POTENTIAL RADON RELEASE DURING FRACKING IN COLORADO

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Abstract

Hydraulic fracturing or 'fracking' has become the industry standard for oil and gas production in the United States. The process entails fracturing large sections of rock with high pressure to release oil and gas reserves and to produce conduits for these fluids to flow more easily to the surface. Along with the intended natural gas, water, or any other fluids or other substances that might be trapped with the gas in the tight formation shales and sandstones that are fracked, come to the surface. There is some evidence that radium-226, radon-222 and other toxic substances have been detected at well heads of fracking operations (McMahon, 2013 and Tait et al., 2013). The foothills and plains along the Front Range in Colorado have become an active area for gas and oil production. Most of this activity takes place in the upper Cretaceous limestone/shale Niobrara formation and the underlying Codell sandstone that generally lie between 2,000 and 3,000 meters below the surface. The fracked rock releases radon that was trapped by the tight shale formation which then is able to flow along the lateral sections of the fracked zone and be pumped up the well bore to the surface. Radon is then released to the atmosphere at the fracking site in levels which may be of some health concern to nearby workers or residents. Actual radon-222 measurements made about 200 feet (60 m) from one well pad (with five well heads) prior to, during, and after fracking showed levels around 3 pCi/L, or 111 Bq/m^3. A second test series at several well three-phase separation/storage facilities and a recently completed well pad, also in northeast Colorado, indicated outdoor radon levels around 4.5 pCi/L, or 166.5 Bq/m^3. We believe additional monitoring needs to be done to better characterize the radon levels released during the fracking process and at the many separation/storage facilities in the rather large geographical area.

Introduction

Recent advances in oil and gas development have dramatically increased the production of these resources, especially in the United States. Not unexpectedly, these increases in production have also come with increasing controversy. One of the major points of contention between gas and oil production advocates and those opposed is the type of chemicals used in the horizontal drilling and high pressure hydraulic fracturing or 'fracking' that artificially fractures rock to release oil and gas reserves. Most of the chemicals are considered proprietary by the individual companies and, therefore, are not known to the public or even regulatory agencies. The second significant concern is the constituents of the materials brought to the surface along with the gas (methane usually) and the oil. It is highly likely that other volatile organic compounds (VOCs), radium-226, radon-222, and other potential toxins are also released by the fracking process.

This paper will focus primarily on the radon-222 (1) which is released to the air surrounding the well site during the flow-back period, when the fracking water returns to the surface, as the radon containing water outgasses once the water is at atmospheric pressure and (2) the radon-222 in the ambient air once the well is completed and is in the production stage. The latter release is presumed to be caused by leakage of the methane/radon-222 from the associated piping and separation tanks/storage tanks at the well site.

Background

Colorado is one of the states that have a large stake in assessing any concerns associated with fracking because of the rapid and expansive increase in oil and gas development in both the western and eastern regions of the state. Development of oil and gas fields in both areas has been increasing, and the concerns surrounding the impacts of this massive expansion are more vocal. The call for additional regulatory oversight of the industry and its practices is starting to have an impact. For example, Collett and Ham (2012) are preparing a large, multi-year study of oil and gas well development in Garfield County in far western Colorado. Colborn, et al, (2012) have looked at non-methane hydrocarbons (NMHCs) released before, during, and after drilling and fracking. The aforementioned works do not deal with releases of radon-222 from the fracking water or, later, into the air from the separation/storage facilities, however.

There are studies and publications that have dealt with radon-222, including a work by Tait et al. (2013) that looks at radon released in Australia from coal seam gas production. There, outdoor radon was measured for 24 hour periods inside and outside the Kenya/Talinga gas fields in southern Queensland with a correlation found between the well number density and the radon-222 concentrations, although open coal seams could not be dismissed as a confounding factor and the radon levels were quite modest (below 1 pCi/L, (37 Bq/m^3). In this country, Resnikoff (2012) has published an analysis of radon carried with the natural gas into apartments in New York City from the Marcellus shale development in New York State. His findings, however, have been the target of industry criticism, by Spectrum Energy[(1)], in particular. The United States Geological Survey (USGS) released a report in 2012 measuring radon in methane in Upper Devonian sandstones and the Middle Devonian Marcellus Shale in Pennsylvania (2012) and reported readings with a median of 37 pCi/L (1369 Bq/m^3). Jenkins (2013), measuring radon from the same deposits, found average levels around 31 to 32 pCi/L in the raw and finished gas products, using scintillation cells which were filled from samples shipped to him overnight in Tedlar bags. McMahan (2013) reports on radiation alarms at a landfill in Pennsylvania that went off because of fracking cuttings carried by a truck that was subsequently refused entry. These cuttings had contained high levels of radium-226 (a precursor to radon-222).

Little research on toxic releases has been done or even planned for in the extensive oil and gas fields of eastern Colorado. This particular study was devised to start to fill that information gap. It was designed to test radon levels at an active fracking operation and was conducted at a fracking site for five wells in the Denver Basin just north of Greeley, Colorado, a mile outside the town of Eaton, Colorado. The Denver Basin consists of thousands of wells that tap both the Upper Cretaceous Niobrara formation and the underlying Codell sandstone member of the

(1) *"A Case Study of Radon Levels and risks in Marcellus Shale Natural Gas", Spectrum Energy, 5400 Westheimer Court, Houston, TX 77056-5310.*

Carlile shale formation (Higley, 2007; Pagano, 2006) (Figure (1)). The wells in this study are specifically tapping the Codell at a depth from 2,073 to 2,256 meters (Hively, 1986). The Codell is a very tight sandstone that contains extensive gas reserves. A tight formation is one where the rock is extraordinarily impermeable and hard. Any oil or gas is locked into microscopic pores in the rock. They can only be released through the fracturing that occurs with high pressure fracking. Fracking not only fractures the rock to release the gas from the confined pores but also creates conduits for the gas to migrate to the horizontal pipes and then to the surface. Any additional substance that is held in the rock along with any petroleum products is also released during the fracking process including radon gas.

Both the Niobrara and Codell are found throughout the large Denver geological basin that underlies an extensive area from south of Colorado Springs north into southeastern Wyoming and northwestern Nebraska. It stretches eastward from the base of the Front Range nearly to the Colorado-Kansas border. In its shallower formations, the basin contains significant groundwater resources that are tapped for irrigation of cropland and municipal water supplies. The basin, especially in Weld County, has been the location of significant oil and gas exploration and development for decades. Fracking and re-stimulation of older well has reinvigorated the oil and gas industry’s interest in the area.

Figure (1): The Denver Basin in which fracking is concentrated and this study took place. Map is in the public domain.

Hydraulic Fracture Stimulation

The first step in the hydraulic fracture stimulation process is to perforate the zone of interest after a correlation is made from the log program run during the drilling phase or at the conclusion of the drilling. The production zones are identified by log character and geologic shows seen in the cuttings during the drilling process. An initial break down of the zone is done with limited treatment fluids to identify the facture pressure of the formation. The break down process helps with the frack design and identifies the pressures that can be expected during the pumping of the job. It will also match the horsepower needed to pump the desired fluid and sand combination into the formation.

The number of fracks or stages a well has is based on the overall footage of quality reservoir rock and the amount of sand to be pumped. On the surface there will be several pump trucks to provide the power needed to pump the slurry of frack fluid and sand into the formation as it is being opened by pump pressure. See Figure 2. The fluid carries the sand into the formation. When all the fluid and sand is pumped the pump pressure is reduced and the formation begins to close. The sand prevents the formation from fully closing and increases the permeability of the formation increasing production. After the job is pumped, the well is shut in for a period of time to let the slurry flow into the formation. The formation pressure builds and the fluid flows or is pumped back from the well. Oil cut in the flow back fluid increases and gas flow increases within days. Eventually a high percentage of the frack fluid is recovered and the well can be production-tested for volume and gas content produced on a daily basis. Within the last 4 years, drilling is seen over a large area of the Denver Basin using a pad that supports several wells and uses horizontal drilling and multi-hydraulic fracturing techniques. This new method is still experimental and techniques and outcome vary across the basin.

Figure 2: Large Tanks (in background) are pumping the water/sand mixture into the ground. Note water truck supplying water for operation (in foreground).

Results from the Fracked Wells

Four visits to the Eaton well site were conducted to establish a baseline for radon-222 in the nearby outside air and to monitor the radon emanation, if any, during the various stages of the fracking process. A recently calibrated Pylon AB-5 continuous radon monitor was used in the active (air pump on) mode with a 3/8-inch clear flexible tubing mounted to the outside of the vehicle used to sample the air. The vehicle carrying the monitor was located approximately 200-feet (60 m) from the well heads, directly south. The wind speed was between 0 and 5 km/hr from the north for all four sampling periods and outside temperatures were near 90 degrees F (32 C), under clear skies. Samples were all taken starting at 10:00 AM and for a minimum of one-hour. Sampling was only concluded once it was determined that the reported radon values had leveled off for at least 15 minutes. Since communications with the drilling company in order to ascertain the dates and times of these various drilling stages were not informative, the visits to the well site were timed by observations made by the authors from a near-by road, not leased to the drilling company.

Drilling completed with wells capped: The first measurement was made when the authors discovered the site by following trucks designed for fracking. Since the drilling rig had been dismantled and the five wells capped, this first radon measurement is used as a baseline for comparing with subsequent tests. The one-hour result was 1.5 pCi/l (55.5 Bq/m^3)

Wells being fracked: The second visit coincided with the actual fracking process ongoing. A slight increase in the radon-222 was measured with a value of 3.0 pCi/L (111 Bq/m^3)

Wells capped while under pressure: The third visit found the fracking process completed and the fracking water being held underground by the wells being capped. A measurement of 3.0 pCi/L was obtained.

Flow-back: A fourth, and final measurement was conducted during the flow-back period. During this time, the water which was previously pumped into the ground returned to the surface. Temporary piping and valves were installed that fed the water from the well head to near-by portable tanks. The whole process was closed to the atmosphere except for a small vent to the atmosphere at the top of the portable tank which is opened while the tank is being filled. Because of this open vent, it was anticipated that the radon released to the atmosphere at this final stage of the fracking process would be noticeably increased over the previous three visits. However, this was not the case. The radon concentration was still around 3.0 pCi/L (111 Bq/m3).

Result from Separation/Storage Facility and Sealed Well Heads

As a separate effort, several Separation/Storage facilities from wells that were already in production near Brighton, Colorado, were also measured as well as a relatively small well pad with 5 completed and sealed well heads located nearby. See Figure (3), Figure (4) and Figure 5, below. Access to these facilities was enabled by their location, as they were only a few feet from near-by public roads. These facilities were chosen by the authors based on this ease of access plus their proximity to a near-by highway. Measurements were taken while the vehicle was

Figure (3): A typical three-phase separator station. Here, the oil, gas and water are separated.

Figure (4): A typical drilling pad with 5 finished wells and sealed well heads. The highest outdoor radon was measured (4.5 pCi/L) at this site.

Figure 5: A 400-gallon tank battery in which oil is stored. The smaller tank holds the separated water. The separated gas has already been sent through the pipeline.

parked approximately 10 feet (3 m) from the separation tanks although the measurements were not of sufficient duration to allow the Pylon to come into equilibrium, being typically about 10 minutes in duration. The readings were consistently at 4.0 pCi/L, about 150 Bq/m^3, and as high as 4.5 pCi/L (166 Bq/m^3) at a nearby drilling pad with 5 sealed well heads. We believe that there is sufficient intentional, and accidental, leakage from these facilities to explain this higher than expected outdoor radon concentration, although this hypothesis has not been tested rigorously.

Conclusion

Preliminary measurements at a fracking site and at a few separation/storage facilities in northeast Colorado seem to indicate that radon-222 is indeed released during the fracking process and, perhaps more importantly, during storage and separation of oil, gas and water of completed wells. It is believed that radon-222 released into the atmosphere during oil and gas production has not been well studied and deserves a closer look. Levels of 3.0 pCi/L (111Bq/m^3) during the weeks-long fracking process and levels of around 4.5 pCi/L (166 Bq/m^3) near the separation/ storage stations, although not alarming, are at 10 times above the normal outdoor level (EPA-1992) and would seem to indicate that outdoor radon is being adversely influenced by the gas/oil production process.

This quick study leaves unanswered whether oil field workers or nearby residents are exposed to levels of radon gas which may be of concern. But it does suggest that more work needs to be done in characterizing the radon concentration at many fracking sites and the separation/storage facilities as well as in calculating the long-term exposure times of the workers in order to determine their total annual exposure. Also, if further work is done, it is intended that the radon-levels of the outdoor air surrounding near-by homes also be evaluated.

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