Radioactive Waste Management Associates

Memo

To: Gary Abraham

From: M Resnikoff

cc: Jackie Travers, Ekaterina Alexandrova

Date: April 7, 2010

Re: Radioactivity in Marcellus Shale

You asked us to review the drill cuttings and drilling fluids from natural gas exploration projects and to opine on the advisability of having the cuttings and dewatered drilling fluid go to a solid waste landfill. To do that, we reviewed the well logs and a large number of references, including DEC and EPA regulations. We regard disposal of these materials as a serious problem that has not been adequately addressed by the DEC. Both waste forms are radioactive; the radioactive concentrations are far higher than background concentrations for radium in New York State.

Geologists consider the Marcellus shale formation to be relatively highly radioactive and regionally extensive. Radioactivity in the Marcellus shale results from the high content of naturally occurring radioactive uranium and thorium, including their decay products, and potassium elements in the rock. In New York State the formation ranges from 25 to over 100 feet in thickness and the depth of the base varies from an outcrop to 1000-foot depth by Syracuse to 4000-foot depth by the border with Pennsylvania[1]. Recent development in natural gas exploration of the Marcellus shale has not been adequately assessed for its environmental and health impacts related to radionuclides originating in the shale.

Drilling operations produce two radioactive waste streams – solid rock cuttings and drilling fluid. Rock cuttings result from grinding and chipping of the bedrock by the drill bit during wellbore operations. Drilling fluid is circulated through the well to cool the drill head and bring the rock cuttings to the surface. The rock cuttings and any solids originally present in the drilling fluid are then filtered out and disposed of in the Chemung County municipal landfill.[2] At this point the landfill is accepting between 1,000-2,000 tons of solid waste per week, or 104,000 tons per year. Moreover, officials are seeking to increase the annual tonnage to 180,000 tons and eventually to 417,000 tons.[3]

It does not appear that NYSDEC has examined the cuttings for its radiological impact and suitability for disposal in a municipal landfill. Radiologically contaminated leachate from the landfill treated at the City of Elmira waste water treatment plant could enter the Chemung River. The procedure for dewatering the radioactively contaminated drilling fluid and what happens to the remaining radioactively contaminated fluid is also not clear. It may be sprayed onto a field (landfarmed), buried in a pit, or treated in a wastewater treatment plant prior to discharge. Both waste products, the solid drill cuttings and the liquid waste, contain radiological contaminants in concentrations that exceed allowable limits for disposal in a landfill or treatment in a publicly owned wastewater treatment plant.

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[1] Hill et al. "Fractured Shale Gas Potential in New York."
[2] Maslanka, 2010a
[3] Wilber, Tom, 2010

Rock Cuttings

Rock cuttings from boreholes have been indirectly studied in order to assess the radioactive content in the shale. We analyzed the gamma-ray (GR) well logs from wells in three towns in New York State, Reading, Dix and Pulteney. The Pulteney well (Bergstresser) would be used as a disposal well for radioactive waste water from other exploratory wells in New York State.[4] Gamma radioactivity within each well was sampled with a sensitive Geiger counter and the measurements were plotted on a graph as GAPI (Gamma-ray, American Petroleum Industry) units against depth. The GAPI unit is defined by a calibration facility at the University of Houston, Texas, where three pits are located, each with a different mixture of thorium, uranium, and potassium. The actual GAPI unit is arbitrary and is defined as 1/200th of the deflection measured between the high and low activity zones in the pits.[5] In order to convert the GAPI units to curies we used a method cited by several sources, in which 16.5 GAPI units equal 1 microgram of Radium-equivalent per metric ton (or 1 picocurie per gram).[6]

In general, the radioactivity throughout the depth of the rock cuttings appears to be equal to or less than 10 picocuries per gram. However, at certain depths in each well the activity is significantly higher. All logs have a provision for the shifting of scale from the standard 0-200 GAPI range to greater than 200 GAPI or even greater than 400 GAPI. It is unclear from the logs how the shifting of scale is recorded, but at a certain depth the gamma ray line indicates measurements beyond the 0-200 GAPI range (Figure1). In the three well logs in Figure 1, the y-axis represents the depth of the well in feet and the x-axis represents the gamma ray measurement in units of GAPI. The gamma ray radioactivity can be traced through the depth of the well by following the solid black line. At a certain point this line, which has been recording the gamma ray radioactivity within the 0-200 GAPI range, stops and traces curves that indicate measurements beyond this range for duration of a little less than 100 feet. In the well log for the well in Reading, NY (Shiavone 2) this occurs approximately between 1550 and 1650 feet, in the well log for Dixon, NY (WGI11) this occurs between 2400 and 2500 feet, and in the log for Bergstresser we see it between 1700 and 1800 feet. We assume that these sections of increased radioactivity represent the Marcellus shale. In each case the thickness (less than 100 feet) and the depth of the shale is consistent with the general geological predictions of the Marcellus formation in the region. It is not possible to give the specific radioactivity measurement due to the log quality, but if we consider that these sections indicate the gamma ray range of 200-400 GAPI, it would represent radioactive radium concentrations of about 12-24 pCi/g or higher.

NYSDEC reported in their 2009 Draft Supplemental Generic Environmental Impact Statement (DSGEIS) radioactivities for rock cuttings from two wells in Lebanon and in Bath, NY, where the total radioactivity levels were 25.4+/-4.6 and 29.2+/-4.3 pCi/gram respectively, which is consistent with these findings.[7] These radium concentrations are far higher than background concentrations in New York State[8], which is 0.85 pCi/g.

Additional studies on radon and produced water and scale confirm the elevated radioactive levels in the region. In a study performed in Onondaga County, NY, Rn-222 was measured in 210 homes situated above the Marcellus shale formation. All homes had indoor Rn-222 levels exceeding 4 pCi/L, EPA's set action level for indoor radon concentrations, with the average being 8.8 pCi/L.[9] The Pennsylvania Bureau of Oil and Gas Management and the Bureau of Radiation Protection conducted a study in Pennsylvania in which they measured radon in a gas sample from the Marcellus shale. The radon concentrations exceeded the allowable levels by 1,000 times.

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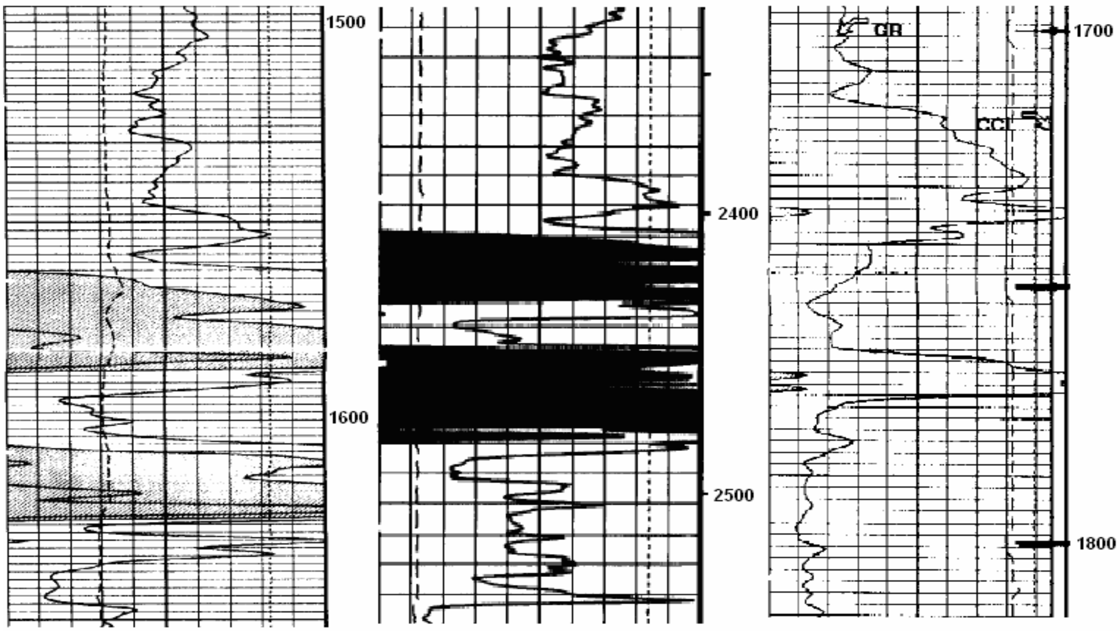
[4] Smith-Heavenrich S., 2010
[5] Hoppie, B.W. et al, 1994
[6] Donnez, 2007 p.33
[7] NYSDEC, 2009
[8] Myrik 1983
[9] Banikowski, 1992



(a) (b) (c)

Figure 1. Excerpts from Gamma Ray Logs for (a) Shiavone 2 Well (Reading); (b) WGI11 Well (Dix); (c) Bergstresser Well (Pulteney)

Drilling Fluid and Flowback Water

Currently, the drilling fluid used to bring up rock cuttings from the well during drilling operations is dewatered and, along with the rock cuttings, disposed of at the Chemung County Landfill in a solid form. The concentrations of Ra-226 and Ra-228 in the drilling fluid from the Shiavone 2 well and WGI11 well were measured to be 16,097 pCi/L and 11,412 pCi/L respectively.

Although at this point the landfill is not accepting dewatered hydraulic fracturing fluid and produced water, we believe that their hazards should also be seriously considered for the future. Hydraulic fracturing is a process used to access hydrocarbon reserves at sites where the rock formation is so impermeable or the pressure is so low that traditional pumping methods are not efficient. The wellbore is hydraulically stimulated with one of three possible agents: nitrogen gas, nitrogen foam, or slickwater. Slickwater fracturing system had been successfully used for the Barnett Shale in Texas and was selected to extract gas from the Marcellus Shale.[10] During this process clean water is mixed with proppants, small particles such as sand and a number of chemicals, and injected into the ground at high pressure to create or to expand already existing fractures allowing the hydrocarbons to flow into the wellbore. Slickwater fracturing is also referred to as High-Volume-Hydraulic Fracturing because of the large volume of water that it requires. The slickwater mixture consists of 98% water and 2% sand and chemical additives. One 4,000-foot lateral wellbore undergoing a hydraulic fracturing procedure requires between 2.4 million to 7.8 million gallons of water.[11]

Some of the hydraulic fracturing fluid flows back to the wellhead after the well has been fractured. At this point the fluid is referred to as flowback water and usually constitutes about 9-35% of the original pumped volume. Since Marcellus Shale is of marine origin, it naturally contains high levels of salt and NORM, which can dissolve in the fluid and be brought to the surface with flowback water.[12] As indicated in NYDEC's Appendix 13 of the dSGEIS, the sampling of

[10] Sumi, 2004
[11] NYSDEC, 2009
[12] Cornell U., 2010

production brine from the Marcellus Shale results in radium concentrations 5000 pCi per liter and higher.[13]

According to Dr. Peter Davies, "The New York Department of Environmental Conservation found 13 samples of returned drilling wastewater (flowback) from vertical Marcellus shale wells in Schuyler, Chemung, and Chenango Counties to contain levels of radium as high as 267 times the limit for discharge into the environment, and thousands of times the limit for drinking water".[14] NYSDEC measured the radioactivity at 9,000 pCi/L in produced water and >100,000 pCi/g in pipe and tank scale.[15]

Landfill Disposal of Radioactive Waste

Under the cleanup standards for land contaminated from inactive uranium processing sites, the EPA limits the concentration of radium within the top 6 inches of soil to 5 pCi/gram and to 15 pCi/gram at deeper depths[16]. Therefore, drill cuttings with radioactive concentrations above 20 pCi/g, such as from Shiavone 2 and WGI11 wells, would exceed these limits if disposed in a municipal solid waste landfill. In addition, employing the standard Department of Energy software RESRAD, we find that radium concentrations of 20 pCi/g in soil lead to a direct gamma dose and ingestion of contaminated vegetation dose as high as 200 mrem/year. This can be compared to the maximum permissible dose at the fence post of an operating nuclear reactor of only 100 mrem/year.

We agree with comments on the NYSDEC DSGEIS by Dr. Davies, a professor at Cornell University and a licensed handler of low-level radioactive material, stating that, "It is imperative that drilling wastes not be disposed of, by either on-site burial or land spreading, in areas that are located close to residences or public facilities, or where they can contaminate water supplies. Radioactive wastes must be taken to an appropriate facility that is designed to handle radioactive waste."[17]

The current DEC approval states that dewatered brine and sludge waste from development of Marcellus shale in Pennsylvania may be disposed of in the Chemung County Landfill. In an email from DEC, the State appeared to be considering only the ignitability of the cuttings[18]. This approval appears to be inconsistent with New York State regulations regarding the disposal of waste containing radioactive contaminants. Specifically, NYCRR Part 360-2.17(m) prohibits the disposal of hazardous wastes, low-level radioactive wastes, or NARM wastes in landfills. The regulations define low level radioactive waste in NYCRR Part 374-1.9 as "radioactive waste which contains source, special nuclear, or byproduct material, and which is not classified as high-level radioactive waste, transuranic waste, spent nuclear fuel, or byproduct material as defined in section 11e.(2) of the Atomic Energy Act." The same section defines Naturally Occurring and/or Accelerator-produced Radioactive Material (NARM) as "radioactive material that occurs naturally and is not a source, special nuclear, or byproduct material". [19] Dewatered brine and drill cuttings containing concentrated naturally occurring radioactive contaminants from the shale formations fit these definitions and, therefore, may not be placed in a standard municipal landfill. Instead, they should be segregated from other wastes and be disposed of in a specially designed facility as specified by NYCRR Part 382.21(a)(3), which states that "the primary emphasis in disposal site [for wastes containing long-lived radionuclides] suitability must be given to isolation of wastes."

The placement of radioactive waste in a MSW facility is not in accordance with the state regulations and also creates a potential hazard to the surrounding areas. Municipal waste

[13] NYSDEC, 2009
[14] Davies P., 2009
[15] NYSDEC, 2009
[16] 40 CFR Part 192.12.
[17] Davies P., 2009
[18] Maslanka, 2010b
[19] NYSDEC, 2010

landfills are lined with a layer of clay and plastic and are not designed to contain low level radioactive wastes. Leachate that forms in such facilities will contain residues of radionuclides from the drill cuttings and dewatered brine. If any of this waste leaks into the soil it may contaminate the groundwater. Furthermore, leachate that is collected from the Chemung County Landfill will be treated at the Elmira wastewater treatment plant. The plant processes up to 4 billion gallons of water per day, but if radionuclides contained in brine produced by fracturing operations of just these two wells are dissolved in this volume of water, the effluent into the Chemung River will contain as much as 30 pCi/L, exceeding the allowable Drinking Water Standards for Ra-226 and Ra-228 of 5 pCi/L.[20] Radium may also follow wastewater treatment plant solids and it is important that the DEC examine the radium concentrations within them.

Summary

The hazard associated with the disposal of dewatered Marcellus shale drill cuttings and drilling fluid in a municipal landfill has not been fully evaluated by NYSDEC. Extensive evidence of the elevated radioactive levels within the Marcellus formation is evident from the well logs and from previous studies performed by NYSDEC and others. Our estimates project that the drill cuttings will have radioactive concentrations far above background concentrations and above the allowable limit for surface disposal in a municipal landfill. Hence, this material must go to a landfill designed specifically for radioactive materials. NYSDEC needs to evaluate the concentrations of radioactive Marcellus shale cuttings that can be accepted by a municipal landfill and the environmental and health impacts of this action. In addition, NYSDEC needs to evaluate the hazards of fluid waste and procedures associated with drilling, which are currently unclear – including how the drill cuttings and drilling mud are dewatered, what happens to the remaining water from dewatering operations, what happens to the hydraulic fracturing fluid.

The issue concerning the fate of fluid drilling waste is important because the ability to deal with it is limited. Currently, the majority of wastewater treatment plants in the Twin Tiers region are not designed to handle the volume and the type of wastewater produced by the Marcellus shale exploration. [21] Although certain plants have been accepting drilling wastewater, the Pennsylvania Department of Environmental Protection recently prohibited municipal sewage treatment plants from doing so without knowing the composition of the wastewater or how to treat it. After the issuance of this order some plants, in fact, had to stop accepting drilling wastewater. For example, a plant in Sayre, PA could no longer accept this type of waste because it could not test for metals and contamination in a time and cost efficient way.[22] Since the amount of wastewater produced by the drilling operations is so large, the companies are always looking for cost-efficient ways to deal with it. Some of the practices that have been used in Pennsylvania include the spreading of wastewater on the roads to control the dust in the summer and to melt the ice in the winter.[23] In New York the option of injection wells is not common because they are not licensed to accept any radioactive wastewater or wastewater originating from the Marcellus shale operations. Thus, most of the drilling wastewater in New York is treated in municipal or industrial treatment plants and then discharged into the waterways. It is not clear which plants in New York, if any, are capable of handling radioactive drilling wastewater so the state usually depends on drilling companies to find legal treatment options.[24]

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[20] U.S. EPA, 2010
[21] Wilber, Tom, 2009
[22] ibid
[23] PADEP, 2009
[24] Lustgarten, Abraham, 2009

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