

In Our Backyard: Perceptions About Fracking, Science, and Health by Community Members

NEW SOLUTIONS: A Journal of
Environmental and Occupational
Health Policy
0(0) 1–10
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DOI: 10.1177/1048291120905097
journals.sagepub.com/home/new



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Abstract

Unconventional oil and gas (UOG) extraction (fracking) has increased in the United States, as well as interest in the associated risks and benefits. This study's purpose was to qualitatively examine residents' perceptions about UOG development in their community. Fifteen interviewees involving residents of Garfield County, Colorado, a drilling-dense region, were transcribed and analyzed. The study found six themes: (1) health concerns, both human and animal, (2) power struggles between government and industry/between industry and residents, and (3) perception and some acceptance of increased risk. Less common themes were (4) reliance on science to accurately determine risk, (5) frustration with potential threat and loss of power, and (6) traffic and safety concerns. Community perceptions of UOG development are complex, and understanding the position of community members can support the need for additional public health research and impact assessments regarding community exposures from UOG drilling operation exposures.

Keywords

unconventional oil and gas development, community members, fracking

Introduction

Unconventional oil and natural gas (UOG) extraction, which combines directional drilling and hydraulic fracturing (commonly called “fracking”), has recently been on the rise in the United States as well as globally.¹ The UOG process combines horizontal drilling of deep rock layers with hydraulic fracturing of the rock via high-pressure injection of a mixture of water, sand, and other chemicals.² This method of oil and gas extraction allows for increased development of shale formations, as well as extraction from formations that had been previously unviable.³ This capability has led to increases in both the production and export of fossil fuels by the United States.^{3,4}

Approximately 70 percent of actively producing wells in the United States are comprised of UOG wells.⁵ Nearly eighteen million people live within a mile of an active oil or gas well, and half of these wells have been drilled since 2000 in the United States.^{6,7} Minor and major wastewater spills are common with 1375 reported in Colorado in 2014 by the Colorado Oil and Gas Commission.⁸ An analysis of UOG wells in Colorado, New Mexico, North Dakota, and Pennsylvania from 2005 to 2014 found 6632 spills associated with 21,300

unconventional wells, or one in three wells.⁹ These spills release chemicals that can seep into the groundwater or runoff into the surface water ultimately used by residents for their drinking water.^{9–11} Due to the complex nature of the mixtures of both UOG drilling introduced chemicals and the released natural minerals and chemicals in the geology and air at UOG drilling sites, there has been increased interest in the associated risks and benefits.¹²

Research has focused on the environmental and economic impacts of UOG drilling.^{13,14} Environmental concerns revolve around water treatment and disposal, as well as local ground and surface water contamination,^{3,15–20} associated UOG drilling-related traffic, and air pollution.^{21–23} Reports of the potential economic impact of UOG drilling have been mixed, some

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indicating high levels of financial returns, while others focus on the “boom-bust” cycle of energy development.³

Community members have voiced support and concern related to the economy of this nonrenewable resource.²⁴ Several studies have engaged residents living near industrial or mining areas^{25–28} or UOG drilling areas^{12,14,24,29–38} and have suggested that the perceived environmental degradation associated with industrial development is linked to increased psychosocial stress.^{25,35,39,40} In the literature that has discussed community responses to UOG drilling, a focus on the issue of personal and community power in particular has been described. For example, participants reported a sense of powerlessness and anxiety over their changing community, as well as a mistrust in their leadership. They described this powerlessness as their “community was coming apart” and “they have been failed by the decision-makers of their community.”^{33,41}

In this paper, we interviewed fifteen local residents regarding their feelings and experiences living close to this UOG development. Our primary data come from the community in Garfield County. This county has experienced substantial development of unconventional gas extraction with more than eleven thousand conventional and unconventional gas and oil wells.⁸ Transcripts of the interviews were analyzed for recurring themes without consideration of any theoretical foundation. For example, Creswell states, “In a qualitative research, one does not begin with a theory to test or verify.”⁴² The following were the most commonly found themes: (1) health concerns, both human and animal, (2) power struggles between government and industry/between industry and residents, and (3) perception and some acceptance of increased risk. Less common themes were (4) reliance on science to accurately determine risk, (5) frustration with potential threat and loss of power, and (6) traffic and safety concerns. Though the data collected from these interviews are not necessarily generalizable, these discussions from rural residents living near UOG drilling operations are likely similar to discussions of residents in other states where UOG drilling has been conducted. We believe that the data and our analysis can support the need for additional public health research and impact assessments regarding community exposures from UOG drilling operation exposures. This body of literature is needed to strengthen inclusion of public health concerns during UOG development decision-making processes.

Methods

Participants

From a preliminary study conducted in 2010 to assess endocrine activity from collected water samples in

Garfield County, a relationship with four landowners proximal to drilling sites was established. To expand this pilot research for a larger water sampling survey in 2014, a snowball technique was used in which the original landowners referred the study team to other residents who might be willing to provide water samples, including members of citizen groups convened to understand the UOG development in their region, and a high school science teacher, who teaches water quality assessment techniques to students. At the time of gathering water samples for the 2014 survey, residents were approached to talk about their perspective on UOG development. One citizen group of four people agreed to discuss their perspectives.

A total of fifteen individuals shared their perspective in seven interviews conducted over a one-week period. All interviewees were residents in Garfield County. To maintain the anonymity of participants, few descriptors of the interviewees are provided. Most participants lived in communities with high-density UOG wells. Representatives from two local groups concerned about impacts from the increase in UOG development also participated in the interviews. Among the residents, three lived in Garfield County for two years or less; the remaining were long-term residents. Among the participants, three had worked in some capacity for the UOG drilling industry and/or as a member of the government. All participants voluntarily participated in the interviews and were not compensated for their time or information. Oral consent was given to record the interviews, and they were approved by the University of Missouri’s Health Sciences Institutional Review Board.

Data Collection

Data were collected from seven separate interviews of local residents over a period of four days. Five of the interviews took place at the participant’s residence, where researchers led unstructured, one-on-one discussions regarding UOG drilling in the area while collecting water samples for analyses of endocrine bioactivity, organic contaminants, and characterization of minerals, metals, and isotopic tracers. The remaining two interviews took place with groups of participants (including residents and local leaders). The interviews of these larger discussion groups were also unstructured. All discussions were audio-recorded and transcribed before analysis.

Data Analysis

The interview transcripts were analyzed using an inductive approach to qualitative research. Three members of the research team (J. M., M. C., A. Z.) independently analyzed the interview transcripts and developed an

initial codebook. The research team then met to discuss and refine code definitions, deciding on a final list of six different codes: (1) human and animal health concerns, (2) power struggles between government and industry/ between industry and residents, (3) perception and some acceptance of increased risk, (4) reliance on science to accurately determine risk, (5) frustration with potential threat and loss of power, and (6) traffic and safety.

After finalizing the list of codes, M. C. and A. Z. independently coded the transcripts. They then met in person to determine intercoder reliability (i.e., the percentage of instances in which the two coders independently selected the same code for the same segment of data.⁴³ They achieved satisfactory (i.e., >90 percent) intercoder reliability for all codes on the first attempt. The study findings are described in detail below.

Results

Theme One: Human and Animal Health Concerns

Area residents had perceived negative impacts on the health of themselves, friends, and extended family, as well as that of animals in the area.

A guy from Texas, wanted to get away from Texas, moved to Colorado—his 40 acres of paradise on Porcupine Creek and it's just a beautiful area and then [unconventional gas and oil drilling boom] came along and just destroyed his life. He was the poster child for what could go wrong and, you know, the truck traffic and then odors, so then people would come to visit his home and after a couple of hours would have to leave [be]cause they had eye irritation and skin irritation, nose-bleeds, whatever. (Interviewee #1)

This was a cause for concern as the industry's presence has increased locally. Warnings had been placed in some areas cautioning residents to not drink or ingest the water. Residents expressed an increased concern as both people and animals were getting sick and residents questioned whether or not the water was being properly treated. One resident described a warning he received that the trihalomethanes in the drinking water were too high. Another reported recognizable changes in her health but was unable to determine a cause for the change:

I mean, this all kind of came about with me in the last six months or something—as far as realizing there could have been something going on with my health and everything I went through. [There was] no reason I went through menopause at 39 and that's when I was walking five miles a day around here and breathing this stuff. So I was healthy, and getting healthy but, you know,

and then we had a hellacious spill down here that nobody wants to talk about what happened. It took them six months to clean up. And I mean, it's just kind of funny like when you talk to people, a lot of women have been affected. I'm not saying no men because Male A was one of them but you know, it's just a lot of weird things that women talk about—I've got growths in my thyroid, growths in my uterus, growth in my lung. (Interviewee #2)

Residents also associated increased traffic from the UOG industry with poorer local air quality. One resident described a situation with a neighbor. She claimed the entire family used nebulizers and had to have various breathing treatments due to the increased exhaust in the air (from the trucks used by the unconventional gas and oil drilling industry). The same was said about another resident's grandson. They reported that he cannot go outside without his breathing medication. They try to limit the child's exposure because of the risks.

Participants reported that local farmers and veterinarians had also seen an increase in defects in animals, rare cancers/diseases, such as canine glucocarcinoma, as well as premature death and inability to conceive. They reported that for several years animals living near UOG well sites and/or with rigs in their own yards had been born with deformities. One local farmer explained the struggles of fertility and birth among his livestock:

Since '97. Started slipping colts. Mares would slip a colt between five and seven months. They'd drop a fetus on the ground, basically abort. Okay, that started in '97. And then the same problem with the goats. First it'd be one out of three still births or one out of four, and then it became two out of four and two out of three, and three out of four. Her sister [doe] had died the year before during birth, but she'd had a mass in her left udder for two years and my other doe died in January of 2011. She had uterine cancer, ate her up pretty bad, and that last one, she developed cancer in her right udder in late 2010 is when her sister died. In 2011 she had two stillborn and she had that one black and white Billy goat that's kind of dwarf. He's the shortest one. (Interviewee #4)

Theme Two: Power Struggle Between Government and Industry/Industry and Residents

This theme was more obvious in discussions with members of local advocacy organizations. An imbalance was noted between government and industry, especially when cleaning up from pumps and sites no longer in use. One resident described his encounter with pump removal (and complying with the official Site

Investigation and Remediation Work Plan, submitted to the director of State of Colorado Oil and Gas Conservation Commission—Form 27 as the protocol in safely removing the pumps) and the fight between government and industry:

When they decided they were gonna take the pumps out, we told them to pump the stuff out, the really bad stuff . . . their Form 27 said, they should pump it for three months. And XX (government official), and YY (industry official) have their private meeting over in Denver and we get this notice on Friday afternoon that we're pulling the pumps out on Sunday [without extensive pumping]. And so what do we do? What are our options? It's a Friday night. We can't contact any government official. Our lawyer is off for the weekend. ZZ calls a local resident who works for the government and said "What's going on with all this stuff," and so this person writes a letter to [industry] [because the letter came from the industry, said that "Well, you're not gonna pull the pumps [because this doesn't meet the Form 27" even though the middle manager, this person's supervisor, told them, "Yeah, you can go ahead and pull them." So it was a week later; it was actually on a holiday weekend and the same scenario [happened]. On a Friday night, they says "We are gonna pull the pumps on Tuesday" or whatever, same old, same thing again. And it's like well, gosh, if you guys are honest and open, why weren't we included in that meeting [about when and the protocol for removing the pumps]? (Interviewee #6)

Another also voiced frustration with the university located close to the county indicating a belief that the university was working with the industry. He felt the university researchers disregarded the health of local residents and were not providing enough research and information to the residents, which felt like the university was giving power away to the industry and supporting the industry's endeavors.

Like that county air quality study they [university researchers] did, and it seems like right when it was about to get concluded, they pulled the plug on it because from what I can understand they didn't want citizens to draw wrong conclusions to the data they found. They didn't give us the data they found. So every time citizens bring up that there is air or water quality problems, they start to do studies and then seems that they always get washed under the table or they're not finished right or this data they come up with isn't scientific enough, whichever. So even though there's plenty of people standing up saying there's issues in the community with the water and air,

it's really hard to get the scientific data, to get real data. (Interviewee #10)

Theme Three: Perception and Some Acceptance of Increased Risk

Despite participants noting either information about negative impact of the industry or acknowledging exposures to chemicals emanating from the UOG industry, many participants shared their cognitive strategy to accept this exposure. The idea that "it is what it is" and "nothing is going to change, so I may as well stay" dominates many of these interviews at one point or another. Many residents shared that they buy bottled water from a different town to drink or fill containers with water from other areas. The behavior indicates that the residents do not accept the water as safe to drink and use strategies to resolve this perceived hazardous exposure.

Some residents who have voiced concerns do not take precautionary measures to protect themselves or believe their simple precautions are acceptable. One resident described her need to hold her breath when passing the UOG drilling containers as her strategy to protect herself from exposure. One resident described how she feels about currently being pregnant:

So, I mean, all the studies that we've seen they say that it's when you've been here for a long time that it will cause birth defects or anything. So I'm not really worried about it. Yeah. See, I was freaking out when I was first pregnant because there was this article in the newspaper, but then my mom [said], "Well, you've lived there a long time so it could affect you first," so I don't think it's really had a chance to affect me much if it has at all yet. If there's anything wrong [with the pregnancy], I wouldn't do anything about it. (Interviewee #7)

In another case, the resident thought about leaving Colorado to move back to her home state when they start a family.

When I drove my husband out to his school in California we actually drove by Rifle, and I remember driving by it and thinking I hope I never live there . . . And then oh, no, I can't believe I'm actually gonna live here. So I think eventually we want to move back to [my home state] before we have kids. I mean, it's a great place to be and explore but in the back of your mind the health risks and studies coming out saying that there's a higher incidence of birth defects around here and stuff like that—something to think about. (Interviewee #8)

On the other hand, another common position is acknowledging the importance in the economy of the community. As one resident stated, “nearly 75 percent of Garfield County’s funding came from the unconventional gas and oil drilling industry” (Interviewee #1). One of the local advocacy groups stated they are not against UOG drilling, despite the negative impact it has had on the residents of the county. They feel it is all part of the growth and development of the area:

I don’t think you can call [local advocacy] members fracktivists. It’s part of life, you know, it’s the Wild West. People come here to hunt Bambi. We’re used to that kind of development. We just want it done right, and the spills are the reason why they keep bulldozers at drilling sites to cover up the stuff that’s spilled. It’s not to moonscape their sites. So we’ve always been concerned that there’s a lot of chemicals leaching into our groundwater, from the top, not coming out from the bottom. (Interviewee #11)

Even though some business owners expressed concern about UOG drilling in their community, some set that concern aside to do business with the industry. For example, after a spill, one concerned business owner provided materials to assist with the clean-up efforts. He said, “Well, let’s help them get it cleaned up. Everybody makes mistakes, let’s get it cleaned up and move on” (Interviewee #6). In addition, some residents may find the royalties from the well pad placement was a boon for their finances.

The only people are the old timers that the only reason they’re still here is they’re collecting a royalty from family land that they’ve owned for a couple hundred years, and they’re all pro gas cause they live in town, out of it now, but they get that check every month from that old abandoned farm out there. I was telling you about my dad. He got more for the first pad than he paid for the whole place so to him he thought the farm’s finally gonna make a profit. (Interviewee #2)

Some residents expressed concern over the large industry boom in the area in 2004. Despite expressing concern with a range of emotional responses, overall, residents have awareness of the impact of UOG in their area:

So our community was, you know, a lovely retirement community. My wife and I moved there when we retired [in 2004], nice golf course, big rec center, different kinds of housing units or villages for the middle income to upper income homes, shopping, churches, schools, a great community. And right before the big boom, and so we’ve experienced that boom and we started getting a little concerned when we saw all this activity around us

and we thought well, gee, I wonder if they’re gonna be doing anything where we live, and people said, “Well, you don’t own the mineral rights on your property.” We don’t? Is that something I should own? You know, most home owners have no idea, and we went back and looked at our closing papers and oh, yeah, there’s a piece of paper that says you don’t own your mineral rights and somebody else owns them. We started getting a little nervous. We talked to the developer. He said “Oh, don’t worry about it. Somebody drilled a well here years ago and it wasn’t very productive and so, its never gonna happen.” So that made us feel a little better, and course then hydraulic fracturing came along and it changed everything. (Interviewee #9)

There is continued recognition of the impact of UOG and its effects on the area and people, and there does not seem to be a mass exodus from the UOG areas. For example, the percent of people staying in Garfield County based on U.S. census 2013–2017 migration statistics was at 84 percent nonmovers. This positions residents at the median level of nonmovers among all Colorado counties with and without UOG activity (non-mover range *with* UOG activity: 79–95 percent; non-mover range *without* UOG activity: 78–92 percent).⁴⁴

Theme Four: Reliance on Science to Accurately Determine Risk

It is clear from most interviews that residents believe in and rely on science. In other words, science will tell residents everything they need to know to make informed decisions. Many seem so sure that the lung conditions, the cancers, and the hormone imbalances can be explained through research. One resident says:

Fracking’s a more recent technology but oil and gas has been there forever ... We didn’t have the technology [tools to determine contamination levels] earlier to be able to disaggregate this information and we perhaps didn’t understand the level of contamination and now we do. It doesn’t matter how long we’ve been dealing with this; it’s time for us to step forward and make sure that our citizenry is safe. (Interviewee #5)

Another resident expressed the importance of science in figuring out this issue:

That’s why I really appreciated AA [consulting firm] because they were up front. It’s like what’s science? Science is the pursuit of truth. It’s like spirituality. What’s spirituality? It’s the pursuit of truth. You find the truth and then you make decisions, but it’s the truth that comes first. And, that’s why science, the art of science is you have a theory and then all the messy

stuff of science is proved or disapproved; the theory and create a new theory if it doesn't meet the facts, and so that's a tough part if you come in with a bias and already you're lost. You might as well just give up. (Interviewee #6)

Local organizations interviewed also believe science will provide them with vital answers to health-related questions. An air quality study being conducted through the university was described by a local organization as being very important. Data obtained from that study would enable them to make informed decisions about their health. A local resident was allowing a meter to be placed on their land so local officials could conduct regular readings on levels of various chemicals in the water. They believed these measurements would be shared and could inform them about their water quality:

They said they were having trouble with people agreeing to it [placing monitoring device] and I said, "Well, heck, no, I want to get it." We agreed immediately to having it put there and they'd come in and sampled at least three times and probably partly our fault that first of all we didn't think we were gonna have to chase that information down. [We] thought that they were gonna help us out by us allowing them to put it right there. (Interviewee #3)

Most participants had very high expectations of scientific studies providing definitive information for informed decision-making.

This reliance on science as a trustworthy source of knowledge was also indicated in a recent study. Specifically, a study asked 390 Colorado residents about a hypothetical nearby oil and natural gas project in which a third party's "green certification" of a production company's activities would be obtained. This situation resulted in substantially increased levels of support for UOG development in their area.⁴⁵

Theme Five: Frustration With Potential Threat and Loss of Power

Residents expressed dissatisfaction in the process about proving safety or harm associated with UOG drilling.

"[We] Can't prove nothing." (Interviewee #2 and #4) One interviewee continued, "Well, you can't prove nothing cause they ain't nobody tested nothing. Even the people that are supposed to test don't do no stinking testing. So how do you prove anything? And they keep it that way. They do it deliberately". (Interviewee #4)

In contrast, most new processes and developments in the United States are introduced without proof of safety,

and individuals and groups are responsible for proving harm.⁴⁶ This burden was implicit in many of the interviews and their description of the community and government's work to evaluate the impact of UOG drilling on the environment.

We've been, it's amazing how knowledgeable we've had to become as citizens about the oil and gas industry, about health, about water quality, about air quality. We're rounded up whenever officials or, or scientists or politicians come through and want to hear ... So surprisingly here, western Garfield County, we've done a lot to put the spotlight on the concern of health. (Interviewee #10)

Theme Six: Traffic and Safety Concerns

With the UOG industry comes the necessary increase of truck traffic to transport the required water, chemicals, and sand. Not only can the large presence of trucks be a safety hazard, it can also act as another health hazard to residents, as is mentioned in the human health section above.²¹ Residents expressed concern over the dangers of the trucks, including the hazardous driving and inattentiveness to pedestrians. They also brought up the added pollution to the air, and how it can affect air quality.

One resident explained the industry was to get permission before having the extra trucks brought in for wastewater removal. Instead, industry implemented a strategy of using two lines of trucks, instead of one line of trucks to remove the wastewater. Another described a near-miss incident for a local three-year-old:

When he was 3 years old. Truck company X about run over him right there by that old bread bus right there. He was riding his tricycle. He was on Grandpa's place. He had one of the tricycles with the great big tires on it, goes anywhere. Hell, you could ride your bike anywhere on Grandpa's place; it's Grandpa's place. Well, he's riding around there and here comes Truck company X up the hill. Twelve trucks—they didn't slow down or see him. He bailed off and jumped in between that shed and the corral and they run over that tricycle. I caught their pusher at the gate and I chewed his ass pretty bad about it and not one of them seen the kid or the tricycle. (Interviewee #4)

Not only was the safety of residents a concern, but the safety of the drivers was a concern as well. One resident described an accident,

This was really weird because when it happened all those trucks, only one went over the cliff, and the guy goes,

I ran out there to see if the guy was dead. I did not even think about it; the truck's gone. And I went out there and I'm like, "Are you okay?" (Interviewee #2)

Discussion

This study offers insight into residents' perception of UOG drilling in a county known for intensive conventional and UOG development with more than eleven thousand oil and gas wells. This study identified six themes that community members shared about their experiences associated with the UOG drilling industry in their community. Although only fifteen participants were interviewed, these six themes have also been reported by others experiencing UOG development in different parts of the United States, as described below. While the findings cannot be generalized to represent other communities or reflect the perspectives of all Garfield County residents, they suggest important areas to consider.

These residents felt tension between economic development and environmental degradation as have residents from other communities.^{33,35,47} The tension reflected a threat to a high standard of living.

Residents were cognizant of potential health impacts on both animals and humans. In a recent thorough systematic review of health effects associated with UOG development, Bamber et al.⁴⁸ identified twenty epidemiological studies. Health outcomes that have received attention and are described in Bamber et al.'s⁴⁸ review, albeit often from only one study, include birth defects and birth outcomes, cancer, respiratory health, neurological, and mental health studied. The Energy Policy Institute at the University of Chicago calculated a net benefit of \$2000 per year for residents in UOG communities in their economic model; however, as noted, this net gain would substantially decrease with the establishment of significant health impacts.⁴⁹

With the intensification of well pad construction, drilling, hydraulic fracturing, and production nearby, residents have had to adjust their view of what their neighborhood looks like. As participants enumerated, numerous wells situated near homes have disrupted the pristine views and increased noise and concern about the hazards with truck traffic and environmental degradation. All these factors are part of the environmental quality that residents seek as a good place to live. Another likely underlying fear is a reduced value of their homes with nearby active well pads. Overall, the weight of the published literature suggests that increased density and proximity to oil and natural gas wells decreases property values,⁵⁰⁻⁵⁴ although Apergis⁵⁵ reported a positive effect on housing prices in Oklahoma. The negative impact on property values

was found to be particularly notable for properties with groundwater-dependent homes,⁵³ that did not include mineral rights,⁵⁶ after the initial boom period,⁵⁷ and closer to the mountains.⁵⁸

Another consistent theme was power imbalance between the government or industry and residents. Malin et al. interviewed one hundred landowners who had negotiated leases for oil and gas wells and found evidence that supports this theme. They described the advantage of corporations in the context of "metapower" that shifts the balance of power toward development and limits authentic citizen participation.⁵⁹ This sense of powerlessness by residents is further exacerbated for residents who do not own the mineral rights on their land and therefore have little legal standing to influence drilling. Some residents did not realize the import of having mineral rights when they purchased their land. This is known as "split estate" property rights in which mineral and surface property rights are owned by different parties. Surface owners experience much of the disruption and environmental impact yet reap few of the direct financial benefits of UOG development.⁶⁰ Colorado law recognizes that the UOG drilling industry may use as much surface as is considered reasonable for UOG drilling development.⁶¹ Residents have sought ways to ameliorate the differential. Although attempts were described to communicate community concerns with both state and industry representatives, many residents from this and other studies shared frustration with communication and lack of response.³⁰

As described in one theme, residents have a strong reliance on science to provide evidence of the safety or harm from exposure to water contaminated and air pollution by UOG drilling activity. Residents seem to place trust in science to provide the evidence necessary to adjust the imbalance. While UOG chemicals have been associated with neurological and neurodevelopmental outcomes,⁶² and epidemiological studies have reported associations between UOG development and a number of adverse health outcomes in nearby populations,⁶³ there is an overall lack of safety information for many chemicals. For example, more than one thousand chemicals have been reported to be used in UOG extraction across the country, but a review of these chemicals reported that less than 25 percent have reproductive toxicity testing data available.⁶⁴ Other researchers have reported that most UOG chemicals lack chronic oral toxicity values for human health assessments.⁶⁵ In addition, many chemicals remain proprietary and as such have no information available on their potential toxicity.

Conclusion

The influence of the UOG industry on the local community is undeniable and complex. Residents described the

desire for both economic viability and environmental quality for their county. In the communities with high-density UOG development, such as the community described here, a power imbalance has arisen with the industry having a disproportional amount of the power, and the local residents—especially those without mineral rights—having significantly less power to influence the decisions made concerning UOG drilling. This situation may be changing with a new Colorado law enacted, Senate Bill 19–181, on 16 April 2019 that directs the Colorado Oil and Gas Conservation Commission to “regulate the development and production of the natural resources of oil and gas in the state of Colorado in a manner that protects public health, safety, and welfare, including protection of the environment and wildlife resources.” Among its most crucial changes is granting city and county governments the authority to regulate drilling and other industry operations within their borders.⁶⁶

Understanding the perceptions of community members can aid in improved communication among the various stakeholders. Examples of community engagement strategies as a form of “social license” to operate seem to be increasing.^{67,68} Research that describes other sectors of this community and other UOG drilling communities will also provide a more comprehensive understanding of the community’s needs.

Declaration of Conflicting Interests

The author(s) declared no potential conflicts of interest with respect to the research, authorship, and/or publication of this article.

Funding

The author(s) disclosed receipt of the following financial support for the research and/or authorship of this article: This work was supported by the Science to Achieve Results Fellowship Assistance Agreement–United States Environmental Protection Agency, FP-91747101, the University of Missouri Research Council, and National Institutes of Health, R21ES26395. None of the funding agencies were involved in the study design; in the collection, analysis, and interpretation of data; in the writing of the report; or in the decision to submit the article for publication. The views and conclusions in this article represent the views of the authors but not necessarily the views of the EPA. Any use of trade, firm, or product names is for descriptive purposes only and does not imply endorsement by the U.S. government.

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References

1. Ceresola RG and Crowe J. Community leaders’ perspectives on shale development in the New Albany Shale. *J Rural Soc Sci* 2015; 30: 62–86.
2. Boudet H, Clarke C, Bugden D, et al. “Fracking” controversy and communication: using national survey data to understand public perceptions of hydraulic fracturing. *Energ Policy* 2014; 65: 57–67.
3. Boudet H, Bugden D, Zanolco C, et al. The effect of industry activities on public support for ‘fracking’. *Env Polit* 2016; 25: 593–612.
4. USEI_Administration. *Annual Energy Outlook 2019 with projections to 2050 (#AEO2019)*. Washington, DC: U.S. Energy Information Administration (EIA), 2019.
5. USEI_Administration. Hydraulically fractured horizontal wells account for most new oil and natural gas wells, <https://www.eia.gov/todayinenergy/detail.php?id=34732> (2018, accessed 24 January 2020).
6. Czolowski ED, Santoro RL, Srebotnjak T, et al. Toward consistent methodology to quantify populations in proximity to oil and gas development: a national spatial analysis and review. *Environ Health Perspect* 2017; 125: 086004.
7. Jacquet JB and Kay DL. The unconventional boomtown: updating the impact model to fit new spatial and temporal scales. *J Rural Commun Dev* 2014; 9: 1–23.
8. Daily Activity Dashboard (DAD). Colorado Oil & Gas Conservation Commission, Department of Natural Resources, <http://cogcc.state.co.us/DAD.html> (2017, accessed 29 January 2020).
9. Maloney KO, Baruch-Mordo S, Patterson LA, et al. Unconventional oil and gas spills: materials, volumes, and risks to surface waters in four states of the U.S. *Sci Total Environ* 2017; 581–582: 369–377.
10. Gross SA, Avens HJ, Banducci AM, et al. Analysis of BTEX groundwater concentrations from surface spills associated with hydraulic fracturing operations. *J Air Waste Manag Assoc* 2013; 63: 424–432.
11. Ziemkiewicz P, Quaranta JD and McCawley M. Practical measures for reducing the risk of environmental contamination in shale energy production. *Environ Sci Process Impacts* 2014; 16: 1692–1699.
12. Watterson A and Dinan W. Health impact assessments, regulation, and the unconventional gas industry in the UK: exploiting resources, ideology, and expertise? *New Solut* 2016; 25: 480–512.
13. Jaspal R, Turner A and Nerlich B. Fracking on YouTube: exploring risks, benefits and human values. *Environ Values* 2014; 23: 501–527.
14. Kriesky J, Goldstein BD, Zell K, et al. Differing opinions about natural gas drilling in two adjacent counties with different levels of drilling activity. *Energ Policy* 2013; 58: 228–236.
15. Harkness JS, Dwyer GS, Warner NR, et al. Iodide, bromide, and ammonium in hydraulic fracturing and oil and gas wastewaters: environmental implications. *Environ Sci Technol* 2015; 49: 1955–1963.
16. Kassotis CD, Iwanowicz LR, Akob DM, et al. Endocrine disrupting activities of surface water associated with a

- West Virginia oil and gas industry wastewater disposal site. *Sci Total Environ* 2016; 557–558: 901–910.
17. Kassotis CD, Tillitt DE, Davis JW, et al. Estrogen and androgen receptor activities of hydraulic fracturing chemicals and surface and ground water in a drilling-dense region. *Endocrinology* 2014; 155: 897–907.
 18. Kassotis CD, Tillitt DE, Lin CH, et al. Endocrine-disrupting chemicals and oil and natural gas operations: potential environmental contamination and recommendations to assess complex environmental mixtures. *Environ Health Perspect* 2016; 124: 256–264.
 19. Lester Y, Ferrer I, Thurman EM, et al. Characterization of hydraulic fracturing flowback water in Colorado: implications for water treatment. *Sci Total Environ* 2015; 512–513: 637–644.
 20. Parker KM, Zeng T, Harkness J, et al. Enhanced formation of disinfection byproducts in shale gas wastewater-impacted drinking water supplies. *Environ Sci Technol* 2014; 48: 11161–11169.
 21. Graham J, Irving J, Tang X, et al. Increased traffic accident rates associated with shale gas drilling in Pennsylvania. *Accid Anal Prev* 2015; 74: 203–209.
 22. Webb E, Hays J, Dyrzka L, et al. Potential hazards of air pollutant emissions from unconventional oil and natural gas operations on the respiratory health of children and infants. *Rev Environ Health* 2016; 31: 225–243.
 23. Garcia-Gonzales DA, Shonkoff SBC, Hays J, et al. Hazardous air pollutants associated with upstream oil and natural gas development: a critical synthesis of current peer-reviewed literature. *Annu Rev Public Health* 2019; 40: 283–304.
 24. Zilliox S and Smith JM. Supraregulatory agreements and unconventional energy development: learning from citizen concerns, enforceability and participation in Colorado. *Extract Ind Soc* 2017; 4: 69–77.
 25. Albrecht G, Sartore GM, Connor L, et al. Solastalgia: the distress caused by environmental change. *Australas Psychiatry* 2007; 15: S95–S98.
 26. Crighton EJ, Elliott SJ, Meer J, et al. Impacts of an environmental disaster on psychosocial health and well-being in Karakalpakstan. *Soc Sci Med* 2003; 56: 551–567.
 27. Kondo MC, Gross-Davis CA, May K, et al. Place-based stressors associated with industry and air pollution. *Health Place* 2014; 28: 31–37.
 28. Van Haaften EH and Van De Vijver FJ. Psychological consequences of environmental degradation. *J Health Psychol* 1996; 1: 411–429.
 29. Sangaramoorthy T, Jamison AM, Boyle MD, et al. Place-based perceptions of the impacts of fracking along the Marcellus Shale. *Soc Sci Med* 2016; 151: 27–37.
 30. Malin SA and DeMaster KT. A devil's bargain: rural environmental injustices and hydraulic fracturing on Pennsylvania's farms. *J Rural Stud* 2016; 47: 278–290.
 31. Fernando FN and Cooley DR. An oil boom's effect on quality of life (QoL): lessons from Western North Dakota. *Appl Res Qual Life* 2016; 11: 1083–1115.
 32. Fernando FN and Cooley DR. Attitudes toward shale oil development in western North Dakota: the role of place based community values in attitude formation. *J Rural Stud* 2016; 46: 132–146.
 33. Eaton E and Kinchy A. Quiet voices in the fracking debate: ambivalence, nonmobilization, and individual action in two extractive communities (Saskatchewan and Pennsylvania). *Energy Res Soc Sci* 2016; 20: 22–30.
 34. Bamberger M and Oswald RE. Impacts of gas drilling on human and animal health. *New Solut* 2012; 22: 51–77.
 35. Hirsch JK, Smalley KB, Selby-Nelson EM, et al. Psychosocial impact of fracking: a review of the literature on the mental health consequences of hydraulic fracturing. *Int J Ment Health Addiction* 2018; 16: 1–15.
 36. Steinzor N, Subra W and Sumi L. Investigating links between shale gas development and health impacts through a community survey project in Pennsylvania. *New Solut* 2013; 23: 55–83.
 37. Weinberger B, Greiner LH, Walleigh L, et al. Health symptoms in residents living near shale gas activity: a retrospective record review from the Environmental Health Project. *Prev Med Rep* 2017; 8: 112–115.
 38. Fisher MP, Mayer A, Vollet K, et al. Psychosocial implications of unconventional natural gas development: quality of life in Ohio's Guernsey and Noble Counties. *J Environ Psychol* 2018; 55: 90–98.
 39. Ferrar KJ, Kriesky J, Christen CL, et al. Assessment and longitudinal analysis of health impacts and stressors perceived to result from unconventional shale gas development in the Marcellus Shale region. *Int J Occup Environ Health* 2013; 19: 104–112.
 40. Perry SL. Development, land use, and collective trauma: the Marcellus Shale Gas Boom in rural Pennsylvania. *CAFÉ* 2012; 34: 81–92.
 41. McDermott-Levy R and Garcia V. Health concerns of northeastern Pennsylvania residents living in an unconventional oil and gas development county. *Public Health Nurs* 2016; 33: 502–510.
 42. Creswell JW. *Research design: qualitative & quantitative approaches*. Thousand Oaks, CA: Sage, 1994.
 43. Krippendorff K. *Content analysis: an introduction to its methodology*. 2nd ed. Thousand Oaks, CA: Sage, 2004.
 44. United States Census Bureau. In-, out-, net, and gross migration. County to county migration flows: 2013-2017 ACS web site, <https://www.census.gov/data/tables/2017/demo/geographic-mobility/county-to-county-migration-2013-2017.html> (2019, accessed 24 January 2014).
 45. Lee MHW, Clark A, Rupp J, et al. Public opinion toward hydraulic fracturing: the effect of beyond compliance and voluntary third-party certification. *Energ Policy* 2019; 128: 306–315.
 46. Jordan A and O'Riordan T. The precautionary principle: a legal and policy history. In: M Martuzzi and JA Tickner (eds) *The precautionary principle: protecting public health, the environment and the future of our children*. Copenhagen, Denmark: World Health Organization, 2004, pp.31–48.
 47. McKenzie LM, Allshouse WB, Byers TE, et al. Childhood hematologic cancer and residential proximity to oil and gas development. *PLoS One* 2017; 12: e0170423.
 48. Bamber AM, Hasanali SH, Nair AS, et al. A systematic review of the epidemiologic literature assessing health

- outcomes in populations living near oil and natural gas operations: study quality and future recommendations. *Int J Environ Res Public Health* 2019; 16(12): 2123. doi:10.3390/ijerph16122123
49. Michael Greenstone JC and Meckel K. *Fracking has its costs and benefits—the trick is balancing them*. Forbes. Jersey City, NJ: Forbes Media, 2018.
 50. Weber JG, Burnett JW and Xiarchos IM. Broadening benefits from natural resource extraction: housing values and taxation of natural gas wells as property. *J Pol Anal Manage* 2016; 35: 587–614.
 51. Boxall PC, Chan WH and McMillan ML. The impact of oil and natural gas facilities on rural residential property values: a spatial hedonic analysis. *Resour Energy Econ* 2005; 27: 248–269.
 52. Bennett A and Loomis J. Are housing prices pulled down or pushed up by fracked oil and gas wells? A hedonic price analysis of housing values in Weld County, Colorado. *Soc Nat Resour* 2015; 28: 1168–1186.
 53. Muehlenbachs L, Spiller E and Timmins C. The housing market impacts of shale gas development. *Am Econ Rev* 2015; 105: 3633–3659.
 54. Throupe R, Simons R and Mao X. A review of hydro “fracking” and its potential effects on real estate. *J R Estate Lit* 2013; 21: 205–232.
 55. Apergis N. The impact of fracking activities on Oklahoma’s housing prices: a panel cointegration analysis. *Energ Policy* 2019; 128: 94–101.
 56. Boslett AJ. *Valuation of unconventional oil and gas development*. PhD Thesis, University of Rhode Island, Kingston, RI, 2016.
 57. Weber J, Burnett J and Xiarchos I. *Shale gas development and housing values over a decade: evidence from the Barnett Shale* (USAAE Working Paper No. 14–65), <http://dx.doi.org/10.2139/ssrn.2467622> (2014, accessed 25 January 2020).
 58. Stephens HM and Weinstein AL. Household valuation of energy development in amenity-rich regions. *Growth Change* 2019; 50: 1375–1410.
 59. Malin SA, Opsal T, O’Connor Shelley T, et al. The right to resist or a case of injustice? Meta-power in the oil and gas fields. *Soc Forces* 2018; 97: 1811–1838.
 60. Haggerty JH, Smith KK, Weigle J, et al. Tradeoffs, balancing, and adaptation in the agriculture-oil and gas nexus: insights from farmers and ranchers in the United States. *Energy Res Soc Sci* 2019; 47: 84–92.
 61. Zucchetto J. Why now?: A case study of split estate and fracking activity in Garfield County Colorado. Master’s Theses. 625, <https://digitalcommons.cwu.edu/etd/625> (2017, accessed 25 January 2020).
 62. Webb E, Moon J, Dyrszka L, et al. Neurodevelopmental and neurological effects of chemicals associated with unconventional oil and natural gas operations and their potential effects on infants and children. *Rev Environ Health* 2017; 33: 3–29.
 63. Hei-Energy RC. *Human exposure to unconventional oil and gas development: a literature survey for research planning (Special Report 2)*. Boston, MA: Health Effects Institute–Energy, 2016.
 64. Elliott EG, Ettinger AS, Leaderer BP, et al. A systematic evaluation of chemicals in hydraulic-fracturing fluids and wastewater for reproductive and developmental toxicity. *J Expo Sci Environ Epidemiol* 2017; 27: 90–99.
 65. Yost EE, Stanek J, DeWoskin RS, et al. Overview of chronic oral toxicity values for chemicals present in hydraulic fracturing fluids, flowback, and produced waters. *Environ Sci Technol* 2016; 50: 4788–4797.
 66. Colorado Oil and Gas Conservation Commission. Senate Bill 19-181, <https://cogcc.state.co.us/sb19181.html#/overview> (2019, accessed 29 January 2020).
 67. Brändle C, Lis A, Fleischer T, et al. *Prerequisites for a social licence to operate in the (Shale) gas Industries*. 2016. doi:10.13140/RG.2.2.32747.75047
 68. Thomas M, Pidgeon N and Bradshaw M. Shale development in the US and Canada: a review of engagement practice. *Extract Ind Soc* 2018; 5: 557–569.

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