Comments on DSGEIS on Marcellus Shale Development
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These comments on the DSGEIS on Marcellus Shale Development[1] pertain primarily to the fate and transport of radionuclides contained in the Marcellus shale formation, and the regulation of these materials. Since the previous GEIS, DEC has examined the regulatory experience in other states and responded to the concerns of New York City and State residents. Nevertheless, the regulatory approach by DEC still needs major improvements and will not be protective of gas workers, the public and the environment. Further, based on our experience in other states, we have grave concerns that DEC has the resources to regulate an industry so powerful and growing in New York State. The author of these comments has had 20 years experience examining NORM in oil and gas exploration and production in Louisiana, Texas, Kentucky, Mississippi and more recently in New York State.

General Comments

Aside from public statements by the oil and gas industry, most disinterested scientists agree that the Marcellus shale contains uranium-238, thorium-232 and their decay products at concentrations significantly above background. The issue is, how much radioactivity above background? If the Marcellus Shale contains significantly more radioactivity than background, as these comments will show, then what happens to this radioactivity when wells are drilled and natural gas is produced? For horizontal drilling, radium remains in the flowback water and the drilling fluid, particularly if the drilling fluid is recycled. During production, the brine is extremely radioactive, as the DEC DSGEIS has shown. The radium plates out as scale within the production pipes or joints, the separator, the feeder lines to the condensate tanks and the condensate tanks themselves. We focus on radium because radium, similar to calcium, concentrates in bone and can give rise to leukemia. As we discuss below, the regulatory scheme proposed by the DEC is inadequate to manage and regulate these radioactive materials in a safe manner. As we also discuss below, some of the regulatory proposals are commendable and should be adopted.

In addition to radioactive materials, some toxic chemicals, such as arsenic and mercury will also be present during gas production. The DSGEIS does not discuss the hazard quotient and risk factor associated with these chemicals.

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[1] "Preliminary Revised Draft, Supplemental Generic Environmental Impact Statement On The Oil, Gas and Solution Mining Regulatory Program, Well Permit Issuance for Horizontal Drilling And High-Volume Hydraulic Fracturing to Develop the Marcellus Shale and Other Low-Permeability Gas Reservoirs," NYS Dept of Environmental Conservation, July 2011.

Specific Comments

1. Radioactivity in Marcellus Shale

In exploring for gas and oil, the industry identifies natural gas formations by the high radioactivity and high carbon content at the Marcellus Shale horizon. Within the Marcellus Shale formation, the radioactive concentrations are 20 to 25 times background. However, DEC claims that "black shale typically contains trace levels of uranium and gamma ray logs indicate that this is true of the Marcellus shale."[2] Based on gamma ray logs, a study by the USGS and statements in the DSGEIS, we differ strongly with the DEC that the concentrations are "trace levels."

At RWMA, 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.[3] 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 $1/200^{th}$ of the deflection measured between the high and low activity zones in the pits.[4] 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).[5]

In general, the radioactivity throughout the depth of the bedrock appears to be equal to or less than 10 picocuries per gram (pCi/g). 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 Reading, NY well (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. These sections of increased radioactivity represent the Marcellus shale. In each case the thickness (less than 100 feet)

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[2] DSGEIS (2011), p, 4-29.
[3] Smith-Heavenrich S., 2010
[4] Hoppie, B.W. et al, 1994
[5] Donnez, 2007 p.33

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. These radium concentrations are far higher than background radium concentrations in New York State[6], which are 0.85 pCi/g. Attachment 1 is a better reproduction of the GAPI log of the Shiavone well.

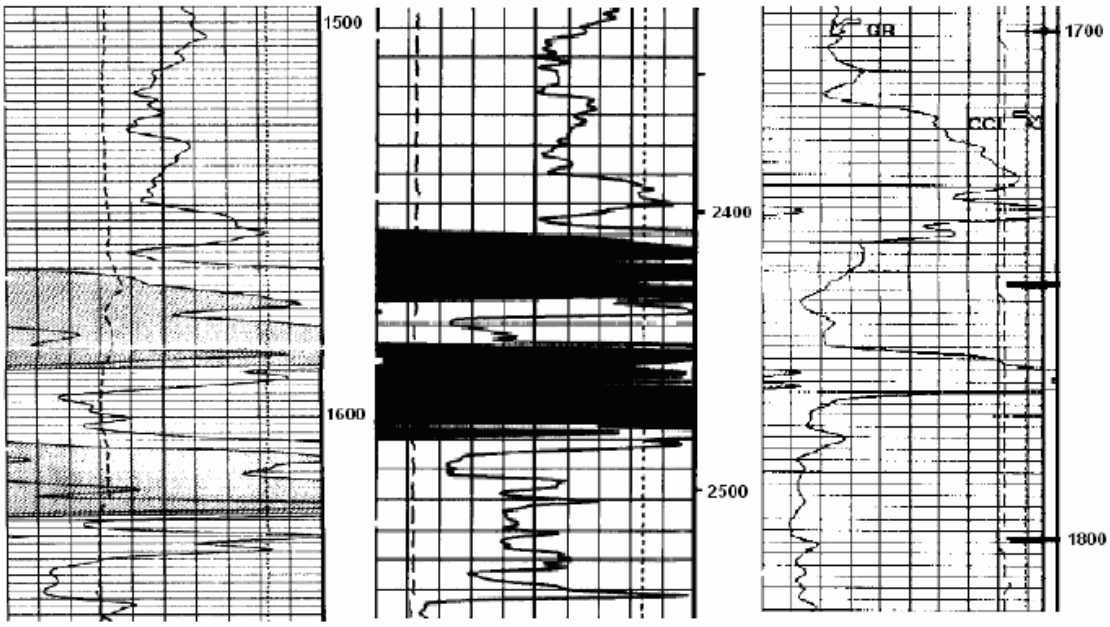

Figure 1. Excerpts from Gamma Ray Logs for (a) Shiavone 2 Well (Reading); (b) WGI11 Well (Dix); (c) Bergstresser Well (Pulteney)

In 1981 the United States Geological Survey (USGS) performed a geochemical study of trace elements and uranium in the Devonian shale of the Appalachian Basin.[7] The Devonian layer refers to sediment formed 350 million years ago from mud in shallow seas. Since the layers do not form in a line parallel to the ground surface, the depth at which Marcellus is found can vary from surface outcroppings to as deep as 7,000 feet or more below the ground surface along the Pennsylvania border in the Delaware River valley,[8] and as deep as 9000 feet in Pennsylvania.[9]

The USGS study analyzed seventeen cores from wells in Pennsylvania, New York, Ohio, West Virginia, Kentucky, Tennessee, and Illinois. The researchers collected a variety of geochemical data to be used for resource assessment and identification of possible environmental problems. Rather than direct gamma spectroscopy employed by

[6] Myrik 1983
[7] Leventhal, 1981
[8] http://www.dec.ny.gov/energy/46288.html
[9] http://geology.com/articles/marcellus-shale.shtml

CoPhysics[10], uranium was measured in each core with a more appropriate and precise method, delayed-neutron analysis. Since CoPhysics is not an ELAP-certified lab, it cannot do this more precise analysis. Nevertheless, DEC or its contractor, Alpha Environmental, quotes these measurements in Appendix 1. The Alpha Environmental report does not even cite the USGS study.

Although the cores varied in thickness and in depth, geologists identified the Marcellus Shale stratum in several cores using data on the organic matter (carbon), sulfur, and uranium content of the samples. Table 1 below summarizes the results from four cores that tapped into the radioactive Marcellus formation. The depths at which the layer was found as well as the uranium measurements are presented.

Table 1. Uranium Content and Depth of Marcellus Shale in Four Cores

Location of the Core	Depth of Sample (feet)	Uranium Content (ppm)
Allegheny Cty, PA	7342 – 7465	8.9 – 67.7
Tomkins Cty, NY	1380 – 1420	25 – 53
Livingston Cty, NY	543 – 576	16.6 – 83.7
Knox Cty, OH	1027 – 1127	32.5 – 41.1

The four cores were taken from different geographical locations, but the characteristics of the identified Marcellus shale layer, specifically the high uranium and carbon content, are consistent. As mentioned earlier, DEC reports uranium content up to 100 ppm. The thickness of the Marcellus shale formation varies between 0 and 250 feet, according to isopach maps.

To compare the uranium content in parts per million (weight) to radioactive concentration in picocuries per gram, we use the correspondence[11]

$$2.97 \text{ ppm} = 1 \text{ pCi/g U-238}$$

Using this relationship, the U-238 ranges up to 28 pCi/g, or 33 times background for radium-226, assuming U-238 and Ra-226 are in secular equilibrium, as it is in MS formation. This is our starting point for the concentrations of Ra-226 in the natural Marcellus Shale formation. The radium itself is found in the pore water of the Marcellus Shale formation, since radium, under the temperature and pressure conditions, is preferentially dissolved in the pore water.

2. Detection of Radium in Marcellus Shale

To detect radium in liquid, DEC must use the appropriate EPA protocols (EPA 903.1). DEC incorrectly uses a Geiger counter to detect radium. Simply passing a Geiger counter over samples will detect Bi-214, a strong gamma emitter, but not Ra-226. Further, citing data from Marcellus Shale in Pennsylvania (DSGEIS 2011, Table 5-3) is

[10] CoPhysics 2010
[11] See discussion in the Health Physics web site, http://www.hps.org/publicinformation/ate/q6747.html.

less than satisfactory. DEC does not cite the source of its data in its DSGEIS, but the data is from an industry-sponsored study by the company CoPhysics.

The CoPhysics report, commissioned by Fortuna, concludes that the rock cuttings are only 2 to 3 times above background radioactivity levels.[12] However, they make several major mistakes in their methodology and should not have been used as a source by DEC.

First, CoPhysics claim the use of EPA 901.1 measurement protocol in their analysis. The EPA 901.1 protocol is a method used for gamma detection in radioactive materials dissolved in water and is not to be used for measurement of radium, unless one makes the additional assumption that radium and bismuth are in secular equilibrium in water. In the underground Marcellus Shale formation, Bi-214 and Ra-226 are in secular equilibrium, but Ra-226 will be dissolved in the interstitial pore water, and Bi-214 will not. To detect radium in water, the sample must be dissolved in acid. Ra-226 must then be chemically separated and detected by measuring emanating radon, according to EPA lab protocol 903.1. CoPhysics is not an Elap-certified lab by New York State and therefore cannot employ EPA lab protocol 903.1.

Second, the CoPhysics study does not measure radium directly and instead measures a surrogate. For the detection of thorium-232, CoPhysics measures actinium-228, a decay product with strong gamma emission, which is acceptable since the two radionuclides are in secular equilibrium and since processing does not alter this equilibrium. However, this is not the case for radium, which is soluble in shale pore water and removed in fluid during the drilling and also production processes. Bi-214 is not nearly as soluble and follows the rock cuttings. That is, use of bismuth-214 as a surrogate for radium-226 in the report is not permissible. The concentration of Ra-226 will depend on the moisture content of the rock cuttings. The moisture content of the rock cuttings measured by CoPhysics is not specified.

Lastly, it is not clear where the measurements were taken and whether any processing took place before the gamma detector readings. The CoPhysics report does not state whether the rock cuttings were taken from a horizontal or from a vertical bore hole. For this, the NEWSNY brought in a professional geologist, Dan Billman to analyze the rock cuttings and support the statement in the CoPhysics report that the rock cuttings were from the MS. Under the temperature and pressure conditions that exist in a deep hole, the drilling fluids will remove and dilute Ra-226 present in shale pore water. If this drilling fluid is recycled, Ra-226 concentrations will increase and eventually theoretically reach the concentrations found in brine, up to 15,000 pCi/L, where no additional materials added to the drilling fluid. DEC has simply accepted the gas industry findings from Pennsylvania, without appropriate QA/QC protocols. It is hard to believe that the DEC radiation division formerly headed by Bill Kelleher and Paul Merges would have accepted industry reports without independent and appropriate DEC measurements and confirmation.

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[12] CoPhysics Corporation, 2010

3. Fate and Transport of Radium

If higher levels of radioactivity are present in the Marcellus shale formation, as shown by gamma logs, USGS measurements, and DEC statements, where does this radioactivity appear in the environment and how will DEC regulate this radioactive waste? Unfortunately, DEC gets its data almost entirely from the oil and gas industry. The industry information is not objective and does not provide guidance for regulations that are protective of the health of workers and the public. The author has experience in dealing with NORM waste in the States of Kentucky, Louisiana, Mississippi and Texas. Much of this information is in court suits, many documents of which are sealed by confidentiality agreements.

Rock cuttings. The Marcellus shale formation is composed of decayed organic matter that has generated natural gas. This shale layer is between other rock formations, like limestone, that have held the gas in place. Uranium and its decay products, such as Ra-226, are present in this organic matter. It is possible that the shale rock itself is no more radioactive than background, but then, what happens to the radioactivity that everyone should agree was originally in the formation? My understanding is the organic material, and particularly the radium that is dissolved in liquid, is brought to the surface in the drilling fluid. The shale is separated from the drilling fluid by use of rock shakers, essentially screens, and is reused. But the rock, really more like sand or dust, which ends up in municipal landfills, may contain up to 20% radioactive liquid. If the original formation, shale plus contaminated pore water, is 25 times background, then the water itself, the drilling fluid plus interstitial pore water, can be much more radioactive. The processing involves separating rock from drilling fluid, in which some of the drilling fluid plus radioactive water in the formation, remains with the shale rock. But it is important to recognize that the drilling fluid is reused, and in the process of being reused, it becomes more radioactive, since the interstitial water, the brine, can be as radioactively concentrated as 15,000 pCi/L. Each time drilling fluid is reused, the radium concentrations increase. This is the process and concentrate step; the radium is technologically enhanced or TENORM. It is also true that there are additions to the drilling fluid. Thus, the wet cuttings that go to municipal landfills will be radioactive, due to the contained drilling fluid. All municipal landfills should have entrance detectors set at twice background. Rock cuttings with higher radioactivity should be returned to the well developer for either dewatering or removal of radioactivity. The radioactivity should be separated and sent to a licensed disposal facility, such as Energy Solutions in Utah. DEC's preferred method, ignoring the problem by relying on the CoPhysics report, will be a serious mistake, since releases of radium from landfills will eventually occur; Ra-226 has a half-life of 1600 years and will be present, essentially forever. Radium concentrates in bone and increases the likelihood of leukemia. By stating that "depending on the moisture content of the cuttings, operators may drain or vacuum free liquids," DEC has essentially washed its hands of the matter; If it is left to the industry to decide, it will choose the least costly approach, which is nothing. The radioactivity in moist rock cuttings should be regulated; dewatering of rock cuttings should be a regulatory requirement.

Flowback water and brine. In comparison to rock cuttings, DEC has a better regulatory system for flowback water and brine. DEC proposes that "before any (drilling) permit is issued, the operator have Department-approved plans in place for disposing of flowback water and production brine," in addition to a tracking system.[13] DEC intends to use the SPDES permit system to control discharges to ground and surface waters. DEC has wisely halted the practice of road spreading, but unfortunately this prohibition is only tentative, "until additional data on NORM content is available and evaluated."[14] Spreading brine, up to 15,000 pCi/L Ra-226, on roadways, essentially exposes the larger public to direct gamma, and in dry conditions, to inhalation of carcinogenic radionuclides that are resuspended. The practice of road spreading should be off-limits. Ra-226 should be removed, packaged and sent to a licensed disposal facility. Commercial methods, employed at uranium mills, for example, are available. In-State industrial treatment plants, regulated under SPDES permits, could be employed, rather than removing Ra-226 at individual drilling sites. This is a major issue; once brine contaminates an aquifer, the aquifer cannot be easily restored to background level.

In addition to radioactive materials, we are concerned with certain toxic materials brought to the surface. Gas formations contain arsenic, mercury and, of course, hydrocarbons. These have the potential to enter groundwater systems, at concentrations that present a cancer risk to residents. Once these carcinogens enter groundwater, they are difficult to remove. In Texas, the risk level due to arsenic has exceeded the EPA cleanup risk standard, 10^{-4}.

Radium scale buildup in gas equipment. During production, radium dissolved in water, is brought to the surface. Scale, radium sulfate, plates out on production pipe surfaces. Scale also appears in water/gas separators, feeder lines and condensate tanks. As DEC states, a high concentration of scale will result in an elevated radiation exposure level at the pipe exterior surface.[15] The NYS Department of Health (DOH) requires a radioactive materials license when exposure levels exceed 50 microR/hr (μR/h).[16] Exposed workers have an increased risk of developing cancer. Workers at, and residents near, pipeyards that clean pipe scale have an additional risk from inhaling radioactive dust. Based on our experience, the DOH regulations are too lax, as we discuss below.

For DEC and DOH to grasp the magnitude of the problem, we provide one example. At one natural gas well in Texas, 368 pipe joints were pulled after 5 years service. Exposure levels exceeded 50 μR/h in 55% of the 30 foot joints (max, 150 μR/h) 38% were < 50 μR/h and 7% were free of NORM. If thousands of gas wells are drilled in New York State, how will DEC and DOH have the resources to regulate the industry? In our experience, oil and gas producing pipes with high external exposure levels have been "donated" to city governments for playgrounds, or to farmers for use in animal corrals. They have been cut up with oxyacetylene torches and welded to fit their use. In

[13] DSGEIS 2011, Executive Summary, p. 21, and p. 5-141.
[14] DSGEIS 2011, p. 5-133.
[15] DSGEIS 2011, p. 6-202.
[16] *Ibid.*

the process, children and farmers have been directly exposed to gamma, and inhaled radium.

We find that direct gamma exposure levels of 50 μR/h are much too high. In order to determine the concentrations of Ra-226 and Ra-228 that correspond to a dose rate of 50 μR/hr, we employed the program MicroShield Version 8.02[17], by Grove Software, Incorporated. MicroShield is a program used to estimate dose rates due to a specific external radiation source.

A linear relationship exists between radiation concentrations and their corresponding external dose rates.

As inputs to MicroShield, we assumed an outer pipe diameter of 4 inches (10.16 cm), a scale thickness of 0.2 cm, and a pipe wall thickness of 0.91 cm, as suggested by the US EPA[18]. We could also have used another standard pipe diameter, 2 7/8 inch. We assumed that each contaminated pipe is 30 feet long, and that radiation measurements had been taken at the center of the pipe, on contact with the outer pipe wall. From MicroShield, for a pipe with external gamma of 50 μR/h, we obtain a Ra-226 concentration in scale of 1,313.5 pCi/g, and a Ra-228 concentration in scale of 437.8 pCi/g that correspond with a dose rate of 50 μR/h. We assumed a 3 to 1 ratio of Ra-226 to Ra-228.

As DEC and DOH are well aware, the EPA cleanup standard for total radium is 5 pCi/g surface radiation and 15 pCi/g 15 cm or more below the surface. Pipes, with external radiation 50 μR/h greatly exceed this standard. If these pipes, with NORM <50 μR/h are released for general use, they will be cut up and welded and the scale will be accessible.

While DEC and DOH intend to regulate joints with external radiation > 50 μR/h, in practical terms, what do the State agencies envisage will become of these radioactive pipes (and separators, feed lines and condensate tanks)? Once the oil and gas industry begins production in New York State, this is a major unresolved problem down the road. This is essentially like building a house with no bathrooms.

[17] Grove Software Incorporated, 2008
[18] US EPA, 1993b

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Attachment 1. Gamma-ray log of a well in Shiavone, NY