Radioactivity:

A Description of its Nature, Dangers, Presence in the Marcellus Shale and Recommendations by The Town Of Dryden to The New York State Department of Environmental Conservation for Handling and Disposal of such Radioactive Materials.

Radioactivity is the term used for the subatomic particles emitted by unstable elements as they decay into other elements. The intensity of radiation depends on how rapidly the element in question decays, and the energy of the subatomic particles produced.

Radioactivity is dangerous even at low levels because the emitted particles can cause damaging mutations in the DNA of cells. If the damage occurs to genes regulating cell division, the result can be uncontrolled cell growth, producing cancer. Radioactivity cannot be seen, felt or otherwise detected by humans without special instruments, but can nonetheless be extremely damaging. There is no safe level of radioactivity, as damage is proportional to dose, and exposure is cumulative. Humans are constantly exposed to low-level radiation in the environment, and any further exposure simply adds to the overall burden. *There is no truly safe level of exposure*: permitted levels of exposure are simply based on cost-benefit analyses.

It is important to realize that radioactive wastes cannot be decontaminated; they are radioactive essentially forever, and will expose anyone near them or who breathes in the radioactive dust or gas. The only “treatment” is to remove the solids (if they can be captured) and transport them, by road, to a radioactive materials holding site. The only treatment for radioactive gas is ventilation. The continuous release of radioactivity from solids, liquids, or gas means continuous exposure.

Radium and Radon

The Marcellus shale is known to contain radium, which is a product of the decay of uranium. Radium (^{226}Ra) is extremely radioactive, being over one million times more radioactive than the same amount of uranium. It decays in seven stages, producing three kinds of radiation: alpha particles, beta particles, and gamma rays, as it decays to successive products, which are themselves radioactive elements. The first product is the element radon, which is a dangerously-radioactive heavy gas, and the later products are radioactive solids. Radium loses about 1% of its radioactivity in 25 years, being transformed into a series of elements, each with an atomic weight a little lower than its predecessor, with lead being the final product of disintegration.

^{226}Ra radiation is caused by the emission of alpha particles. Alpha particles travel only a very short distance, and quickly lose their energy within a short distance of their source. However this results in all their energy being deposited in a relatively small volume of material, which increases the chance of cellular damage in cases of internal body contamination. Alpha radiation is more effective at causing cancer or cell-death than the equivalent radiation exposure from other forms of radiation.

Radium is, chemically, an alkaline earth metal, as is calcium. Because radium is chemically similar to calcium, it has the potential to cause great harm by replacing calcium in bones. This is because radium is treated as calcium by the body, and deposited in the bones, where the radioactivity degrades marrow and can mutate bone cells. Inhalation, ingestion, or body exposure to radium can cause cancer and other disorders.

Radon is a highly radioactive, colorless, odorless, tasteless “noble” (or chemically un-reactive) gas, occurring naturally as the decay product of radium. Radon is responsible for the majority of the public’s exposure to ionizing radiation. It is often the single largest contributor to an individual's background radiation dose, and is the most variable from location to location. Radon gas from natural sources can accumulate in buildings, especially in confined areas such as attics, and basements. It can also be found in some spring waters.

Epidemiological evidence shows a clear link between breathing high concentrations of radon and the incidence of lung cancer. Thus radon is considered a significant contaminant that affects indoor air quality. According to the EPA, radon is estimated to cause 21,000 deaths per year in the US; radon is the second most frequent cause of lung cancer, after cigarette smoking.

Radon emanates naturally from the ground, particularly in regions with soils containing granite or shale, which have a relatively high concentration of uranium. It usually migrates freely through faults and fragmented soils, and may accumulate in caves or water. Gas from a gas well often contains radon. The radon decays to form solid radioactive elements, which form coatings on the inside of pipework, so that used pipework is frequently radioactive.

In the open air, radon concentration ranges from 27 to 2,700 pCi per cubic yard of air (one picoCurie [pCi] is a unit of radiation representing 2.2 atomic disintegrations per minute). Typical domestic exposure to radon in homes is approximately 2,700 pCi per cubic yard of air; in poorly-aerated houses over radioactive rocks its concentration can climb to 27,000 pCi per cubic yard. The EPA recommends that homes should be fixed if an occupant's long-term exposure will average 4,000 pCi per cubic yard or more, the equivalent to roughly 200 chest x-rays per year. The limits do not correspond to a known threshold of biological effect, but are determined solely by a cost-efficiency analysis.

Radiation Exposure Measurement

Radiation exposure depends upon the amount of radioactivity, the nature of the radiation, the proximity of the exposed tissue, and the duration of exposure. There is no fixed conversion from radiation measured in pCi, it depending on all the above factors.
Units: a RAD (Radiation Absorbed Dose) is a measure of the absorbed dose of energy and one REM is the damage produced by 1 RAD in body tissue, which varies with the radiation type, and has a factor of x20 per RAD for the alpha radiation given off by ^{226}Ra. ^{226}Ra is most dangerous if ingested in drinking water, as the radiation accumulates in the body.

Dosage Limits
The Nuclear Regulatory Commission limits dosage to less than 100mrem per year,.
The New York State regulations state: “Discharge of radioactive material to the environment... is not permitted for… naturally-occurring… radioactive material… that presents a realistic potential for exposures to the public in excess of the limits for doses to the public in Part 380”
380-5.1 Dose limits for individual members of the public states: “The total effective dose equivalent to individual members of the public [shall] not exceed 0.1 rem [= 100 mrem] in a year”

However it should be noted that all radiation is potentially dangerous, and these amounts are in addition to any natural radiation in the environment to which an individual is exposed. The International Atomic Energy Authority has recommended 1-10 mrem per year, and the Conference of Radiation Control Program Directors recommends a range of 4-5 mrem per year as “more appropriate in light of risk estimates”

Intake of ^{226}Ra results leads to a steadily accumulating dose: for example a daily ingestion of 10 pCi ^{226}Ra would lead to an annual dose of 4.4 mrem by the end of 10 years. While this is negligible, proportionally more radioactivity would lead to greater exposures so that if the daily ingestion was 1000 pCi, the annual exposure at 10 years would be 440 mrem, well in excess of even the most lax regulations.

[Natural radiation exposure is approximately 50 mrem/year from cosmic radiation, and 200 mrem from radon, depending on location. A chest x ray exposes to about 6 mrem. Radiation effects are cumulative.]

Radioactivity in the Marcellus Shale

In the gas industry, radioactive materials known as “Naturally Occurring Radioactive Materials” or NORM, can be brought to the surface through gas wells. This can happen when fluids that are present in the radioactive formation are pumped out of the well or when radon is present in the natural gas. It must be emphasized that such radioactive materials are not *normal* just because they are naturally occurring at 3,000 feet below the surface; on the surface they are not part of the normal environment and should be treated as hazardous. Because the radioactive materials become concentrated on gas-field equipment, the highest risk of exposure to oil and gas NORM is to workers who cut and ream oilfield pipe, remove solids from tanks and pits, and refurbish gas-processing equipment.

The Marcellus shale is considered to be "highly radioactive." In Onondaga County, NY, where the Marcellus shale is close to the surface, all of the homes underlain by Marcellus shale had indoor air levels of radon above EPA's "action level", with the average concentration being more than twice that level. The Pennsylvania Bureau of Oil and Gas Management (BOGM) and Bureau of Radiation Protection found that a concentration of radon in a gas sample from the Marcellus shale of Pennsylvania was 1,000 times the above level. 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.

In the DEC dSGEIS, radioactivity receives detailed attention only in section *5.2.4.2,* where radioactivity measurements are reported in Table 5-2 for various rock core samples, and in section 6.8. The radioactivity for the rock samples is claimed to be background, but calculations show that it is well above background (see footnote). It also reports that the EPA measured values of radioactivity for flowback water of 9,000 picocuries per liter (pCi/l), or 9,000 times the natural radiation in normal well water (see Eisenbud & Gesell), and >100,000 picocuries per gram (pCi/g) for pipe and tank scale, or about 1,000 times the radiation level given off by normal concrete (see *Radioactivity in Nature*). Given that samples measured were only 1 gram (1/28 of an ounce in size) or 1 liter (close to 1 quart) the conclusion can be made that the radiation from tons of removed shale or thousands of gallons of water would be proportionally higher, and thus significantly radioactive. A major concern is the radioactivity of recovered gas, but there is no mention of radon in the dSGEIS beyond noting that it is a product of radium decay. Given that radon is of major concern, this is a major deficiency of the dSGEIS.

As the Marcellus shale is developed it will be important to understand the radioactivity of the various waste streams that are produced (e.g., returning fluid (flowback), gas, pit/tank sludge, and drill cuttings). During drilling there may be a large volume of radioactive shale rock removed in the drill cuttings, especially from horizontally drilled wells. It is therefore imperative that drilling wastes not be disposed of, by either on-site burial or landspreading, 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. Measures must also be taken to ensure that the radioactive gas does not leak into the water supply from wellheads, through generated fractures in the overlying rock, or from well casings.

"The findings [of high-level radioactivity in the Marcellus shale] have several implications: The energy industry [must] face stiffer regulations … Companies [will] need to license their waste handlers and test their workers for radioactive exposure, and possibly ship waste across the country [for disposal]. And the state [will] have to sort out how its laws for radioactive waste might apply to drilling and how the waste could impact water supplies and the environment."(Lustgarten).

The Town of Dryden Recommends to the DEC:

1) That, other than small analytical quantities, no use fluids for injection into the Marcellus shale be permitted until there is a thorough analysis of the levels of radioactivity in both the returned fluids and the gas contained therein in every well, and all potential withdrawals of liquid or gas be subject to the rules of the EPA, and that surveys be conducted monthly thereafter.

Given that, under New York State regulations, discharge of radioactive material to the environment is not permitted for naturally-occurring radioactive material that presents a realistic potential for exposures to the public, we request that, if such levels of radioactivity are detected:

2) That all radioactivity that is elevated to the surface but that, regardless of its source, is not normally present on the surface at that location, be treated as *non-natural* for the purpose of state regulations.

3) All such radioactive fluids and the solids therein are not permitted to be disposed of on or in the locality of the site and must be transported to approved and licensed radioactive-waste handling facilities.

4) All precautions be taken to prevent contamination of ground water supplies with any form of radioactive material from any source, with heavy penalties being imposed for any violation of this rule.

5) That all workers dealing with any solid or fluid with radioactivity above the stated limits be trained and licensed to handle radioactive materials.

6) Given that radioactive deposits can accumulate on the inside of pipes and all equipment involved in gas handling, that all such pipes and equipment be monitored for radioactivity and if found to have a level exceeding the above limits that they must not be left on or in the vicinity of the drilling site but must be transported to an approved and licensed radioactive waste handling facility when no longer in use.

7) Given that radon, from the actual well, the gas, or potential fractures in the rock, in homes and other buildings is of major concern, that all homes and buildings within one mile of the drill site are surveyed for radon prior to drilling, and annually thereafter, at the expense of the gas drilling companies, and that, should the level of radon exceed the EPA action level following drilling, the gas company shall either remedy the problem (e.g., by sealing the basement) or purchase the home and surrounding land at the current market value, or the market value prior to drilling, whichever is the greater.

8) Further we recommend to the New York State Department of Environmental Conservation that the New York State limits for the exposure to the public resulting from industrial uses be reduced from 100 to 10 mrem per year in light of the limits set forth by the International Atomic Energy Authority.

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