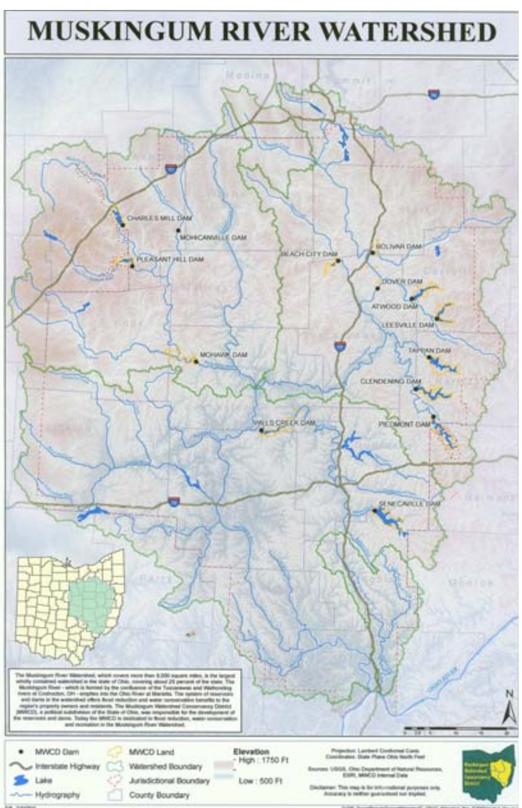
Concerns of the pollution of our environment and drinking water sources are not only related to the management of the waste that is produced and where it is stored and disposed of, but also are focused on the process of fracking as a whole, long before the waste and natural gas is generated at the soil surface. A high density of drilling wells in an area essentially creates numerous holes, fractures and connected land masses throughout the landscape underneath the soil. Although these fractures cannot be seen from aboveground, an area that has been heavily hydro-fracked and drilled may more closely resemble a piece of swiss cheese than that of the assumed solid landscape. The millions of gallons of water used to fracture these wells are also taking away from fresh-water drinking supplies. The Muskingum watershed in eastern Ohio is a prime example of this scenario.

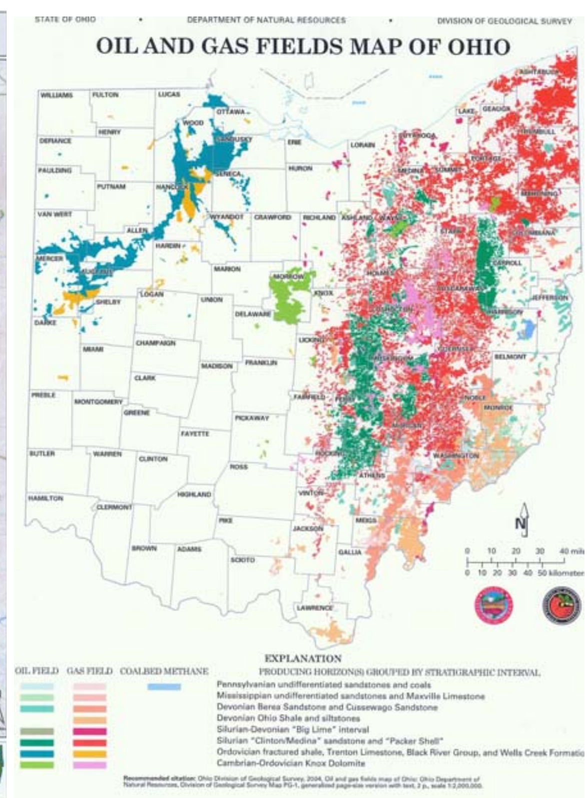
Draining a full fifth of the entire state and providing drinking water for thousands of residents, the Muskingum watershed is comprised of numerous large reservoirs as well as the lengthy Muskingum River. The Muskingum Watershed Conservancy District (MWCD) is responsible for caring for the reservoirs, yet they have approved several controversial water sales to the fracking industry[51]. In short, this means that the MWCD gave the oil and gas industry permission to buy water from several of the reservoir lakes in the Muskingum Watershed. In June and July of 2013, the maximum daily withdrawal will be 2 million gallons from just the one reservoir, Seneca Lake, alone. Two other reservoirs, Piedmont and Clendening, are also under contract for large water sales. Drilling companies are charged varying rates of $6.00 to $8.00 per 1,000 gallons of water from the reservoir[40].



Not only are residents worried about the reduction of water in the reservoirs due to the sale and permanent removal of mass quantities of water to serve the oil and gas industry, but concerns are also focused on the actual drilling operations themselves. The MWCD website[41] states that, “The MWCD oil and gas drilling program has been in place for decades, today resulting in hundreds of wells.” However, the MWCD fails to point out that high volume horizontal hydraulic fracturing is not the same industrial activity as vertical drilling, and the process consumes much greater amounts of water and land mass.

The image on the right depicts the placement of oil and gas wells around Seneca Lake in southeast Ohio, such that aquifer and reservoir water quality will almost certainly be degraded (image source: Rubin 2012). The abandoned wells (black dots) are densely clustered and show the connectivity of the underground landscape (with red lines portraying the horizontal fractures associated with each well). Leasing this land for widespread oil and gas drilling can have many consequences on the surface. Professional hydro-geologist Paul Rubin assessed the Muskingum River watershed in great detail[48] and warns of toxic contamination to water sources created by fracking near and underneath the lakes. Rubin, as well as numerous environmental support groups in the Ohio, have requested an immediate moratorium imposed upon hydraulic fracturing on MWCD lands and underneath all associated reservoirs. The Southeast Ohio Alliance to Save Our Water was formed to stop the conservancy district from leasing public land for fracking and for selling and potentially polluting millions of gallons of watershed district water. In addition, the FreshWater Accountability Project Ohio was formed to track those who profit from water sales to document liability for future water shortages and toxic pollution.





The image on the left portrays the size of the Muskingum River Watershed and the inset on depicts the location and size of the watershed within the state of Ohio[48]. The image on the right, comparatively, shows the state of Ohio as well as the locations of the oil and gas fields throughout the state[48]. The entire Muskingum River Watershed lies almost completely within the heart of the oil and gas drilling operation that is occurring.

As some gas and oil wells were drilled more than 50 to 100 years ago, the structural integrity of these wells is in question. The ability of these wells to age successfully is unknown; the concern is that toxic contaminants will gain access to freshwater aquifers and reservoirs over time. The structural integrity of the wells at locations that cut through aquifers is in question, not only after aging, but from the initial construction. Packed soils around the well support the casing material and help prevent it from rupturing, however areas that pass through marine environments, and thus offer less support to the well casing, may be at risk for weakening and eventual rupture under pressure from hydraulic fracturing. Toxic contaminants will leak into the environment and will move with ground water flow systems, eventually affecting local soils and drinking water sources. Due to underground placement, assessment of these situations are not conducted as routinely as they should be, and therefore leakage of pollution could occur for lengthy durations of time without any indication of the issue from the surface. The high density of wells drilled in the same area only increases chances of contamination to aquifers, as repeated hydraulic fracturing will result in interconnecting old, poorly plugged gas and oil wells, allowing upward contaminant migration into drinking water supplies and reservoirs. Rubin states in his report, “The ultimate result of extensive gas exploitation in the Muskingum River Watershed *will be* that groundwater and surface water contamination will occur. Such pollution is assured because (1) the durability of well sealant materials available today to effect zonal isolation of freshwater aquifers is poor and short-lived, and (2) toxic hydro-fracking fluids injected deeply into the ground will move with groundwater flow systems, eventually moving upward into freshwater aquifers, reservoirs and waterways. Permitting of horizontal gas wells proximal to reservoirs will needlessly jeopardize water quality.”

The Muskingum Watershed Conservancy District receives revenue from the oil gas industry for selling water from the reservoir for fracking operations. For instance, from leasing just one reservoir, Seneca Lake, the MWCD received a signing bonus of $6,200 per acre of land for 6,500 acres and a share of 20% of the royalties on gross revenues of oil and gas produced from its property[52]. This serves as an example of the skewed priorities by the MWCD to place economic interests before area property values, public health protections, conservation of important natural resources, and consideration of long-term sustainability to serve other important industries such as agriculture and recreation, as well as the protection of safe drinking water supplies from the impacts of future droughts.

What about public health concerns?

Communities and homeowners are already feeling the effects of hydro-fracking, pipeline construction and well drilling across the reaches of the Marcellus and Utica shale formations. Landowners are presenting symptoms, namely rashes and illnesses, believed to be caused by exposure to drilling fluid chemicals in their drinking water from drilling activities that have taken place on or near their land, as described in these recent articles[42, 43, 44]. One doctor was quoted as saying, “There is an epidemic of rashes occurring” (J. Skinner, personal communication, February 14, 2013). With the amount of acute health issues popping up throughout Pennsylvania and now Ohio, believed to be in response to drilling practices, we have concern this is just the tip of the iceberg when radium eventually migrates into source water for public drinking supplies and leaches out of landfills. When ingested, radium concentrates in bone and can increase the probability of leukemia. The serious health effects as a result of radiological exposure are not readily apparent as victims first endure a latency period. This means that although residents could be currently exposed, their symptoms may not appear until years from now.

A hydro-fracking drilling pad and storage pond in Pennsylvania show the proximity to the homeowner’s house as well as the large scale of the operation. (Source: Steve White/MarcellusProtest)

What are the current laws and/or regulations in place for managing fracking waste? ...Or lack thereof.

State governments, like Ohio, say their hands are tied in regulating NORM from drilling operations due to the Cheney Amendment. Also known as the Halliburton Amendment, this loophole can be found in the Energy Policy Act of 2005. This amendment exempts the fracking process from federal oversight under the Safe Drinking Water Act of 1974 and exempts companies that are doing Marcellus shale drilling from having to meet the requirements of the Clean Water Act[45]. “Due to federal exemptions, drilling occurs in close proximity to residential zones, elementary schools, playgrounds, hospitals, and public places; and citizens have no recourse,” said Shane Davis, Sierra Club Rocky Mountain Chapter’s Oil & Gas Campaign Information & Research Manager[46]. However, State governments can regulate technically-enhanced NORM, also known as TENORM. Recycling is such a process that enhances NORM. Fracking itself, the process of creating fractures in shale, increases the rock surface area and the solubility of radium, thereby producing TENORM. While this will be a matter for the courts to decide, it is clear to us that the States can regulate TENORM and therefore this method of gas production.

As of June 2013, verbiage regarding the management of TENORM was reintroduced into Ohio Governor's budget bill, via the Omnibus amendment for consideration by the Ohio Senate. The definition of TENORM states that, "TENORM does not include drill cuttings, background radiation, byproduct material, or source material." This excludes all fracking waste as TENORM and instead incorrectly labels the enhanced material as NORM, relieving the states of responsibility to regulate such materials. Changes also state that any natural gas well owner needs to collect and analyze samples of material, if identified as TENORM, associated with the well to determine the concentration of radium-226 and radium-228, but that the testing of radium levels are not required if material is reused on-site or transferred to another site for fracking operations, if the material is disposed of at an injection well, if the owner uses the material in association with a method of enhanced recovery, or if the material is transported out of state for lawful disposal. The mention of TENORM in proposed amendments is included, however fracking material has yet to be properly defined, and management and handling of such materials must still be further investigated before regulations are set into place.

In May of 2013, Ohio state officials introduced legislation to ban Class II fracking waste injection wells in Ohio. The bill would prevent waste from being discharged into Ohio's waterways after treatment and would make it illegal for municipalities to use the liquid waste from oil and gas operations for dust and ice control on roadways[5].

Conclusion

The natural gas industry is eager to develop the Marcellus and Utica shales, and has been successfully deploying this relatively new and highly unregulated process by promising jobs to Ohio workers, campaign contributions to legislators, and by providing revenue to regulators and royalty payments to landowners. However, we believe better protections should be in place before the industry ramps up production. Based on the actual environmental impacts in Pennsylvania, the potential impact in Ohio is not promising.

Hydraulic fracturing or fracking of shale rock is conducted by first drilling a vertical bore down to the Marcellus shale horizon, where high radioactivity and total organic content is reached. After lining the vertical hole part way down with cement casing, drillers move horizontally through shale rock, then subject shale to high hydraulic pressure to create additional fractures using hydraulic pressures of approximately 10,000 psi, explosives and millions of gallons of water.

This process in its entirety has been known to contaminate air and drinking water supplies. In numerous instances in Pennsylvania, the drilling fluid has escaped the cement casing, which is weakest at aquifer intersections. Contaminated aquifers and private water wells have caused skin rashes to residents, and infertility and death to livestock.

Following fracking, residual drilling fluid and radium-laced saline water is brought back to the surface as flowback water. During gas production, more radium-contaminated water is separated from natural gas, with even higher saline and radioactive concentrations. Millions of gallons of radium-contaminated flowback water and brine must be disposed. Much of this brackish liquid is transported to Ohio for "treatment" and disposal. The Patriot treatment plant in Warren, OH, the proposed GreenHunter processing plant in Wheeling, WV, on the banks of the Ohio River, would separate the liquids and solids. The proposed GreenHunter storage facility in New Matamoras, Ohio and deep well disposal operations in Racine, Ohio and elsewhere would receive fracking waste via barge from Wheeling, West Virginia. The solids presently go to municipal landfills; the liquids are either disposed in deep Class II non-hazardous injection wells, are directly dumped in surface waters (example D&L in Youngstown, OH), or spread on highways as a de-icer. Spreading brine on roads in Ohio can cause detrimental health impacts to residents, as this radium-contaminated water will be airborne during dry days and be inhaled. Inhaled radium will concentrate in bones and increase the likelihood of leukemia.

We also find that the chemical treatment methods at Patriot and GreenHunter cannot remove radium in solution and the testing methods cannot detect radium. The operators at the Patriot plant claim that the radioactivity present is background, nothing more. The landfill operators, with some exceptions, claim the radioactivity is near background. We are dealing here with magicians. The industry would have us believe that radioactivity below ground in the Marcellus shale disappears when it is brought to the surface.

Testing methods need to be improved; the State of Ohio needs to step up its regulatory program. Solids containing radium should be disposed in a low-level radioactive waste disposal facility and not in a municipal landfill, where the radium can eventually leach out into surface waters or be piped for inadequate processing at municipal water treatment plants[53]. Drillers have an economic incentive to use municipal landfills. Our research shows that the cost of disposal in a municipal landfill is a fraction of the burial cost in a low-level radioactive landfill, and the transportation distances and costs are also far less. This industry savings, however, could ultimately be at the cost of public health.

Two additional issues need to carefully examined: the impact of fracking on the Muskingum watershed by the active participation and promotion of industry for profit by the MWCD, and the transportation of liquid and solids to Ohio and to processing and waste disposal facilities. Fracking requires millions of gallons of water for each well. Waters, such as the Seneca Lake, are a convenient resource for drillers. But we fear the matter which is plaguing Pennsylvania will also affect the MWCD, once fracking begins. High hydraulic pressure will force drilling fluids into aquifers through faulty casing and old wells, potentially contaminating reservoirs needed for recreation, agriculture and drinking water supplies. The area around the MWCD is pockmarked with old wells. Like the New York City watershed, this area should be avoided for fracking.

The second issue involves the transportation of flowback water and brine in Ohio, either by rail, truck or even barge, as the GreenHunter plant is proposing. Our research finds that the State of Ohio is not properly regulating this radioactive material. Under Federal DOT regulations, produced (brine) and flowback water are considered radioactive material; the activity is much higher than the minimum threshold.

Ohio must upgrade its packaging and transportation regulations to meet Federal standards. Ohio's insurance regulations for brine-carrying trucks are less than what most drivers have on personal cars. Federal regulations require $5 million coverage, while Ohio requires $600,000. Further, Federal regulations requires placarding, to label trucks as carrying radioactive material, but Ohio has no such requirement. This puts unaware local emergency responders at risk in case of an accident.

All this in combination with the disposal of radioactive waste materials in non-hazardous Class II injection wells that leak and solid waste disposal sites not classified to handle the material will lead to radioactive leachate, as well as the potential contamination of reservoirs and aquifers due to migration of residual frack fluids from deep underground. Further, accidental and deliberate dumping and brine spreading on roads will combine to threaten the health and safety of Ohio residents. If current regulatory, transportation and disposal practices continue, the cost to future Ohioans will be large and remediation may not be possible. Clearly, now is the time to address these important issues. Legislators, regulators and public officials such as the MWCD Board and Conservancy Court are certain to be held accountable in the future for the huge cost of remediation, the loss of valuable freshwater supplies, and the negative impacts to public health that are certain to occur in the future.

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Appendix A.

49 CFR 173.410 - General design requirements.

§ 173.410
General design requirements.
In addition to the requirements of subparts A and B of this part, each package used for the shipment of Class 7 (radioactive) materials must be designed so that—

(a) The package can be easily handled and properly secured in or on a conveyance during transport.

(b) Each lifting attachment that is a structural part of the package must be designed with a minimum safety factor of three against yielding when used to lift the package in the intended manner, and it must be designed so that failure of any lifting attachment under excessive load would not impair the ability of the package to meet other requirements of this subpart. Any other structural part of the package which could be used to lift the package must be capable of being rendered inoperable for lifting the package during transport or must be designed with strength equivalent to that required for lifting attachments.

(c) The external surface, as far as practicable, will be free from protruding features and will be easily decontaminated.

(d) The outer layer of packaging will avoid, as far as practicable, pockets or crevices where water might collect.

(e) Each feature that is added to the package will not reduce the safety of the package.

(f) The package will be capable of withstanding the effects of any acceleration, vibration or vibration resonance that may arise under normal conditions of transport without any deterioration in the effectiveness of the closing devices on the various receptacles or in the integrity of the package as a whole and without loosening or unintentionally releasing the nuts, bolts, or other securing devices even after repeated use (see §§ 173.24, 173.24a, and 173.24b).

(g) The materials of construction of the packaging and any components or structure will be physically and chemically compatible with each other and with the package contents. The behavior of the packaging and the package contents under irradiation will be taken into account.

(h) All valves through which the package contents could escape will be protected against unauthorized operation.

(i) For transport by air—

(1) The temperature of the accessible surfaces of the package will not exceed 50 °C (122 °F) at an ambient temperature of 38 °C (100 °F) with no account taken for insulation;

(2) The integrity of containment will not be impaired if the package is exposed to ambient temperatures ranging from −40 °C (−40 °F) to 55 °C (131 °F); and

(3) Packages containing liquid contents will be capable of withstanding, without leakage, an internal pressure that produces a pressure differential of not less than 95 kPa (13.8 lb/in ^{2}).

[Amdt. 173-244, 60 FR 50307, Sept. 28, 1995, as amended by Amdt. 173-244, 61 FR 20750, May 8, 1996; 64 FR 51919, Sept. 27, 1999]

Appendix B.

49 CFR 173.410 - General design requirements.

§ 173.411
Industrial packagings.

(a) General. Each industrial packaging must comply with the requirements of this section which specifies packaging tests, and record retention applicable to Industrial Packaging Type 1 (IP-1), Industrial Packaging Type 2 (IP-2), and Industrial Packaging Type 3 (IP-3).

(b) Industrial packaging certification and tests. (1) Each IP-1 must meet the general design requirements prescribed in § 173.410.

(2) Each IP-2 must meet the general design requirements prescribed in § 173.410 and when subjected to the tests specified in § 173.465(c) and (d) or evaluated against these tests by any of the methods authorized by § 173.461(a), must prevent:

(i) Loss or dispersal of the radioactive contents; and

(ii) A significant increase in the radiation levels recorded or calculated at the external surfaces for the condition before the test.

(3) Each IP-3 packaging must meet the requirements for an IP-1 and an IP-2, and must meet the requirements specified in § 173.412(a) through (j).

(4) Tank containers may be used as Industrial package Types 2 or 3 (Type IP-2 or Type IP-3) provided that:

(i) They satisfy the requirements for Type IP-1 specified in paragraph (b)(1);

(ii) They are designed to conform to the standards prescribed in Chapter 6.7, of the United Nations Recommendations on the Transport of Dangerous Goods, (IBR, *see* § 171.7 of this subchapter), "Requirements for the Design, Construction, Inspection and Testing of Portable Tanks and Multiple-Element Gas Containers (MEGCs)," or other requirements at least equivalent to those standards;

(iii) They are capable of withstanding a test pressure of 265 kPa (37.1 psig); and

(iv) They are designed so that any additional shielding which is provided shall be capable of withstanding the static and dynamic stresses resulting from handling and routine conditions of transport and of preventing a loss of shielding integrity which would result in more than a 20% increase in the radiation level at any external surface of the tank containers.

(5) Tanks, other than tank containers, including DOT Specification IM 101 or IM 102 steel portable tanks, may be used as Industrial package Types 2 or 3 (Type IP-2) or (Type IP-3) for transporting LSA-I and LSA-II liquids and gases as prescribed in Table 6, provided that they conform to standards at least equivalent to those prescribed in paragraph (b)(4) of this section.

(6) Freight containers may be used as Industrial packages Types 2 or 3 (Type IP-2) or (Type IP-3) provided that:

(i) The radioactive contents are restricted to solid materials;

(ii) They satisfy the requirements for Type IP-1 specified in paragraph (b)(1); and

(iii) They are designed to conform to the standards prescribed in the International Organization for Standardization document ISO 1496-1: "Series 1 Freight Containers—Specifications and Testing— Part 1: General Cargo Containers; excluding dimensions and ratings (IBR, *see* § 171.7 of this subchapter). They shall be designed such that if subjected to the tests prescribed in that document and the accelerations occurring during routine conditions of transport they would prevent:

(A) Loss or dispersal of the radioactive contents; and

(B) Loss of shielding integrity which would result in more than a 20% increase in the radiation level at any external surface of the freight containers.

(7) Metal intermediate bulk containers may also be used as Industrial package Type 2 or 3 (Type IP-2 or Type IP-3), provided that:

(i) They satisfy the requirements for Type IP-1 specified in paragraph (b)(1); and

(ii) They are designed to conform to the standards prescribed in Chapter 6.5 of the United Nations Recommendations on the Transport of Dangerous Goods, (IBR, see § 171.7 of this subchapter), "Requirements for the Construction and Testing of Intermediate Bulk Containers," for Packing Group I or II, and if they were subjected to the tests prescribed in that document, but with the drop test conducted in the most damaging orientation, they would prevent:

(A) Loss or dispersal of the radioactive contents; and

(B) Loss of shielding integrity which would result in more than a 20% increase in the radiation level at any external surface of the intermediate bulk containers.

(c) Except for IP-1 packagings, each offeror of an industrial package must maintain on file for at least one year after the latest shipment, and shall provide to the Associate Administrator on request, complete documentation of tests and an engineering evaluation or comparative data showing that the construction methods, packaging design, and materials of construction comply with that specification.

[Amdt. 173-244, 60 FR 50307, Sept. 28, 1995, as amended by Amdt. 173-244, 61 FR 20750, May 8, 1996; 66 FR 45379, 45383, Aug. 28, 2001; 68 FR 75747, Dec. 31, 2003; 69 FR 3673, Jan. 26, 2004; 69 FR 55117, Sept. 13, 2004; 69 FR 58843, Oct. 1, 2004; 72 FR 55693, Oct. 1, 2007]

Appendix C

Testing Methods for Radium-226

The measurement of gamma emitting radionuclides at a landfill is customarily done with portal monitors or hand held detectors. Ra-226 decays to radon gas, Rn-222 and subsequently to bismuth-214, whose gamma emission can be detected. Hand held detectors generally measure total gamma, which includes potassium-40 and other radionuclides. But portal monitors can detect different energy gamma emissions and thereby distinguish Bi-214 (a decay product of Ra-226) and therefore Ra-226 from other radionuclides. Because of the larger detector area, portal monitors are more sensitive than hand-held detectors. We used the software Microshield to determine the dose rate 3 inches from the side of a truck carrying soil. To read 5 pCi/g in rock cuttings, assuming truck walls 1/8 inch thick, you would need to read a dose rate of 15 microrems/hr above background (generally 10 microrems/hr), which portal detectors can easily do. However, it is important to calibrate the portal monitor with the truck Ra-226 content. To do this, a representative sample of rock cuttings should be sent to a laboratory for specific analysis of Ra-226, using EPA protocols[1]. This EPA protocol requires a detailed chemical separation of Ra-226 from the rock matrix, followed by the standard method for detecting Ra-226 in a liquid, EPA testing protocol 903.1.

EPA protocol 903.1 generally takes about 21 days in a laboratory, from acceptance of a sample to quality assurance and the final report. Without going into great detail, radium is chemically separated from other elements and placed in a closed system. In four days, total alpha emissions build up to 4 times the alpha emissions from radium-226 and can be measured in a photomultiplier tube, where light emissions from alpha production can be measured. Though four days is the minimum, generally the holding period is longer, about 14 days.

For the measurement of Bi-214 in water, assuming that Bi-214 and Radium are in equilibrium: 1 pCi/L of Bi-214 would give rise to a dose rate of 0.0011 microrems/hour. Therefore, considering a load of brine water, with radioactive concentration of 10,000 pCi/L, Microshield estimates a dose rate of 10.91 microrems/hr- which could be detected in the field from a portal monitor. However, Ra-226 concentrations of 1,000 pCi/L yielding a dose rate of 1.1 microrems/hr would not be detected in a background dose rate of 10 microrems/hr.

[1] EPA-600-R-12-635, www.epa.gov/narel, August 2012, Revision 0, "Rapid Method for Radium in Soil Incorporating the Fusion of Soil and Soil-Related Matrices with the Radioanalytical Counting Method for Environmental Remediation Following Radiological Incidents"