Radon in Natural Gas from Marcellus Shale
By Marvin Resnikoff, Radioactive Waste Management Associates
Executive Summary[*]
January 10, 2012

A significant public health hazard associated with drilling for natural gas in the Marcellus Shale formation must be seriously investigated by the New York State Department of Environmental Conservation (DEC). This hazard is from radioactive radon gas and the potential for large numbers of lung cancer among natural gas customers. This issue, which has been ignored in the DEC's Draft Supplemental Environmental Impact Statement, must be addressed in a revised Impact Statement and before DEC issues any drilling permits.

Unlike present sources for natural gas, located in Texas and Louisiana, the Marcellus Shale is considerably closer to New York consumers. In addition, the radioactive levels at the wellheads in New York are higher than the national average for natural gas wells throughout the US.

In this paper Radioactive Waste Management Associates calculates the wellhead concentrations of radon in natural gas from Marcellus Shale, the time to transit to consumers, particularly New York City residents, and the potential health effects of releasing radon, especially in the smaller living quarters found in urban areas.

It is well known that radon (radon-222) is present in natural gas.[1] Published reports by R H Johnson of the US Environmental Protection Agency[2] and C V Gogolak of the US Department of Energy[3] also address this issue. Radon is present in natural gas from Marcellus Shale at much higher concentrations than natural gas from wells in Louisiana and Texas.

Since radon is a decay product of radium-226, to calculate radon levels it is necessary to know the concentrations of radium-226, Based on a USGS study[4] and gamma ray logs (also known as GAPI logs) that we have examined, the radium concentrations in the

---

[*] Great appreciation for the excellent assistance of Minard Hamilton, RWMA Associate

[1] Agency for Toxic Substances and Disease Registry**,** *Toxicological Profile for Ionizing Radiation and* U.S. National Research Council, *Health, Risks of Radon and Other Internally Deposited Alpha-Emitters: BEIR IV* (National Academy Press, 1988)

[2] Johnson,R.H. *et al,* "Assessment of Potential Radiological Health Effects from Radon in Natural Gas," Environmental Protection Agency, EPA-520-73-004, November 1973.

[3] Gogolak, C.V., "Review of 222 Rn in Natural Gas Produced from Unconventional Sources," Department of Energy, DOE/EML-385, November 1980

[4] J.S. Leventhal, J.G. Crock, and M.J. Malcolm, *Geochemistry of trace elements in Devonian shales of the Appalachian Basin*, U.S. Geological Survey Open File Report 81-778, 1981

Marcellus Shale is 8 to 32 times background. This compares to an average radium-226 in surface soil in New York State of 0.81 picoCuries per gram (pCi/g)[5]

Using this range of radium concentrations and a simple Fortran program that simulates the production of radon in the well bore, and transit to the wellhead, we calculate a range of radon concentrations at the wellhead between 36.9 picoCuries per liter (pCi/L) to 2576 pCi/L.

These wellhead concentrations in Marcellus shale are up to 70 times the average in natural gas wells throughout the U.S. The average was calculated by R.H.Johnson of the US Environmental Protection Agency in 1973 (pre-fracking) to be 37 pCi/L[6] to a maximum of 1450 pCi/L.

In addition, the distance to New York State apartments and homes from the Marcellus formation is 400 miles and sometimes less. This contrasts with the distance from the Gulf Coast and other formations which is 1800 miles. At 10 mph movement in the pipeline, natural gas containing the radioactive gas, radon, which has a half-life of 3.8 days, will have three times the radon concentrations than natural gas originating at the Gulf Coast., everything else being equal, which it is not..

Being an inert gas, radon will not be destroyed when natural gas is burned in a kitchen stove.

We have examined published dilution factors and factored in numbers for average urban apartments where the dilution factor and the number of air exchanges per hour are less than those of non-urban dwellings. This analysis implies that the radon concentrations in New York City and urban apartments is greater than the national average.

We assume a figure of 11.9 million residents affected. This figure is calculated in the following manner: Based on US Department of Energy figures our calculations assume 4.4 million gas stoves in New York State. This figure is multiplied by 2.69 persons per household to determine the number of residents affected: this number equals 11.9 million.

We calculate the number of excess lung cancer deaths for New York State. Our results: the potential number of fatal lung cancer deaths due to radon in natural gas from the Marcellus shale range from 1,182 to 30,448.

This is an additional number of lung cancer deaths due to radon from Marcellus Shale over deaths from natural radon already impacting New York State homes and their residents.

---

[5] Myrick, T. E., et al. 1981. *State Background Radiation Levels: Results of Measurements Taken During 1975-1979*, ORNL/TM-7343, Oak Ridge, Tenn..
[6] Johnson, Op cit.

The Draft Supplemental Environmental Impact Statement produced by the New York State Department of Environmental Conservation needs to be revised to take into account this public health and environmental hazard. In the entire 1400 page statement there is only one sentence containing the word "radon" and no consideration of this significant public health hazard.

Further, NYDEC needs to independently calculate and measure radon at the wellhead from the Marcellus Shale formation in presently operating wells before issuing drilling permits in New York State. The present RDSGEIS should be withdrawn.

Introduction

It has been known for over 40 years that radon, a radioactive gas, is present in natural gas. Reports by R.H. Johnson[7] and C.V. Gogolak[8] calculate the health effects due to burning natural gas in kitchen stoves and space heaters. In an US Environmental Protection Agency report, Raymond Johnson calculates the number of lung cancer deaths due to inhalation of radon in homes throughout the U.S. as 95 due to radon concentrations in the pipeline of 37 pCi/L.

Radon is an inert radioactive gas. This means it does not react chemically with other elements. Whatever radon is in the pipeline and is delivered to homes is released to the home environment from kitchen stoves and space heaters. The radon is not oxidized and is not made benign or non-radioactive in the burning process.

Since radon is an inert gas, when it is inhaled, the gas is mostly exhaled. Except radon will decay to other radioactive decay products, such as polonium, bismuth and lead. These are solid fine radioactive particles that can be inhaled and subsequently reside in the lung.

Most calculations assume this radon gas mixes uniformly within the living space and the concentrations of radon and its decay products are thereby diluted. Thus, once radon enters the home, the average concentrations depend on the home volume, and also on the number of air interchanges. Previous calculations by Johnson and Gogolak make specific assumptions about the average volume of a home and the number of air interchanges per hour. Their assumptions are not necessarily appropriate to apartments in major urban areas, such as New York City.

---

[7] Johnson,R.H. *et al,* "Assessment of Potential Radiological Health Effects from Radon in Natural Gas," Environmental Protection Agency, EPA-520-73-004, November 1973.

[8] Gogolak, C.V., "Review of 222 Rn in Natural Gas Produced from Unconventional Sources," Department of Energy, DOE/EML-385, November 1980

To estimate the health effects of radon in natural gas three factors must be addressed. One, the concentration of radon at the natural gas wellhead. Two, transport from the wellhead to the household. And, three, the dilution of incoming radon in the home.

The first step is to calculate the initial source term, the concentration of radon at the wellhead. The Marcellus shale formation is more radioactive than other sources of natural gas in the United States. Based on a simple model of a hydraulic fractured well, in the next section, we calculate the radon concentrations at the wellhead.

Radon at the wellhead is then transported through natural gas pipelines to distribution centers and to homes for use in cooking and heating. During the time of transport, radon decays. This radioactive gas has a half-life of 3.8 days.

Most of the natural gas currently consumed in New York State arrives from the Gulf Coast, a distance of 1800 miles. The closer to the point of use, the shorter the transport time. And the Marcellus shale is much closer, less than 400 miles to New York City. With a travel time of 10 mph in the pipeline, only about 25% of the initial radon from the Gulf Coast remains to enter homes. Since gas from the Marcellus shale travels a much shorter distance, a greater fraction remains. We estimate closer to 76% of the initial concentration of radon at Marcellus Shale wellheads will arrive at New York State residences.

Once radon enters the home through cooking, it is diluted within the home volume and also by air exchanges with the outside air. Radioactivity due to radon decay products is inhaled and resides in the lung, yielding a radiation dose to the lung. Using the latest dose conversion factors, based on ICRP-60, which convert the inhaled radioactivity to a radiation dose, we can calculate the radiation dose to an individual over a 30-year period. From the radiation dose to the population, we can determine the number of lung cancer deaths to New York State residents. As will be seen, the total number of lung cancers is significant, far more than estimated by Johnson in 1973.

None of this analysis appears in the Generic Environmental Impact Statement prepared by the New York Department of Environmental Conservation. In the entire 1400 page Environmental Impact Statement, one sentence appears. "Radon gas, which under most circumstances is the main human health concern from NORM, is produced by the decay of radium-226, which occurs in the uranium-238 decay chain."[9] (NORM refers to Naturally Occurring Radioactive Material.)

This one sentence is the full extent of the Department of Environmental Conservation's analysis of the environmental impact of radon.

[9] Rdsgeis, p. 6-206.

Radon at the wellhead

In exploring for gas and oil in shale, 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, the New York Department of Environmental Conservation (DEC) claims that "black shale typically contains trace levels of uranium and gamma ray logs indicate that this is true of the Marcellus shale."[10] Based on gamma ray logs, a study by the United States Geological Survey and statements in the Draft Supplemental Environmental Impact Statement, we differ strongly with the DEC assessment that the concentrations are "trace levels."

At RWMA, we analyzed the gamma-ray well logs from wells in three towns in New York State, Reading, Dix and Pulteney. The Pulteney well (also referred to as the Bergstresser well) would be used as a disposal well for radioactive waste water from other exploratory wells in New York State.[11] Gamma radioactivity within each well was sampled with a sensitive Geiger counter and the measurements were plotted on a graph as what are known 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. Located at this facility are three pits, each with a different mixture of thorium, uranium, and potassium. The actual GAPI unit is arbitrary. It is defined as 1/200th of the deflection measured between the high and low activity zones in the pits.[12] 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).[13]

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 radioactive 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

[10] Rdsgeis (2011), p, 4-29.
[11] Smith-Heavenrich S., 2010
[12] Hoppie, B.W. et al, 1994
[13] Donnez, 2007 p.33

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.

The measurements beyond the 0-200 GAPI range are found at the following depths: 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 the Bergstresser well in Pulteney, NY 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) 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[14], which are 0.85 pCi/g.

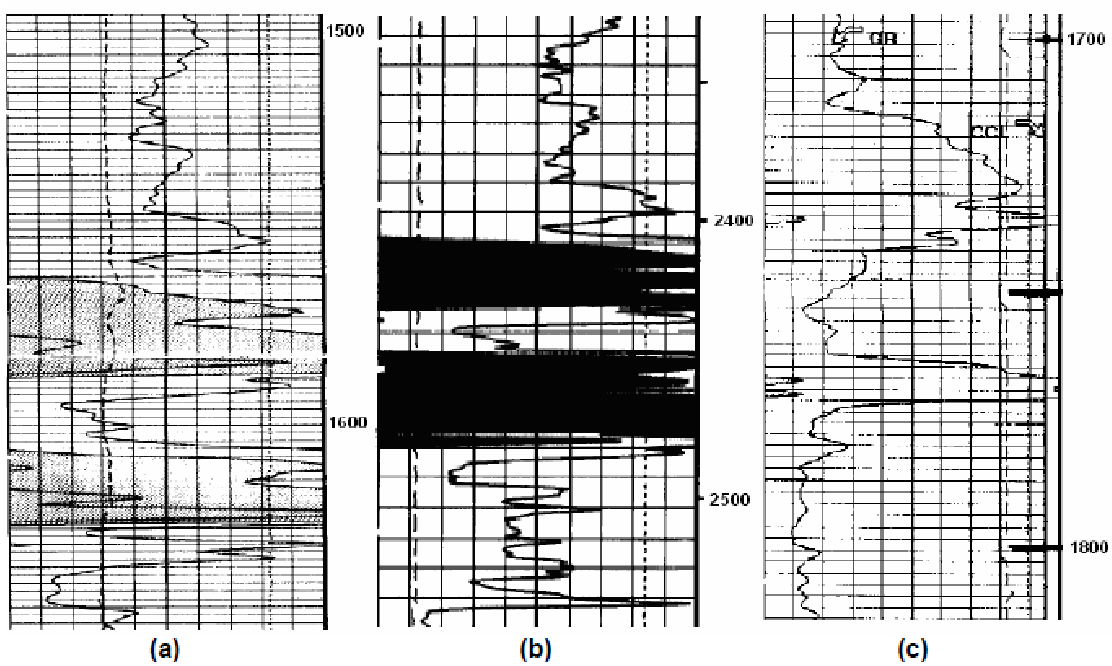

Figure 1. Excerpts from Gamma Ray Logs for (a) Shiavone 2 Well (Reading); (b) WGI11 Well (Dix); (c) Bergstresser Well (Pulteney)

[14] Myrik 1983

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.[15] A brief review of this analysis is necessary to evaluate and verify the data provided by the GAPI logs for the three locations in New York State.

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,[16] and as deep as 9000 feet in Pennsylvania.[17]

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. It is important to note the method of analyzing cores.

Rather than the direct gamma spectroscopy employed by CoPhysics[18], in the USGS study uranium was measured in each core with a more appropriate and precise method. This is called delayed-neutron analysis. In contrast, the oil and gas industry hired, CoPhysics, a non-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. Since USGS is a reputable and objective government agency, DEC should request an explanation why this reference was omitted.

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.

[15] Leventhal, 1981
[16] http://www.dec.ny.gov/energy/46288.html
[17] http://geology.com/articles/marcellus-shale.shtml
[18] CoPhysics 2010

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[19]

2.97 ppm = 1 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 Marcellus Shale formation. That is, the USGS measurements and the GAPI logs are consistent. The range of 6.6 to 30 pCi/g is our starting point for the concentrations of Ra-226 in the natural Marcellus Shale formation, to determine radon concentrations at the wellhead.

Numerical simulation shows the high concentrations of radon that will be found at the wellhead for Marcellus Shale gas, based on a variety of realistic assumptions. These assumptions include the rate at which radon is generated by radium-226 which, in turn, depends on the radium concentration in the shale. Otherwise there are no major uncertainties about the rate at which radon is produced. The radon's ability to escape from the rock matrix and be entrained by the natural gas flowing inward toward the well bore is less certain, but it can be estimated reasonably well. Our assumptions in the model we employed are listed in Table 2.

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

Table 2. Input Parameters For Model Simulation		
Parameter	***Value***	***Unit***
Depth of Horizontal Bore	5000	feet
Gas Temperature	105	° F
Well Bore r(min)	0.5	feet
Max gas-yielding radius r(max)	200	feet
Length of horizontal well bore	4000	feet
Gas Production Rate	10000	MCFD
Standard temperature for gas	59	° F
Standard pressure for gas	1	atm
Flowing pressures at r(min)	1500	psi
Flowing pressures at r(max)	2000	psi
Porosities at r(min)	10 - 50	%
Porosities at r(max)	4	%
Radium Activity	6.6 - 30	pCi/g
Rock Density	2.55	g/cm^3
Radon Emanation Factor	10 - 30	%

Numerical simulation thus shows – for typical flow rates, well dimensions, and other reasonable assumptions – that the concentration of radon in natural gas at the wellhead (expressed in pCi/liter) ranges between 36.9 to 2576 pCi/L. The two high values in Table 3, 1,858.6 pCi/L and 2576 pCi/L, are based on a radium concentration of 30 pCi/g. For the radon concentration 858.6 pCi/L, we assume a porosity of 30% and an emanation rate of 30%. The highest value assumes a porosity of 10% and an emanation rate of 30%.

All these are reasonable values and indicate the need for independent testing of production wells in the Marcellus shale formation. These radon concentrations in gas at the wellhead are far higher than the 40 pCi/liter wellhead concentration estimated by ATSDR or the 37 pCi/liter concentration that Raymond Johnson *et al.* considered average in pre-fracking days, though Johnson did find a maximum of 1450 pCi/L.

Transport from Wellhead to Household

Marcellus Shale gas and the accompanying radioactive gas, radon, is transported from the natural gas wellheads in Pennsylvania and New York to apartments and homes via pipelines. It is known that natural gas moves through pipelines at a speed of 10 to 12 miles per hour.

Because of the longer transit time from the Gulf Coast to New York City there is a lower concentration of radon than is the case with Marcellus Shale gas. The natural gas piped in from the Gulf Coast allows a radon decay up to two half-lives. This is equal to a reduction by 75% of the wellhead radon concentration.

The distance from Marcellus shale to New York City is much shorter; we are estimating this distance at the conservative figure of 400 miles. As shown in Table 3, the fraction of radon (Rn-222) remaining after transit is 76%.

Thus, over and above the effects of increased well concentrations of radon, the shorter transit time for Marcellus Shale gas will at least triple the risk compared to the risk that Raymond Johnson *et al* calculated for New York residents.

Radon Dilution in the Home and Potential Health Impacts

Given the radon concentration in natural gas arriving at the kitchen stove, the next issue is the dilution of radon within the apartment or home. This will allow us to determine the radon concentration within the home and the health impact to residents who use natural gas.

Johnson bases his dilution factor of 7111 on two values. First, he assumes the volume of a home, which he estimates at 8000 cubic feet (or 226.6 cubic meters). Secondly, he , figures the expected number of air exchanges as one per hour. An air exchange is the amount of time to replace the entire air volume of a dwelling.

We base our calculations on data from the US Environmental Protection Agency. On the basis of the EPA Factors Handbook[20], we take the volume of a dwelling as 183 cubic meters, rather than 226.6 cubic meters used by Johnson. This smaller volume is more representative of the size of an apartment in New York City.

For the number of air exchanges per hour, rather than one per hour, we take 0.71 air exchanges per hour. This is also more representative of New York City apartments[21]. With these changes, the dilution factor of 7111 is substantially modified. The factor of 7111 is multiplied by 0.57 and becomes 4053. This increases the radon concentration within a dwelling, as compared to Johnson's calculations.

To obtain the radon concentration within the home, we divide the radon concentration entering the home via a kitchen stove by the dilution factor of 4053, As seen in Table 3, the indoor concentrations range between 0.0187 pCi/L to 0.482 pCi/L.

Assuming a person resides in the home 70% of the time, we can determine the risk to a resident of developing lung cancer. The risk is based on a US Environmental Protection Agency analysis[22]. As seen in Table 3, the risk of developing cancer in a lifetime ranges from 1 in 10,000 to 1 in 391, an extremely high number. One then multiplies this risk by the number of persons who are potentially at risk.

---

[20] Environmental Protection Agency, Exposure Factors Handbook, EPA/600/P-95/002Fa, August 1997.
[21] *Ibid*, p. 26-
[22] EPA, "EPA Assessment of Risks from Radon in Homes," EPA-402-R-03-003 (June 2003).

The number of persons potentially at risk in New York State can be roughly determined by the number of kitchen stoves fueled by natural gas in New York State multiplied by the number of persons in a household. According to the US Department of Energy[23], the number of households with natural gas fueled stoves in New York State is 4.4 million.

From the 2010 Census, the average number of persons per household in New York State is 2.69. Thus 11.9 million persons in New York State are potentially at risk. Multiplying the lifetime risk of inhaling radon gas by the number of persons in New York State at risk, we finally determine the potential number of lung cancers as ranging between 1183 to 30,484, out of a population at risk of 11.9 million. This is a major environmental impact and a public health impact that the New York Department of Environmental Conservation must carefully assess.

[23] DOE, Energy Information Administration, Table HC1.8

NY Baseline	Table 3. Approximate NY Range for Marcellus gas				
4.2	100	151	858.6	2576	pCi/l of radon in gas at wellhead
1500	400	500	400	400	miles from wellhead to customer
11	11	11	11	11	mr/hr typical speed of gas in pipeline
5.68	1.52	1.89	1.52	1.52	days transit time in pipeline
0.3576	0.76	0.7089	0.758528828	0.758528828	fraction of Rn-222 remaining after transit time
1.50192	75.85	107.0439	651.27	1953.97	pCi/l in natural gas delivered to customer
7111	4053	7111	4053	4053	Dilution factor
0.000211211	0.019	0.015053284	0.161	0.482	pCi/l lifetime exposure level in living space
1.23E-06	9.94E-05	8.75E-05	8.54E-04	2.56E-03	Lifetime risk (excess deaths per capita)
21	1183	1465	10160	30484	Excess deaths per 11.9 million residents
<1{.27)	17	20	145	435	Excess deaths per year per 11.9 million residents
Johnson, p. 14 for NYC distribution lines*	Numerical Similation Low-End values	Gogolak pp.5-26 Devonian shales*	Numerical Simulation High-End Values	Numerical Simulation High-End Values	**Basis for Radon Concentration**
*based on 16.76 million residents			porosity 10%, emanation 10%, radium 30 pCi/g	porosity 10%, emanation 30 %, radium 30 pCi/g	

Mitigation of Impacts

Because radon is an inert gas radon cannot be chemically removed from the natural gas stream. But since radon has a 3.8 day half-life, the radioactive gas potentially could be stored for a sufficient period of time to allow the radon to decay to safe levels. In order to adequately protect residents of New York State, the material could be stored at wellhead locations for several months. If the gas was stored for two months, there would be a significant diminution of the hazard. Over this time period, the hazardous radioactive gas, radon, will decay by a factor 100,000.

From Gogolak, the estimated cost is on the order of $10 billion to develop sufficient pressurized storage in tanks. Some lag storage will be required in any case, since use of natural gas will not be uniform. The estimated costs for mitigating the environmental impact of radon is beyond the scope of this report.

Conclusion

The potential environmental and public health impact of radon in natural gas from the Marcellus Shale formation is enormous. This paper has calculated the number of lung cancers in New York State as ranging between 1,182 and 30,448. This calculation is based on reasonable assumptions for a gas well in the Marcellus Shale, including the concentration of radon at the wellheads, the transit time between wellheads and homes, the dilution expected in a typical household, and reasonable risk factors drawn from studies by the US Environmental Protection Agency.

In its 1400-page Draft Supplemental Environmental Impact Statement, the New York Department of Environmental Conservation has devoted one sentence to the issue of radon.. The sentence states "Radon gas, which under most circumstances is the main health concern from NORM [Normally Occurring Radioactive Materials], is produced by the decay of radium-226, which occurs in the uranium-238 decay chain."

Clearly, this one sentence does not constitute an adequate or thorough analysis of the potentially serious risks associated with the impacts of transporting radon-contaminated natural gas into the apartments and homes of New York State residents. The Draft Supplemental Environmental Impact Statement is obviously insufficient as written. It has completely ignored the problems associated with radon and the Marcellus Shale formation.

The Draft Supplemental Environmental Impact Statement must be withdrawn and it must be substantially revised so as to discuss the important environmental impacts and public health concerns of the radon problem. Until the radon risk has been appropriately studied and assessed, the Department of Environmental Conservation should not award any drilling permits in the Marcellus Shale formation in New York State. As a first and crucial step the DEC must make certain that radon at the wellheads from the Marcellus Shale formation in presently operating wells is measured. Tests must be conducted by independent experts and agencies. Such tests also must be scientifically rigorous in their design and be conducted with full transparency to assure public confidence in the validity of the testing.

There are strong economic interests supporting the development of Marcellus Shale gas. The potential for significant generation of jobs through the development of this resource is a real and important factor. Doubtless these economic factors will weigh on policy makers in Albany and potentially influence decisions regarding whether the Department of Environmental Conservation will move forward to adequately address the concerns raised in this paper.

The long-term environmental risks and public health concerns of radon in Marcellus Shale natural gas formations are far too serious to be ignored. The potential impacts of radon must not be swept under the rug. Nor should these impacts be sacrificed to short-term, economic policies or to unrealistic and/or inaccurate assessments of the benefits of natural gas development in New York State.

The long-term safety and health of New Yorkers is at stake, as is the health of New York State's extraordinary natural environment.