

HEI STATEMENT

Synopsis of Research Report 233, Part 2

Water Quality in the Oldest Hydrocarbon Basin in the United States

BACKGROUND

The onset of unconventional oil and gas development (UOGD)* through hydraulic fracturing in the early 2000s has led to a substantial increase in oil and gas production in the United States, and concurrently, concerns about effects on human health from exposure to water potentially contaminated from UOGD. This concern is particularly acute in rural areas where many residents rely on private groundwater wells for drinking water.

Research on water quality changes from accidental UOGD releases is challenging as any contamination of the soil and groundwater typically requires substantial effort and resources to determine the extent and severity of effects on groundwater. Furthermore, it is difficult to distinguish UOGD-related contamination from other natural or anthropogenic sources, particularly in areas with a history of conventional oil and gas or coal extraction, because associated contaminants are often the same.

In Part 1 of their study, funded under ([RFA E20-2](#)) Community Exposures Associated with Unconventional Oil and Natural Gas Development, Baka, Brantley, and colleagues at The Pennsylvania State University used statistical analyses and machine learning to identify links between various UOGD sources and potential groundwater contamination. They also used focus groups to understand community concerns regarding UOGD. Based on publicly available water quality data primarily collected before 2014, they found areas of elevated salts that may indicate localized areas of potential groundwater contamination, and they reported that residents in Southwestern Pennsylvania were principally concerned about health effects of UOGD related to water quality, waste disposal, and radioactive contaminants.

As a follow-on, in Part 2 of the study, the investigators sought to evaluate the groundwater quality in these areas and address

What This Study Adds

- Part 1 of the study, based on decade-old water quality data, identified elevated salts as a potential indicator of groundwater contamination related to unconventional oil and gas development (UOGD) in areas of Pennsylvania. It also documented community concerns about potential radiation exposures and water quality impacts from UOGD waste management.
- In Part 2, this study provides more recent water quality data from surveys conducted in areas where evidence gathered in Part 1 suggested that groundwater may have been contaminated by UOGD.
- The investigators collected 97 water samples from private groundwater wells, springs, and streams near oil and gas activities, as well as control sites, and analyzed them for 41 chemicals associated with UOGD and human health. They also used multiple statistical analyses and chemical fingerprinting to identify impacts from UOGD versus other sources.
- The investigators found that few analytes exceeded drinking water standards, and exceedances were limited to secondary standards, which are based on aesthetic qualities rather than health effects. Overall, based on multiple lines of evidence, the investigators found no conclusive evidence of UOGD-related impacts in private groundwater wells, noting that geological, geographical, and land use variation across the relatively small number of sample sites may also explain their observations.
- This study contributes to the broader understanding of groundwater and drinking water quality in areas proximate to UOGD and adds valuable data that may help distinguish localized UOGD-related impacts to groundwater from broader regional effects of historical energy extraction or geology. The study also directly addressed community concerns by investigating whether private drinking water wells were contaminated by UOGD.

This Statement, prepared by HEI Energy, summarizes a research project funded by HEI Energy and conducted by co-principal investigators Jennifer Baka and Susan L. Brantley (The Pennsylvania State University) and their colleagues. Research Report 233, Part 2 contains the detailed Investigators' Report and a Commentary on the study prepared by the HEI Energy Review Committee.

*A list of abbreviations and other terms appears at the end of this report.

community concerns about potential contamination in privately owned drinking water sources. Thus, they conducted water quality surveys in areas where evidence suggested that groundwater may have been contaminated by UOGD.

APPROACH

Baka, Brantley, and colleagues conducted several sampling campaigns during 2024. They collected 97 water samples from private groundwater wells, springs, and streams in select “treatment” and “control” areas. These samples were collected to address two questions:

1. Do these groundwater wells contain contaminants associated with UOGD that pose human health concerns?
2. Do groundwater wells previously identified as being at elevated risk of UOGD contamination show evidence of actual impact?

The treatment areas, many of which overlap, were defined as those within 2–3 km of locations of interest:

- Those that had increased chloride concentrations near one or more UOG wells (“hotspots”).
- Impoundments that stored oil and gas wastewater (also known as “produced water”) that were directed by the Pennsylvania Department of Environmental Protection to either close or store only fresh water (“impoundments”).
- Areas near produced water spills that had occurred in Southwestern Pennsylvania between 2022 and 2024 (“spills”). The team also included 12 UOGD-related brownfield sites in the “spills” area. Finally, control sites were located between 5 and 7 km from the central points of impoundment and hotspot areas and more than 5 km from spills.

Within the hotspot, impoundment, spills, and control areas, the team recruited 68 homes to approach to sample private groundwater wells. The team also included “goodwill” sample sites that did not meet criteria but were sampled to generate interest and goodwill in the study.

The investigators analyzed all samples for 41 chemical analytes, which are more likely to be elevated if UOGD contamination had occurred, with a focus on those that are of concern to human health. To estimate potential health concerns, they compared the results to the US EPA Primary and Secondary Drinking Water Standards. When these standards were not available, they used other health-based benchmarks or guidance established or proposed by federal agencies.

They also employed several different analyses to tease out any potential impacts from UOGD specifically

from those of other sources. These included statistical comparisons of samples from “treatment” sites with control sites, geospatial analyses to analyze whether concentrations were higher closer to UOGD operations, and isotope analyses and element ratios, which can serve as chemical fingerprints, to interpret the origin of analytes.

KEY RESULTS

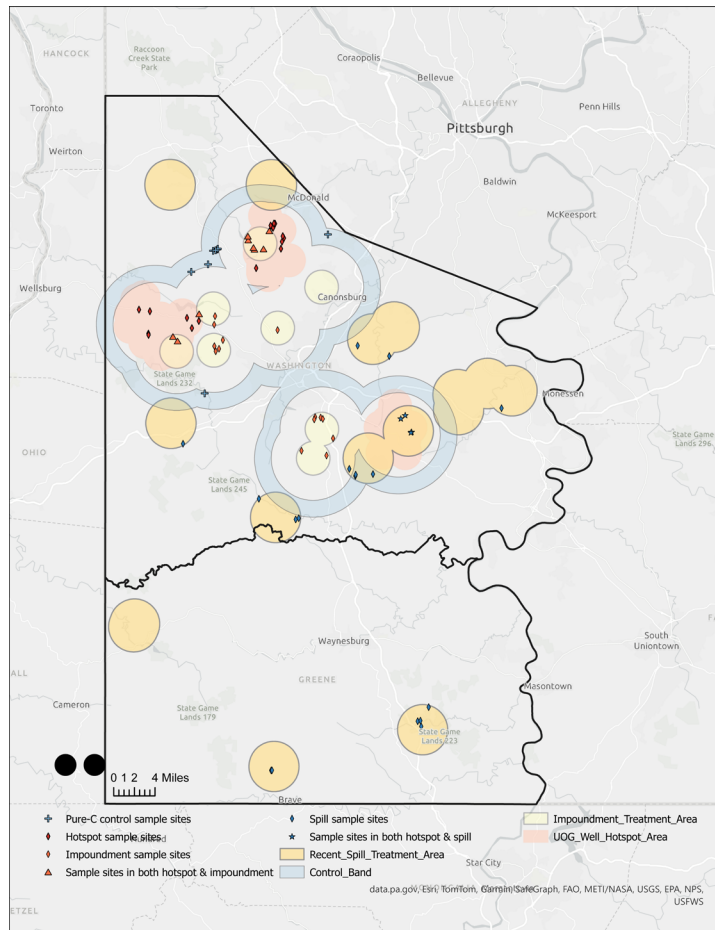
Between May and November 2024, the investigators conducted seven field campaigns, collecting 97 water samples (79 groundwater wells, 14 springs, and four streams) from 91 residential properties and three public sites. Of these, 62 samples came from hotspots, impoundments, and spill sites, some overlapping (**Statement Figure**), distributed among the three types, with eight from control areas and 27 classified as goodwill samples.

None of the samples exceeded health-based, US EPA Primary Drinking Water Standards, although one sample equaled the primary standard for barium. Some samples exceeded Secondary Drinking Water Standards (aesthetics-based) for aluminum, iron, manganese, total dissolved solids, or chloride. However, those are some of the most common elements in Pennsylvania bedrock. BTEX compounds (benzene, toluene, ethylbenzene, and xylene), which are commonly associated with oil and natural gas, and radium compounds, which are naturally occurring in the Marcellus shale, did not exceed drinking water standards in any sample.

Thirty-three samples exceeded the US EPA proposed water standard for radon (values above which could indicate risk from exposure to radon in indoor air), and 46 exceeded the US EPA health-based screening level for lithium. Three samples exceeded US Department of Interior action levels for further investigation for dissolved methane in water, which indicates a potential need for venting, monitoring, or mitigation to prevent gas buildup.

In each case where the team found analytes above standards or guidelines, they provided a letter describing the specific findings and potential mitigation resources and called the homeowners.

After accounting for suspected contamination from agriculture and potential artifacts in the statistical analyses, the investigators found that only radium concentrations were statistically higher in groundwater wells within hotspots and impoundments as compared to control sites. However, none of the samples exceeded the maximum contaminant levels established for radium in drinking water, and the investigators note that radium concentrations were within the typical range for principal aquifers in the United States.



Statement Figure. Map of the study treatment and control areas and sample locations in Washington and Greene Counties, Pennsylvania. Source: Investigators' Report Figure 1.

Other analytes showed higher concentrations closer to impoundments and spills, but the data were variable. It is possible that these analytes could be related to produced water leaks from impoundment sites or spills at well pads. When the team considered additional lines of evidence, including isotopic analyses of geochemical tracers and methane, they could not conclusively identify UOG as the source. Instead, they note that the observed variations may reflect differences in local geology or land use.

INTERPRETATION AND CONCLUSIONS

In Part 2 of the study, Baka, Brantley, and colleagues examined whether groundwater presumed to be at higher risk of UOGD contamination showed evidence of such impacts. In so doing, they also directly addressed community concerns about whether UOGD activities were adversely affecting local water quality in private groundwater wells. The investigations found that few analytes exceeded drinking water standards, and exceedances were primarily limited to secondary

standards, which are based on aesthetic qualities rather than health effects. Across all sampled sites, the team found no conclusive evidence of UOGD-related contamination in private groundwater wells based on multiple lines of evidence.

In its independent review of the study, the HEI Energy Review Committee identified the study's rigorous analytical approach as a key strength, noting that it focused on a well-considered subset of water quality analytes relevant to both potential UOGD-related contamination and associated health effects.

The Committee also recognized the value of the community-centered approach, which accommodated community requests for increased and transparent water sampling. Each participant received a letter with individual water quality analysis results, with additional information and resources in the cases where the investigators found analytes above standards or guidelines. The Committee appreciated the strong, consistent communication with the community.

The Committee recognizes that a study of this size and scope cannot conduct every analysis or obtain every type of data. The inherent complexity of subsurface groundwater flow, limited information on private well construction, or unevenly distributed controls may all complicate the ability to delineate the extent of potential groundwater contamination. While acknowledged by the investigators as limitations in the study, the lack of discussion of the potential effect of these limitations on the findings was a notable omission.

The Committee also noted that some key findings are presented without context to understand the implications of such results, such as samples with lithium concentrations that exceeded their health-based screening level. The Committee also questioned why the investigators suggest that future analyses of the blood and hair of residents could be used to discern the potential effects of contamination. Given the findings of this study, such an intervention seems unwarranted and unsupported.

In summary, this study contributes to the broader understanding of water quality in areas proximate to UOGD and adds valuable data that may help distinguish localized impacts of UOGD on drinking water from broader regional effects, including legacy energy extraction or underlying geological conditions.