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A Perspective on the USEPA Study of Pavillion, Wyoming – Relevance and Lessons for NY

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What is the issue

In December 2011 the US Environmental Protection Agency (USEPA) released a draft study entitled "Investigation of Ground Water Contamination near Pavillion, Wyoming." The study was initiated in response to a series of complaints by Pavillion residents regarding taste and odor problems in domestic water wells. These water wells overlie and produce fresh water from the Wind River Formation. This formation, and the Fort Union Formation below it, also constitutes the Pavillion natural gas field, which has been developed at various times since the 1950s. From the 1990s through 2006 the gas field was developed relatively intensely, and included the hydraulic fracturing of vertical gas production wells, along with other activities associated with natural gas development. The objective of the USEPA study was to determine whether ground water contamination had occurred and, if possible, to differentiate between shallow sources of potential contamination – such as surface pits - and deep sources – such as gas production wells. It was not the intent of the study to evaluate the extent of contamination, nor was the objective to evaluate the hydraulic fracturing process itself as a route of potential contamination.

Overview

Overall, the study provides compelling evidence to support the conclusion that ground water contamination from natural gas drilling operations has occurred in several locations. Among these locations, evidence is given that suggests that separate contaminant sources may exist; in some cases shallow sources such as waste fluid pits seem the most likely origin of contamination, while in other cases there is evidence for deeper sources of contamination such as gas production well bores. That being said, several conclusions made by the authors are not clear-cut, and there is significant uncertainty with respect to contaminant origin and interpretation of limited data.

Interpretation of results is confounded by several factors: 1) the presence of "legacy" waste fluid pits from previous gas drilling operations in the study area as a possible shallow contaminant source; some of these pits seem to be undergoing active remediation, and little data concerning this remediation, pit location, and hydrology is provided; 2) limited data regarding deep ground water chemistry as a result of cost constraints in drilling deep monitoring wells; historic data on deep ground water chemistry is not provided and may not be available; 3) limited hydrologic data, including direction of ground water flow and velocity; the authors state that evaluation of contamination extent is not an objective of the paper, yet several conclusions would be strengthened (or refuted) with more complete hydrologic data; 4) limited baseline data with respect to methane in domestic wells, and a limited statistical analysis to support the conclusion that a trend exists with respect to proximity to gas production wells (as opposed to discrete methane migration events at one or more locations).

To be fair, it can be extremely difficult to accurately determine the cause, origin, and extent of contamination in complex field environments, especially in cases such as this where development has occurred over time involving multiple actors. The cost of comprehensive studies capable of acquiring the needed data can also be a challenge, as was clearly the case here. Analysis of the data presented would be aided greatly by the existence and inclusion of background data that could sufficiently characterize the quality of ground water prior to development. While the authors refer in some cases to such data, it is unclear whether they had access to enough of such information, and if so, what reasons they had for not including it in this draft. A basic ground water hydrology survey is also needed.

Some will wonder whether this study proves that hydraulic fracturing has indeed contaminated an Underground Source of Drinking Water (USDW). It does not. The authors do, however, speculate that fracturing fluids are the likely source of at least some of the various inorganic and organic compounds found in Pavillion ground water at elevated levels. While the authors implicate these fluids as a contaminant source using a line of reasoning approach, it is important to note that the study design did not explicitly address contamination pathways. Rather, "deep sources" of contamination were loosely differentiated from shallow sources. These deep sources potentially include the hydraulic fracturing process, but also include contamination as a result of improper or failed cementing and well integrity practices. More study, with an explicit focus on the mechanism of contamination, would be needed to say more definitively whether one of these explanations is appropriate.

In general, it is wise to keep in mind that this report is a draft. As it goes through the review process, and as the USEPA receives criticism and feedback, it is possible that

portions of the report and the flavor of its conclusions may change. Ideally, USEPA will be able to identify gaps in data and/or areas where the presentation of additional information may be helpful.

Why Wyoming is relevant to New York

In the discussion that follows, it is first made clear that natural gas development and its consequences in Wyoming are not necessarily similar to natural gas development that may be happening in other states, particularly New York. The activities involved, their regulation, and their potential impacts on the environment may be similar in some ways, but critically different in others. Next, the specific conclusions of the USEPA study are briefly discussed with an emphasis on their strengths and weaknesses given the data provided. The issue of ground water contamination is a complex one, and a single study is rarely enough to address all of the issues that will be important to various stakeholders. It is no surprise that some conclusions are well supported while others are more speculative. Finally, and most importantly, several issues raised by the USEPA study are discussed that are important with respect to natural gas development anywhere, including New York.

Although the situation in Pavillion, Wyoming is fundamentally different in many ways to natural gas development in New York, this study does highlight some timely issues that are worth considering now, at a point when regulation of natural gas development and associated hydraulic fracturing activities are coming under scrutiny, and as regulatory agencies at both the state and federal level evaluate their strategies for managing this development. These issues, which will be revisited later, include the following:

1. Regional differences and their impact on resource development and environmental protection
2. Waste fluid handling and management practices, and associated state and federal regulations
3. Gas production well integrity and isolation from USDW formations
4. Chemical additives used during drilling and hydraulic fracturing, and disclosure to regulatory agencies
5. Federal versus state regulation

In some ways this USEPA study helps to bring needed attention to the topics listed above. If many of the assertions made by the authors are true, than Pavillion may represent an unfortunate example of the negative outcome that results when important issues are not thought through carefully enough. On the bright side, a constructive dialogue about these issues, and many more related to energy resource extraction, should help to minimize environmental risk in the future.

Why Wyoming is not New York

From the perspective of a concerned stakeholder in New York, it is important to keep several critical facts in mind. It should be clear that gas development in this area in Wyoming **is different from** Marcellus shale gas development. Although there are general similarities with respect to some of the industrial activities that take place as part of gas development everywhere, it is misleading to draw a direct link between what may have happened in Pavillion, and what might happen in NY. Some of the key differences between the two situations are:

- Drilling Location – In Wyoming drilling occurred within the same formation that contains ground water. The Wind River Formation is both the target for fracturing and gas production AND the USDW for the residents of Pavillion. In the areas of NY where Marcellus Shale is likely to be developed under proposed state regulations, the gas producing formation will always be much deeper than fresh ground water and separated from it by a confining geological layer of low permeability. Although the Marcellus does outcrop throughout the Northern tier of the state, NY regulators have stated that permits will not be issued for any Marcellus Shale gas well proposed to target a formation within 1000' of ground water supplies, or within 2000' of the surface, without further site-specific review
- Geology – The Wind River Formation is primarily a sandstone, with higher permeability and different physical characteristics than a shale such as the Marcellus; fluids would be expected to move through sandstones more easily, whereas an intact shale would essentially prohibit fluid migration on time scales relevant to this study
- Regulation – Of the 169 total gas production wells within the study area, 97 are managed by the Bureau of Land Management, a federal agency, with the remaining gas wells falling under the oversight of the state of Wyoming. Regulations within these jurisdictions vary considerably, and are generally less stringent and environmentally protective than those in place and proposed in NY, particularly with regard to use of waste pits and cementing of production bore holes (for example, it is required in NY that surface casing extend below fresh water zones and be cemented from below such zones up to the surface)
- Fracturing Technology – The last gas production well in the area of study was drilled and fractured in 2007. At least some of the gas wells – we're not told how many - were fractured using a CO_2 foam fluid rather than water; in general, chemical additives used both for the CO_2 foam fracturing and the slickwater formulations utilized a greater number of petroleum-based compounds than would be allowed in more modern formulations under the regulations proposed by NY

What did the EPA find?

When trying to understand the USEPA study, its context, and what it sought to do (and not do), some additional points of general interest are helpful:

- All gas production wells were vertical wells only; some gas wells were fractured multiple times at various depth intervals
- Fracturing occurred as shallow as 372 meters (1,220 ft)
- Domestic and stock water wells in the area run as deep as 244 meters (800 ft)
- Surface casing of some gas production wells ran as shallow as 110 meters (360 ft), indicating that some gas wells were not cased within the zone of domestic water well intake
- The study area contains at least 33 pits previously used for waste fluids & cuttings, some of which were legacy pits inherited by the most recent operator
- The study utilized 4 sampling events over 2 years and included the installation of two "deep" monitoring wells screened at depths of approximately 235 and 295 meters (770 and 968 ft)

Below, the main conclusions of the study are briefly summarized. In some cases, commentary is provided as to whether or not conclusions seem well supported by the evidence provided.

USEPA Conclusion: Open waste pits are a source of shallow ground water contamination

- Comment: It is difficult to judge the validity of this statement since the locations of old waste pits are not given, nor is data provided related to ongoing remediation of legacy pits that could help characterize contaminant sources. Analytical results for many organic compounds are presented for deep monitoring wells only, and a more direct comparison of domestic water wells with deep monitoring wells would help clarify the study for readers. This conclusion may be made stronger with additional data, but is open to criticism given the current draft

USEPA Conclusion: High pH in newly established "deep" (250 – 300 m) wells is likely due to a combination of low buffering capacity of native water and use of alkaline solvents and additives during hydraulic fracturing

- Comment: This conclusion is plausible. However, data indicates that hydroxide alkalinity decreased over time from 2010 to 2011 in both deep monitoring wells, potentially implicating a more recent source of contamination, such as from the drilling of deep monitoring wells themselves. Lack of baseline deep ground water data, as well as limited sampling (two sample points from two deep wells) makes interpretation of this conclusion difficult

USEPA Conclusion: High concentrations of potassium in both newly established ground water monitoring wells, and high concentrations of chloride in one, are not consistent with native water characteristics, and correspond to a number of potassium and chloride containing additives that were used during this type (carbon dioxide foam) of hydraulic fracturing.

- Comment: Although native potassium and chloride concentrations do vary considerably, Figure 12 shows elevated levels of both in deep monitoring wells. Without further information to the contrary, the author's interpretation is a reasonable one

USEPA Conclusion: A range of synthetic organic compounds was found in one or both of the newly established deep ground water monitoring wells. These compounds are not expected naturally. In most cases the compounds correspond directly to additives used during hydraulic fracturing or the expected breakdown products of those compounds.

- Comment: Some of the compounds yielded false positive results in field and laboratory blanks, leaving some of these results open to criticism. In general, however, there do appear to be detectable levels of several organic compounds in deep monitoring wells (testing of domestic water wells was not performed) that are unlikely to occur naturally. Author conclusions are plausible

USEPA Conclusion: BTEX compounds - benzene, toluene, ethyl benzene & xylene - were found in the deeper ground water monitoring well, while other petroleum-based organics were found in both monitoring wells (again, testing of BTEX in domestic water wells was not performed). These compounds correspond to additives used during hydraulic fracturing

- Comment: Although some of these compounds could exist naturally in ground water, particularly within a formation know to produce hydrocarbons, it is also possible that chemical additives used during hydraulic fracturing are to blame

USEPA Conclusion: Organic compound concentrations were higher in the deeper ground water monitoring well. Hydrological evidence, along with the greater concentration of breakdown products such as acetate in the shallower monitoring well, suggest that contaminants and ground water are migrating in an upward & lateral direction.

- Comment: While this interpretation is plausible, it is hard to determine what is going on here in terms of hydrology and "source" of contamination without more data. The theory that an upward gradient exists cannot be justified on the basis of two monitoring wells located several kilometers apart, and sampled on an infrequent basis. More information is needed with respect to ground water flow, velocity, etc.

USEPA Conclusion: There is evidence for poor cement bonding outside production

casing in some gas wells. Geological characteristics provided poor protection from migration, and lack of cement in some lower well bores could have contributed to migration issues

- Comment: This is reasonable given the evidence provided

USEPA Conclusion: Gas composition and stable isotope analyses suggest that production gas and gas present in ground water monitoring wells is the same. Gas in domestic water wells has the signature of production gas following biodegradation

- Comment: This is a plausible interpretation

USEPA Conclusion: Concentration of methane in domestic water wells increases with proximity to gas wells. Other evidence, such as a recent blowout during the drilling of a water well and cement bond log results showing poor bonding, support the conclusion that the methane has migrated from production sites

- Comment: This interpretation is possible. However, the authors fail to distinguish between what might have been a migration event (an accident or multiple discrete incidents), and a trend that applies to all gas wells regardless of their location in the Pavillion gas field. The data provided here leaves little doubt that methane is present in several domestic water wells, and provides some evidence that gas production wells may be to blame in some cases, but does not offer strong statistical evidence of a trend. This is confounded by the possibility that methane may have naturally migrated into domestic water wells drilled into a gas bearing formation. It is hard to say if this was caused by development without baseline testing. This is perhaps the weakest argument of the paper, and will certainly be criticized during the review process

What does it mean?

The EPA study attempts to address a complex array of issues over a sizeable geographic area. The draft presented provides a volume of data that helps to identify the nature of ground water contamination. It also provides some interpretation of the data and suggests sources and pathways related to natural gas development for both shallow and deep ground water impairment. In some cases the quality or quantity of data makes interpretation difficult, and several conclusions made by the authors are confounded by the issues raised in the overview above. It is certain that this study will be contested, criticized, and revised. It is also possible that new information will either be collected or pulled together in order to clarify many of the uncertainties that make determination of causation difficult.

The bottom line, however, is that this study shows that more could have been done in Pavillion to prevent environmental contamination during gas development. More study and in-depth discussion of specific details within this study will likely show that the authors were more or less correct in certain assertions, and potentially incorrect in others. However, despite the debate over detail and interpretation, and regardless of who or what is to blame for the poor water quality in Pavillion, Wyoming, there are several reasons to acknowledge this report as being relevant to other states, such as New York, where development of natural gas resources is also occurring.

1. Regional differences matter – The situation in Wyoming is not like the situation in New York or Pennsylvania. Each gas development region will have its own characteristics and challenges, its own regulatory environment, and its own mix of land use, industry, and infrastructure that will influence environmental risk and industry best practice. Regulatory agencies need to be aware of this regional character and develop management strategies that are effective and appropriate. More study is needed on the link between regional development characteristics and environmental risks that are likely to occur.
2. Management of waste fluids is a critical issue, and open waste pits are not worth the risk – Although this study does not definitively link ground water contamination with the use of open waste pits, it does place the practice into the spotlight for critical evaluation. In New York regulators have chosen to move toward the requirement of closed-system waste containment as a way to minimize contamination risks associated with wastewaters that have complex and sometimes toxic chemistries. Although wastewaters will vary across the country and as a result of differences in geology, it seems prudent for state and federal agencies to closely assess the risks of open waste pits. On-site wastewater management and treatment technologies have evolved rapidly and provide the industry with alternatives that may not have been available in the past, but which should be encouraged or required in the future.
3. Cement quality and gas production well integrity are critical – As with the open pit issue, this study does not necessarily illustrate a direct link between cementing practices and ground water contamination. However, it does show that cementing in the area of study was often done poorly in terms of quality, and insufficiently in terms of depth and coverage relative to the screened depth of local domestic water wells. Best practice with respect to cementing, bond-logging, and gas well integrity has received significant attention in recent years, particularly in the Marcellus Shale where public scrutiny and criticism has been intense. State and federal agencies should be looking closely at implementing the most effective and stringent gas well integrity guidelines.

4. Chemical additives need to be on record – Situations in which contamination is thought to occur, but for which the exact nature of the contamination source is unknown, highlight the need for better documentation of chemical additives used during the drilling and hydraulic fracturing processes. At the very least, there is a need to make chemical additives and their volumes available to state or federal regulatory personnel and emergency responders, regardless of location or purpose. Replacing the most toxic additives such as petroleum derived organic compounds is, and should continue to be, a priority area of research.
5. Targeting of formations containing an USDW should elicit strict regulation – Given the attention to detail that seems to follow rule-making in New York with respect to gas development, it seems hard to believe that gas production wells in Pavillion were allowed to contain surface casing that did not extend below nearby domestic water wells. It is common in some cases, such as coal bed methane, to target gas-bearing formations that also act as an USDW. However, to do so without the strictest of regulations regarding casing, cementing, and other gas well-integrity issues seems irresponsible. In cases where such development occurs on federal land, this is an opportunity for the federal government to lead the way in ensuring that development occurs safely or not at all.

Inevitably this study will fuel the debate about whether regulation should be the responsibility of the state or the federal government. States still likely possess the ability to more effectively oversee the day-to-day activities of industry, and states are more likely to understand local characteristics that must be considered when trying to ensure that development occurs efficiently and safely within the context of the region. That being said, this study should provide incentive for all gas producing states to review their regulations and, if necessary, bring them into line with best practice in such a way as to address some of the risks highlighted here. At the same time, it is fair to think that the federal government may be able to play a larger role in ensuring that some best practices are being employed by industry everywhere, and that states are adequately regulating certain activities in such a way as to minimize risks that may be universal to gas development regardless of geology, technology, climate, or regulatory philosophy.

In the words of the authors:
"This investigation supports recommendations made by the U.S. Department of Energy Panel (DOE 2011a, b) on the need for collection of baseline data, greater transparency on chemical composition of hydraulic fracturing fluids, and greater emphasis on well construction and integrity requirements and testing. As stated by the panel, implementation of these recommendations would decrease the likelihood of impact to ground water and increase public confidence in the technology."