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Water: Out of the Wells

A discussion of the waste fluids from Marcellus drilling: what they are and where they will go.

Did you know?

- Most of the injection wells used for oil and natural gas operations in the US are located in Texas, Oklahoma, Kansas, and California. There are around 28,000 of them.
- The characteristics of the formation being fractured, and the hydraulic fracturing chemicals used influence how much wastewater returns to the surface after well stimulation.
- The 430,000 gallons of wastewater produced from an average well is enough to fill more than 22 school buses.

Introduction

Water continues to be one of the most contentious issues that surround proposed Marcellus Shale drilling in New York. Concerns have been raised about the amount of water required, the chemicals used in the hydraulic fracturing process, the fate of the fluid that stays in the well after the shale has been fractured, and the storage and disposal of the fluid that returns to the surface. This paper will describe the water that comes out of the wells after the fracturing process. It is designed to be read in conjunction with *Marcellus Shale Issue 7: Water – Into the Wells* for a more complete picture of water and the Marcellus Shale.

What is wastewater?

The fluids that come back out of a well after it has been hydraulically fractured are called drilling **wastewater**. Wastewater is made of fluids from two distinct sources: the water that was pumped into the ground to be used to hydraulically fracture the well, and the water already present in the pores and cracks in the rocks of the **target formation** (the rock layer from which gas will be extracted, in this case, the Marcellus Shale). Wastewater varies in composition depending upon how long ago the well was fractured, and the fracturing chemicals that were used.

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What about the New York City watershed? [2,3]

In the revised version of the draft Supplemental Generic Environmental Impact Statement, released in June and September, 2011, the NY DEC has recommended that neither Marcellus Shale drilling nor its associated surface disturbances be permitted within 4,000 feet of either the Delaware/ Catskill watershed, which supplies unfiltered water to New York City, or around Skaneateles Lake, which supplies unfiltered water to Syracuse. Why?

It is not because the risk is higher in these areas. It is, rather, that these two municipal water supplies do not have the same drinking water filtration systems in place to remove the contaminants before they reach the public drinking supply. In order for NYC and Syracuse to continue use the Delaware/Catskill watershed as a source of unfiltered drinking water, they must adhere to the terms of long-standing agreements (known as Filtration Avoidance Agreements) with the U.S. Environmental Protection Agency and the New York Department of Health. These agreements include stringent requirements (more stringent than the requirements in places that drain into filtered water systems) on levels of phosphorus, suspended sediment, microbes, and toxic compounds, including petroleum in watershed water. If the EPA and NY Department of Health find that NYC is not meeting the requirements of its Filtration Avoidance Agreement, they would be required to build water treatment facilities that would cost the state billions of dollars.
That is why the permitting process is harder for NYC and Syracuse watersheds.

The NY DEC found potential surface spills of petroleum resulting from equipment ruptures, surface impoundment failures, vandalism, fires, other improper operation, or accidents, including vehicle accidents present a risk of contaminating these watersheds beyond the levels allowed by their filtration agreements. The same can be said of suspended sediment levels, due to increased truck traffic, access road and well pad construction, etc.

Some of the fluid used for hydraulic fracturing returns to the surface; this is called **flowback fluid**. The flowback fluid is similar in composition to, though not exactly the same as, the fluid pumped down a well to hydraulically fracture it. For more on the constituents of hydraulic fracturing fluid, please see *Marcellus Shale Issue 7: Water – Into the Wells*.

Formation water is water from joints and pores in the Marcellus Shale itself. It was present before drilling, and comes back up the well along with the flowback fluid. A small amount of wastewater comes up the well with the gas after the well begins producing. This is called **produced water**, and is mostly formation water.[1] Formation water from the Marcellus Shale contains a variety of naturally-occurring contaminants, including heavy metals, naturally occurring radioactive material (NORM), volatile organic compounds, and high levels of total dissolved solids, all of which are the result of the water being in contact with the rock in the target formation.

How much wastewater is produced?

The amount of water – both flowback fluid and formation water – that returns to the surface after hydraulic fracturing varies among different formations being drilled, and from well to well within the same formation. The specific characteristics of the target formation and the combination of chemicals used in the fracturing fluid, both of which can vary from drill site to drill site, determines how much water returns to the surface. In Marcellus Shale drilling, most of the water that is used to **stimulate** (the industry term for cracking the shale through hydraulic fracturing to release the natural gas - for more information, see *Marcellus Shale Issue 6: Drilling Technology*) a well will not return to the surface. For example, Marcellus drillers in Pennsylvania find that between 9% and 35%[4] of the hydraulic fracturing fluid returns to the surface over the lifetime of a well, with an average of about 10% returning.[5]

The Susquehanna River Basin Commission estimates that4.3 million[6] gallons of water are used to fracture an average Marcellus gas well. This suggests that between 387,000 gallons and 1,505,000 gallons of fluid will return to the surface, of a typical well, the average amount being closer to 430,000 gallons.

Typically, 60% of the wastewater that is going to come to the surface will be produced within the first four days after the well is fractured. After that, the amount drops to 2-5% of the total for about 2 weeks.[1] Wells can and do produce wastewater for longer than this, but the quantities are typically very low compared to this initial period. The New York Department of Environmental Conservation (NY DEC) estimates that between 3,400 gallons and 400 gallons of wastewater will be produced per day, depending upon how long the well has been in production.[7] The ratio of flowback fluid to formation water changes over time, as well. The wastewater has a higher percentage of flowback water at first, which decreases over time until the wastewater flowing from the well is almost entirely formation water. See Figure 1.

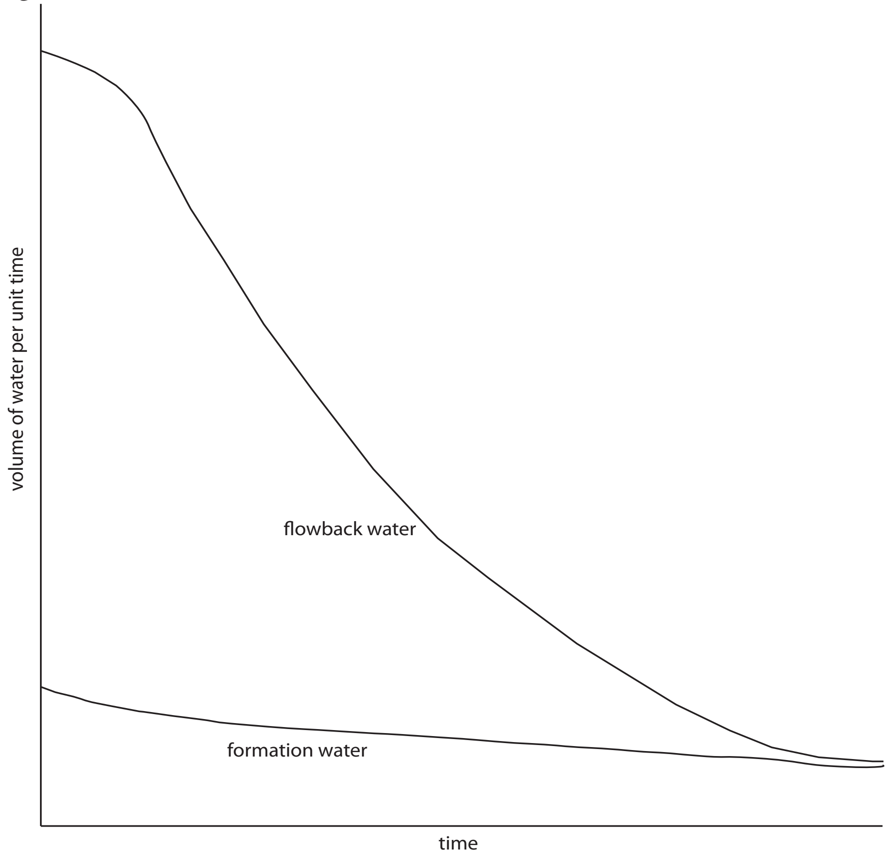
What is in wastewater?

Wastewater that comes to the surface after a well is fractured contains chemicals used in fracturing and the products of the reactions of those chemicals. The fracturing fluid that flows back is similar in chemical composition to the fracturing fluid pumped down the well, but it is not identical. They are not identical because chemicals in fracturing fluid can break down, interact with each other, or interact with chemicals in the target formation. These interactions decrease the amount of the chemicals originally added to the fracture fluid. They also create chemical compounds not originally present in the fracturing fluid. Certain chemicals stay in the formation at higher rates than others.[8] For more information on the chemicals that are added to the hydraulic fracturing fluid, see *Marcellus Shale Issue 7 – Water: Into the Wells*.

Wastewater also contains the naturally occurring chemicals found in the formation water. Formation water is generally brine (salty water) because of the origin of the Marcellus Shale in a shallow sea. For more on how the geology of the Marcellus Shale influences drilling conditions and outcomes, see *Marcellus Shale Issue 3: Why the Geology Matters*. Formation water is not unique to shale gas wells; it is present to some degree in almost all sedimentary rocks and is an expected part of almost all fossil fuel extraction. Formation water also contains heavy metals, naturally occurring radioactive materials (NORM), volatile organic compounds (VOCs), and other dissolved solids (primarily salts). All of these things have the potential to harm human health and the environment if they are not disposed of properly.

Produced water comprises the vast majority – 98% – of the volume of waste (all waste, not just water) produced by the oil and gas industry.[10] Though produced water from all fossil fuel production contains the same kinds of chemical constitu-

Figure 1: **The proportion of flowback fluid to produced water over the life of a well**



Schematic diagram showing that in the weeks and months after drilling, flowback fluid dominates waste water. Later in the life of the well, formation water is dominant, thus the chemistry of waste water changes through time.

Table 1: **What is in Wastewater?**

Flowback Fluid	Formation Water
Though this is modified during and after well stimulation by chemical interactions among the constituents of the fracture fluid itself and among the fracture fluid and the chemicals present in the target formation, flowback fluid will contain **many of the same compounds found in the fracture fluid that was pumped down the well**. These include **acid, gels, cross-linkers, breakers, friction reducers, surfactants, corrosion inhibitors, boosters, biocides, clay stabilizers, and pH adjusters**. For more on these chemicals, see *Marcellus Shale: Water – Into the Wells.*	**Heavy Metals** (Like lead, arsenic, and chromium)
	Naturally Occurring Radioactive Materials (Like radium, uranium, and strontium)
	Volatile Organic Compounds (Like benzene, toluene, ethylbenzene, and xylene)
	Total Dissolved Solids (Salts)

ents, the amount of each individual element or compound can vary by orders of magnitude depending upon the characteristics of the formation itself.[10]

Heavy Metals

Formation water can contain a number of heavy metals. Common heavy metals found in formation water in Marcellus Shale wastewater in Pennsylvania include lead, arsenic, barium, chromium, magnesium, manganese, strontium, and uranium.[11] Heavy metals can harm living things even at low concentrations and can **bioaccumulate** in organisms and food webs.[12]

Exposure to heavy metals can have various adverse health effects for humans if the exposure exceeds certain thresholds for a long enough period of time. Specific ill effects vary by the type of metal. Lead exposure, for example, can cause brain and nervous system damage, anemia, increases in blood pressure, kidney damage, damage to reproductive organs in both men and women, and even death – if the exposure is severe or prolonged enough. The effects of lead are more severe in children than adults.[13] Exposure to arsenic at low levels over a long time can cause skin and nerve damage, gastrointestinal problems, and cancer.[14] Exposure to barium at levels above the Environmental Protection Agency (EPA) and Department of Health (DOH) drinking water can cause gastrointestinal problems, muscle weakness, and changes in blood pressure. Chromium exists in several forms and danger from chromium exposure depends upon which form is present. Chromium–3 is an essential element to human health. Chromium-6 and -0, on the other hand, are toxic. Chromium-6 is likely carcinogenic. Manganese is also essential to human health, but

What is bioaccumulation?

Organisms take in all sorts of things from their environments. They can absorb chemicals via respiration, ingestion, and contact with the skin or certain membranes. Some of these chemicals are excreted from the body if they have been consumed in excess. For instance, the human kidney regulates the amount of potassium and sodium retained in or excreted from the body. Some chemicals are stored in the body instead of excreted. In humans, these include vitamins D and E. When the chemicals being absorbed are harmful, and organisms are not able to excrete them, buildup of these harmful chemicals will occur in various tissues and organs. When this buildup occurs and results in the concentration of the chemical being higher in the affected organisms than it is in the surrounding environment, that is called bioaccumulation.

When animals at higher levels in the food web have much higher concentrations of certain chemicals because they have absorbed those chemicals from their prey, that is called biomagnification.

Table 2: **Heavy Metals that Occur in Marcellus Wastewater**[16,17]

Element	EPA Maximum Level in Drinking Water (in parts per billion)	DOH Maximum Level in Drinking Water (in parts per billion)	Median Concentration in Marcellus Wastewater (in parts per billion) (footnote 1)	Number of wells in which chemical was detected/ number of wells tested
Lead	15	15	35	6/43
Arsenic	10	10	90	7/43
Barium	2,000	2,000	1,450,000	47/48
Chromium 6	100	100	539	10/19
Magnesium	-	-	177,000	180/193
Magnesium, Dissolved	-	-	2,170,000	3/3
Manganese	-	300	1,890	29/43
Manganese, Dissolved	-	-	2,975	12/22
Strontium	-	-	1,115,000	36/36
Strontium, Dissolved	-	-	629,000	21/22

acute exposure affects the nervous system. Strontium is both a heavy metal and a radioactive element (radionuclide). Like radium (discussed in the next section), strontium is absorbed by the body like calcium, and stays in bones, sometimes causing cancers like leukemia.[12] Uranium is also both a heavy metal and a radionuclide. It can cause kidney damage as well as cancer. Strontium and uranium are measured by the DOH as part of a general radiation testing requirement. (For more information on NORM, see the section below and read *Marcellus Shale Issue 4 – Understanding Naturally Occurring Radioactive Material in the Marcellus Shale.*)[15]

There are several sources of water contamination from heavy metals that are unrelated to gas drilling. Most of the radioactive strontium people encounter, for example, is a result of nuclear weapons testing decades ago. Strontium was spread all over the world when nuclear weapons were tested in the atmosphere in the 1950s and 1960s.[12] Most people exposed to uranium in dangerous quantities live near government weapons facilities or uranium mines. Dangerous lead exposure usually comes from lead pipes or paint dust from old homes. Even though there are other major sources of these heavy metals, natural gas wastewater poses a potential contamination risk. Improper disposal of wastewater or spills associated with gas drilling could expose local populations to increased levels of these metals, especially if this water makes it into local waterways without adequate treatment.

Naturally Occurring Radioactive Material

Naturally occurring radioactive material (NORM) is a common characteristic of black shales like the Marcellus Shale. This is because radioactive elements preferentially adhered to the clay and organic material that sank to the bottom of the Devonian shallow sea and formed the Marcellus Shale. Because black shales tend to have more organic material (and thus more gas) and clay than other rock layers, the amount of NORM in these layers is higher as well.

Of all of the radioisotopes brought to the surface during drilling, radium, particularly ^{226}Ra and ^{228}Ra, is of the greatest concern for human health and the environment. First, these isotopes are soluble in water. This means that their concentrations can be high in the formation water that comes to the surface after wells are drilled and fractured. Radium can precipitate out of the water along with salt, which concentrates the radium. This precipitation can occur in and around pipes as flowback water comes back to the surface. This accumulation of minerals in pipes and other equipment is called **scale**. Concentration can also occur if salts are purposely precipitated as a means of wastewater treatment. NORM that has not precipitated out, but remains dissolved in water would be transported to ground or surface waters in the event of a leak or spill.

Radium is processed by organisms in a way that is very similar to how they process calcium. This causes bioaccumulation of radium in the body, especially in the shells of common shellfish such as clams (made of calcium carbonate), and in the bones of vertebrates, such as fish and humans. The radium atoms will continue to emit radiation from within the body, so ingestion of radium is harmful to organisms.[18] ^{226}Ra and ^{228}Ra were found in flowback water in all 3 Marcellus wells sampled for it. Levels of ^{226}Radium ranged from 2.58 – 33 pCi/ L and ^{228}Radium range from 1.15 – 18.41 pCi/ L.[4] The EPA sets a maximum level of ^{226}Radium in drinking water to 5 pCi/L and ^{228} Radium to 15 pCi/L.

Because radium bioaccumulates, it can affect humans not only through drinking water, but also through animals used for human consumption if those animals are exposed to elevated levels. One model used in a study found that the risk of cancer from eating fish from the Gulf of Mexico to be below the level accepted by the EPA.[19] Drilling operations in the Gulf of Mexico treat their produced water on-site, then discharge it into the surrounding water. This produced water contains radium, just like formation water in the Marcellus Shale, but several important factors that would affect how much radium organisms are exposed to are different between the Gulf of Mexico and New York State. More research is needed to determine the applicability of the results of this study to the specific case of Marcellus Shale wastewater disposal. The amount of produced water discharged from all offshore drilling operations, such as those in the Gulf, is around 175 million barrels per year.[10] In order to reach this amount in Marcellus drilling, all of the 430,000 gallons of wastewater produced by over 22,000 wells (10 times the amount predicted by the NY DEC to be drilled in any given year) would have to be discharged into New York waterways every year. However, the Gulf of Mexico holds approximately 660 quadrillion (10^{15}) gallons of water. New York has far less water than that, so its capacity to dilute and disperse the chemicals in wastewater is much lower than the Gulf of Mexico. In general, the smaller the water body receiving the discharge, the more affected the ecosystem will be by the radium in the discharge. These differences would change the amount of radium fish would be exposed to in New York in comparison to the Gulf of Mexico, so while this study suggests that there is little danger, repeating this study using model conditions similar to New York State would tell us more about how radium would affect New York's waterways.

Table 3: **Occurrence of BTEX Compounds in Marcellus Wastewater**

VOC	EPA Maximum Level in Drinking Water (in parts per billion)	Median Concentration in Marcellus Wastewater (in parts per billion) (footnote 1)	Number of wells in which chemical was detected/ number of wells tested
Benzene	5	479.5	14/35
Toluene	1,000	833	15/38
Ethylbenzene	700	53.6	14/38
Xylene	10,000	444	15/38

Volatile Organic Compounds (VOCs)

Volatile organic compounds (VOCs) are relatively light **hydrocarbons** (molecules made up of carbon and hydrogen) that readily evaporate. They can be toxic to humans and they sometimes persist in drinking water.[20] The BTEX compounds are of particular concern in Marcellus Shale drilling. BTEX stands for benzene, toluene, ethylbenzene, and xylene, all VOCs that co-occur with the methane in the Marcellus Shale, and are frequently found in the formation water that comes to the surface after hydraulic fracturing.

The BTEX compounds represent threats to human health. Benzene is a known carcinogen, and also causes a number of other health problems.

Table 4: **How salty is Marcellus formation water?**

Water Type	Amount of Total Dissolved Solids (in parts per million)
Drinking water: Ideal	<500
Potable Water	<1,000
Saline	>5,000
Sea water	35,000
Produced water from Marcellus Shale wells in PA and WV, median	93,200

For this reason, the EPA has determined that for acceptably low risk to human health, there should be no benzene at all in drinking water (though the accepted maximum level according to regulations is 5 parts per billion (ppb). Although toluene, ethylbenzene, and xylene are not suspected carcinogens, prolonged exposure above the levels set by the EPA have been shown to cause liver, kidney, and nervous system damage.

Total Dissolved Solids (TDS)

Total dissolved solids (TDS) are solids dissolved in water that a normal filter cannot remove. They are mostly salts, which break apart into their constituent ions, (e.g., table salt (NaCl) breaks down to the positively charged Na+ and the negatively charged Cl-) when they are dissolved in water.[21] Sea water has a TDS of about 35,000 parts per million (ppm)[21] and drinking (potable) water is defined as water having less than 1,000 ppm TDS, although the EPA recommends a maximum concentration for TDS of 500 ppm. The *median* level of TDS detected in flowback water from Marcellus wells in Pennsylvania and West Virginia has been 93,200 ppm – between 2 and 3 times the level found in sea-water and more than 180times the level that the EPA deems acceptable to drink; maximum TDS levels from these wells are much higher.[4]

While contact with NORM-free salts is not directly associated with negative human health effects, changes in environmental TDS concentrations can cause harm to aquatic organisms, especially aquatic plants, algae, and invertebrates like mollusks and insects.

High TDS can cause buildup of scale, which can be problematic in natural gas drilling because it damages well casings and clogs fractures. Scale buildup can also concentrate the naturally occurring chemicals found in formation water, like NORM. (To learn more about the role of scale build up in human hazards, see Marcellus Shale Issue 4 – *Understanding Naturally Occurring Radioactive Material in the Marcellus Shale*.)

What happens to wastewater?

Wastewater disposal is a major topic of concern in the debate over Marcellus drilling. This section discusses the short and long term fate of the fluid that is removed from the well after hydraulic fracturing, specifically with reference to proposed regulations in New York State.

On-site storage and wastewater recycling

Wastewater must be stored on the well site at least temporarily before final disposal. Though other states have allowed drillers to store the wastewater in lined open pits, regulations proposed by the NY DEC require that wastewater be stored in tanks instead of pits.

Storing water in closed tanks provides a number of environmental benefits over open pits. First, leaks can be more easily detected and fixed in above-ground tanks than they could be in a large open pit. Second, it prevents the loss of water by evaporation. Drillers are moving toward recycling more of their wastewater for use in other wells, and less wastewater evaporation means more water preserved for the next well, and ultimately less taken from surface and groundwater sources. Third, storage in tanks poses less of a threat to local wildlife and livestock. The USDA has quarantined cows in Pennsylvania, for example, after they may have ingested hay from damp ground contaminated by a leak in a nearby wastewater pit.[22] There have been additional reports of cattle dying in Louisiana and Pennsylvania after ingesting substances near drilling rigs. While tanks do not eliminate the potential for such contamination at drill sites, they do significantly reduce these risks.

Even assuming zero leakage, storing flowback and formation water into open pits will allow VOCs from formation water to escape. Volatile organic compounds by definition evaporate from solids or, as in this case, liquids under normal ambient temperature and pressure. Many VOCs are of particular concern because they react with other chemicals in the air to produce ground-level ozone, an important air quality concern.[23]

Wastewater recycling is growing within the natural gas industry. This means that well operators use flowback fluid from one Marcellus well to hydraulically fracture another well. From June 2008 to June 2011, the Susquehanna River Basin Commission reports that drillers reused 14.5% of the water withdrawn for Marcellus wells: 311 million gallons of water were recycled of the 2.14 billion withdrawn from the Susquehanna River Basin.

"Recycling" can refer to any of a number of processes. It can mean the dilution of flowback water with fresh water, or it can be a more complicated process in which certain chemicals are removed from the flowback water. For example, recycling processes can target chlorides, calcium, suspended solids, oil and other soluble organics, bacteria, barium, carbonates, and sulfates when they treat wastewater for reuse.[7]

Factors that influence the amount of water that is recycled include the distance and time to the next hydraulic fracture treatment, cost of implementing treatment systems, amount of local freshwater, how much flowback water is recovered from the well and what is in the flowback water, and the local environment, topography, state regulations, and population density.

Wastewater recycling reduces the amount of freshwater that will need to be withdrawn in a region and reduces the amount of wastewater that must ultimately be disposed of.

Final disposal options

Even with intensive recycling, some wastewater must be eventually be disposed of, either treated in such a way that it can be released safely back into the environment, or removed permanently from the water cycle. The revised Supplemental Generic Environmental Impact Statement (SGEIS) on hydraulic fracturing of shales like the Marcellus outlines a few options for the final disposal of drilling wastewater, including: injection into a storage well; treatment in a New York municipal sewage treatment facility that is permitted to accept both industrial waste and drilling wastewater; shipment to a treatment plant in another state; or processing in a privately owned facility subject to the same standards as publicly owned facilities. Proposed NY DEC regulations will require a formal fluid disposal plan for each drilling site. Such plans must include information on both transportation of the fluid and the method of ultimate disposal.[23] Options could be added or eliminated when the final SGEIS is released.

Injection Wells

Injection wells make use of deep geological formations to store large quantities of gasses or liquids underground. Injection wells should isolate their contents from both groundwater sources and other rock layers. Most of the around 28,000 injection wells related to oil and gas operations (known as "Class II" wells) are located in Texas, Oklahoma, Kansas, and California. In such wells, wastewater is injected well below the water table and/or surficial aquifer. In New York, this will occur only after a permitting process involving the NY DEC and the Division of Mineral Resources. Because injection wells will not be regulated under the dSGEIS, they will require site-specific environmental review.

Use of injection wells for disposal of brine and industrial waste is more common in the western U.S. than the eastern U.S., because the geology of the eastern U.S. makes it

Existing treatment plants may not have the capacity to reduce TDS levels in wastewater. [SGEIS]

A rough estimate by the DEC puts the maximum amount of water that can be accepted at all current wastewater treatment facilities at 300 million gallons per day; though they estimate the total amount of Marcellus wastewater that is treatable in current conditions to be "much less" than 1 million gallons per day. They estimate the amount of water produced from a well per day to be between 400 and 3,400 gallons per day.(finaldSGEIS)
If a high production year sees 2,462 wells per year (the highest estimate used by the DEC for a high-production year of drilling), that means that between 984,800 gallons and 8,370,800 gallons of wastewater could be produced in New York per day. That is more than the "much less" than 1 million gallons estimated to be treatable daily.

more difficult to find suitable sites. One of the most important features of an underground injection well is that the fluid will stay in the formation into which it is being injected, without migrating to other formations. Properly sited and executed, an underground injection well is currently the only disposal option that completely prevents wastewater from entering surface and groundwater. It is not without its risks, however. Underground injection wells involve pumping billions of gallons of fluid into rock formations, orders of magnitude more than hydraulically fractured wells for natural gas extraction. High pressures are sustained for weeks at a time for fluid injection. This is useful because it means that the well can be used over years to dispose of the fluids. It is potentially hazardous, however, because it means that injection wells have the potential to cause **induced seismicity** (human-caused earthquake activity). For example, a **swarm** (a large number of very small earthquakes) was caused in central New York in 2001 as a result of injection wells in the cases of Avoca, NY in 2001[24] and Dale, NY[25] in 1970. For a more detailed explanation, please see Marcellus Issue 3: Making the Ground Shake: Understanding Induced Seismicity.

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Wastewater Treatment

Of the more than 600[26] publicly owned treatment works (POTWs) in New York State, 115 are capable of accepting industrial wastewater – a prerequisite for accepting and treating Marcellus Shale wastewater.[4] None of these facilities can accept Marcellus Shale wastewater without modification of their permits, which depend upon testing their facilities' capacity to treat the water effectively without disrupting their current program. As of summer 2011, no water treatment facilities have applied to accept Marcellus Shale wastewater.

According to the NY DEC, New York may not have the existing infrastructure at POTWs to handle the chemicals, NORM, and TDS, in volumes of water required for drilling. One of the limiting factors for how much water these facilities can accept is their ability to dilute the concentration of TDS present in their discharge water – the water that is released from the facility after treatment – to 1000ppm, the amount in potable water. Existing wastewater treatment plants may not have the capacity to sufficiently reduce the TDS levels. (See text box)

Another factor that limits how much wastewater facilities can treat is the amount of radium in the wastewater. The NY DEC proposes to cap the level of maximum concentration of radium that treatment plants can accept in wastewater at 15 pCi/L to ensure wastewater treatment plant sludge does not become too contaminated to be disposed of.[7] Recall that levels of ^{226}Radium ranged from 2.58 – 33 pCi/ L and ^{228}Radium range from 1.15 – 18.41 pCi/ L.

In case current capacity to treat wastewater is insufficient, the NY DEC has left open the possibility of using private wastewater treatment plants. They would be held to the same permitting standards for operation and discharge of treated water, but they would lighten some of the burden of treating wastewater from municipal facilities.

Additionally, the NY DEC will allow wastewater to be shipped to other states. In the preliminary revised SGEIS, they list 11 sites in Pennsylvania and West Virginia that were proposed as disposal sites in permit applications. The water would be subject to the receiving states regulations rather than New York's, and it is possible that these treatment facilities would refuse the wastewater.

A series of articles in *The New York Times* in February and March 2011 detailed how Pennsylvania water treatment plants were taking in drilling wastewater from the Marcellus Shale that they could not fully treat. NORMs were of special concern, as regulations in Pennsylvania allowed drinking water plant operators to test for NORM only once every 6 to 9 years. They also found that some wastewater treatment plants located upstream from drinking water plants were discharging water with levels of NORM and benzene much higher than the acceptable drinking water levels. After the news story came out, The Pennsylvania Department of Environmental Protection (DEP) asked drilling companies to (voluntarily) stop bringing wastewater to be treated at these plants. The DEP also released results of water testing for untreated water going into the drinking water plants, which showed that levels of radium and radiation were at or below background levels and below EPA drinking water maximum allowable levels.[28, 29]

An environmental group, The New York Water Environment Association, released a report in May 2011 listing questions that New York wastewater treatment plants should ask before they accept any drilling wastewater. The list includes whether treating the water at the plant would conform to their existing permit conditions, what exactly are the chemicals and concentrations in the wastewater the plants would be treating, whether the water can be adequately treated at the plant, and whether the volume of water required can be treated at the plant.[5]

What are the contamination risks?

All of the surface risks discussed in *Marcellus Shale Issue 7: Water – Into the Wells* are relevant to wastewater as well. This water will be transported by truck from well sites to treatment centers and injection wells, so the potential for accidents that spill wastewater into the environment is always present. Tanks on site for storage can leak and materials can be improperly stored and handled.

There is also the potential for contamination of groundwater by substances found in wastewater. It is important to examine environmental problems experienced in other sites of active natural gas development, though comparisons among different reservoir rocks (e.g., tight shales, tight sands, and coal bed methane) must also consider the geologic differences between them. For more information on the differences among reservoir rocks and how they relate to contamination, please see *Marcellus Shale Issue5: Jointing and Fracturing*. For example, reports of BTEX contamination and attendant health effects have been associated with natural gas drilling in coal bed methane formations in Sublette County and Pavillion, Wyoming and tight sands in Garfield County, Colorado.

It is important to examine environmental problems experienced in other sites of active natural gas development, though comparisons among different reservoir rocks (e.g., tight shales, tight sands, and coal bed methane) must also consider the geologic differences between them.

In the instance of contamination in Colorado, the contamination was due to human error. The company operating the well did not case the well properly. When they attempted to fracture a tight sand formation 7,000 feet below the surface, the protective well casing failed, and they instead contaminated ground water 3,500 feet away through a shallower fracture system. After the incident, a report was commissioned by Garfield County to explore the hydrology and geology of the region and to "assess the vulnerability of surface water and ground water resources in the area to impacts from natural gas well-development and other human activities and to evaluate if a relationship exists between water quality variations and lithology type."[30] Benzene was found in some of the samples, but not in the domestic water wells. Along with methane, which they were not able to definitively source from the natural gas wells, they found increased levels of chloride, fluoride, nitrate, selenium, iron, and manganese.

The EPA sampled 39 wells in 2009 in Pavillion in Fremont County, Wyoming - the site of a natural gas field extracting coal bed methane - after complaints from community members. Samples indicated "high levels"[31] of benzene, xylene, and other hydrocarbons like methylcyclohexane, naphthalene, and phenol. They also found levels of lead, phthalate (a substance found in gelling agents, surfactants, and viscosity adjusters – all used in hydraulic fracturing fluid – that is a public health concern because it can change hormone levels in humans), and nitrite that were above drinking water standards. EPA resampled in 2010 and confirmed that this was "highly contaminated shallow groundwater occurring in the same aquifer as drinking water wells."[32] As of the time of the 2010 report, EPA had not yet determined the source of the contamination. The Wyoming Bureau of Land Management tested well water in Sublette County, Wyoming, and found benzene levels 1,500 times the acceptable concentration levels. One of the largest natural gas fields in the US is in Sublette, where they extract coal bed methane.[33]

Summary

The water that returns from fractured wells, both the water that is injected to fracture the well and the water from the formation itself carries with it substances that can be harmful to human health and the environment. These substances include chemicals from the hydraulic fracturing process and the compounds formed from their interactions with each other and reactions with substances present in the Marcellus formation itself. Water present in the Marcellus formation contains heavy metals and radioactive materials, volatile organic compounds and high levels of total dissolved solids, mostly salts. Instances of contamination of groundwater by some of these compounds have been documented in other areas of the country. To reduce the risk of surface contamination by this wastewater, New York will require that wastewater be stored in tanks rather than lined open pits. Final disposal options include treatment in capable publicly owned wastewater treatment plants, capable private facilities, or shipment out of state to be treated there, or disposal in underground injection wells. Doubts remain about whether New York publicly owned wastewater treatment plants have the capacity to adequately treat wastewater. Careful regulation and adherence to regulation can reduce, but not eliminate the risks posed by wastewater from Marcellus wells.

Glossary

target formation - the rock layer from which gas will be extracted, in this case, the Marcellus Shale
flowback fluid - the fluid used for hydraulic fracturing returns to the surface after well stimulation
formation water - water from joints and pores in the Marcellus Shale itself
produced water - wastewater that comes up the well with the gas after the well begins producing gas
stimulate - the industry term for cracking the shale through hydraulic fracturing to release the natural gas
bioaccumulate - see text box
scale - accumulation of minerals in pipes and other equipment
Volatile organic compounds - are relatively light hydrocarbons that readily evaporate
hydrocarbons - molecules made up of carbon and hydrogen
induced seismicity - human-caused earthquake activity
swarm - a large number of very small earthquakes

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