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Waste Management of Cuttings, Drilling Fluids, Flowback and Produced Water

(Updated May 9, 2014)

Waste Management: Drilling Phase

At the beginning of the Drilling Phase the well bore is begun in much the same way as other types of wells, such as water or oil wells. First a vertical well is drilled that extends straight down into the earth. Then, the horizontal portion of the well (the lateral) begins. Drilling down to the shale, and then horizontally through it, are the activities that occur during the Drilling Phase. The well has not yet been hydraulically fractured, nor is it producing significant quantities of gas.

Cuttings and Drilling Muds

When a well is drilled, the 'cuttings' of drilled rock need to be removed from the well bore. The deeper a well is drilled, and the longer the lateral portion is made, the more drill cutting will need to be removed. Cuttings are often transported from the well to the surface by a continuously circulating fluid that also serves to cool and lubricate the drill bit as it cuts deeper into the earth. This fluid, which is used only during the Drilling Phase of well development, is sometimes called "mud." Drilling muds containing rock cuttings are brought to the surface where the liquids and solids are separated. The cuttings are generally dried and left as a solid waste, and the mud is reused and sent back down the well. After drilling is completed, muds must be reused or properly disposed.

Cuttings are made up of whatever rock separated the shale from the surface, as well as the shale itself. Although the composition of these cuttings is generally not concerning, the volume of cuttings can be large as wells are drilled deeper, and with longer laterals. Some concern has been raised over the levels of naturally occurring radioactive materials (NORM) that can be present as a result of uranium decay products (eg. radium) associated with the organic content of the shale.

Drilling muds are made up of a base fluid (water, mineral oil, or a synthetic oil-based compound); weighting agents (most frequently barite, which contains barium); a clay; and a stabilizing organic material such as lignosulfonate or lignite. Besides these components, which are present in the mud to begin with, the fluid also picks up other constituents that were originally associated with the geology itself. Since the mud flows through the well and comes into contact with the shale and other geological formations, material can dissolved or adsorb into the mud fluid and get transported to the surface. Marcellus shale naturally contains salts, metals, and the same NORM present in the cuttings. The exact nature and concentration of constituents will depend on local geological conditions and the length of the well.

According to data collected by the Pennsylvania Department of Environmental Protection (PADEP), nearly all of the cuttings generated during Marcellus shale development are disposed of in landfills. In New York, proposed regulations for Marcellus shale development stipulate that the methods used for management of cuttings will depend on the nature of the drilling muds being used (see section 1.7.10 of the rdSGEIS). When water-based drilling muds are used, on-site burial of cuttings is deemed acceptable. However, when oil or synthetic-based muds are used, the cuttings must be contained in a closed-loop system on-site and disposed of in a landfill. In the latter case, cuttings are considered industrial, non-hazardous waste, requiring permitted waste haulers.

When the Drilling Phase is completed, drilling muds are often disposed of at industrial wastewater treatment facilities. Reuse of muds has been increasing over the last few years, while disposal at public wastewater treatment facilities (POTWs) has been decreasing, and is now rarely done; other disposal options include landfills and deep injection into disposal wells. As with cuttings, NY is proposing to allow lined pits when drilling muds are water-based, but would require closed-loop systems when muds are oil or synthetic-based.

Waste Management: Stimulation/Completion Phase

After the well has been drilled, the rig is removed and the Completion Phase begins – this is also called “stimulation” or “hydrofracking” (there are several variations of spelling). Here, a water-based fluid is injected so as to fill a portion of the well. This fluid is then put under pressure to create and elongate tiny fractures in the shale, thus allowing the natural gas to escape into the well bore and up to the surface. Once the fractures are created, the pressure is released and some of the fluid is immediately expelled from the well. A mixture of gas, hydraulic fracturing fluid, and naturally occurring water from the shale formation comes to the surface and must be managed.

Hydraulic Fracturing Fluid

Hydraulic fracturing fluids are created on-site by mixing a proppant (commonly sand), and a number of chemical additives into water. The role of the proppant is to keep the fractures created in the shale from closing once the pressure is removed from the well. Chemical additives serve a number of purposes including, but not limited to:

- A friction reducer is added to reduce the friction pressure during pumping operations.
- A surfactant is used to increase the recovery of injected water.
- A biocide is used to inhibit the growth of organisms that could produce gases (particularly hydrogen sulfide) that could be dangerous as well as contaminate the methane gas.
- Scale inhibitors are used to control the precipitation of carbonates and sulfates.

Since different companies utilize different chemical additives, and because fracturing fluids are tailored to local geology, it is difficult to summarize the exact chemical composition of a “typical” fracturing fluid. Indeed, there is considerable controversy about the composition of fracturing fluids, as the exact formulas are usually not disclosed publically. Some websites exist that allow companies to post this information, and a review of these sites gives us a rough idea as to what additives are used for hydraulic fracturing of Marcellus shale. While some common components (eg. guar gum, polysaccharides, and certain alcohols and acids) are relatively benign, other common components (eg. Hydrocarbon distillates and biocides) raise concern in the event that such fluids are spilled or leaked into environmental or drinking water systems. More information on hydraulic fracturing additives can be found at the following sites (there are many more than this!):

FracFocus - http://fracfocus.org/
Geology.com - http://geology.com/energy/hydraulic-fracturing-fluids/

Flowback Water

After hydraulic fracturing is complete, some of the injected fluid comes back to the surface. For Marcellus Shale gas wells in Pennsylvania, about 10% of the injected fluid returns to the surface within one month according to Susquehanna River Basin Commission. This fluid, which returns to the surface relatively quickly, and in high volumes, is referred to as flowback. Flowback will contain the chemical additives used during hydraulic fracturing; thus, flowback is an industrial wastewater that requires proper treatment and/or disposal. In addition to chemical additives, flowback water will also contain chemical constituents associated with the shale. The Marcellus shale is of marine origin and the rock itself naturally contains high levels of salt, certain metals and organic compounds, and NORM. As was the case with cuttings and drilling muds, some of these will dissolve in the fluid used to fracture the shale and will subsequently be brought to the surface in the flowback water. In fact, many potential wastewater components of concern are of geological origin, including arsenic, strontium, and radium.

Flowback waste fluid, which consists of the hydraulic fracturing fluid plus geology-associated contaminants, is considered industrial waste. According to proposed NY regulations (see section 1.7.8 of the rdSGEIS), this waste must be contained on-site in closed-loop tanks. This is an improvement over past practices and practices allowed in some states where storage of flowback in open pits was/is allowed. Once collected, flowback must be treated or disposed of in one or more of the following ways (according to proposed NY regulations): 1) industrial treatment followed by reuse in subsequent hydraulic fracturing operations, 2) industrial treatment followed by discharge to POTWs for further treatment, 3) treatment at POTWs that have an approved pretreatment program for industrial waste, 4) underground injection in federally permitted disposal wells, and 5) on-site treatment (see here for a brief introduction to on-site treatment technologies) followed by reuse or discharge to another treatment facility.

Each option has both advantages and disadvantages. Although reuse following industrial treatment has become common in PA there are currently no significant industrial waste treatment facilities for handling Marcellus shale flowback in NY. POTWs on the other hand, while common across the region, are not designed to properly treat the types of contaminants typical in Marcellus shale flowback waste, and do not have sufficient capacity to accommodate large quantities of new waste (see a recent WRI publication for further details). Underground injection requires a federal permit and specific geologic conditions that are not common in NY. Disposal by injection well is possible only by trucking wastes to states where disposal wells exist, such as Ohio and West Virginia. On-site treatment technologies have also been developed, and are now widely utitilized.

Waste Management: Production Phase

Once the well has been completed (hydraulically fractured) it is ready to start producing gas. The well is connected to a gas distribution pipeline and, assuming no other wells need to be drilled, the site is partially reclaimed as much of the industrial equipment is moved. On multi-well pads, however, one well may be in the Production Phase while others are just being drilled.

Produced Water

As gas is pumped out of the well, decreasing amounts of the remaining water (including any water that was naturally contained within the shale formation) will continue to be withdrawn and stored at the surface. This water is called produced water. During shale gas development, the volume of water produced can vary depending on the age of the well and the characteristics of the targeted shale. Produced water volumes tend to be quite small relative to flowback water. However, over the lifetime of a well, and depending on the total number of wells in a region, the total amount of produced water over time can be large. Since produced water spends more time in contact with the shale compared to flowback, it picks up greater amounts of geology-associated constituents such as salts (TDS), certain metals and organic materials, and NORM.