Journal of Environmental Management 234 (2019) 379–386

Contents lists available at ScienceDirect

Journal of Environmental Management

journal homepage: www.elsevier.com/locate/jenvman

Research article

Water quality perceptions and natural resources Extraction: A matter of geography?

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ARTICLE INFO

Keywords:
Water quality
Perceptions
Proximity
Density
Presence
Wells
Mines

ABSTRACT

Recent events in the United States have shown the vulnerability of water quality in certain communities. Accordingly, we conducted a survey in a large community in north central West Virginia (US) to explore the factors that influence the perceptions of water quality. We sought to assess whether respondent's proximity to a mine, gas/oil well, or bodies of water would affect their perceived health risks and environmental concern. Additionally, we aimed at understanding how these perceptions were affected by the density of these sites and the presence of these sites within defined distances. As West Virginia is rapidly expanding its natural gas production, there is no research that has objectively associated water quality perceptions with geographic location in regard to oil and gas extraction sites. With small effect sizes, our results add some evidence to the link between unconventional oil and gas extraction, geographic location, and water quality perceptions. This study suggests the need for further water quality monitoring and increased public communication about water management practices in West Virginia.

1. Introduction

1.1. Context of West Virginia

Considering the recent numerous and diverse water crises throughout the U.S., water quality has become a major issue in natural resource management, affecting populations and changing public perceptions of tap water quality (Merkel et al., 2012; Stough-Hunter et al., 2014). As recently as January 2014, a coal-related solvent leaked from its tank into the Elk River, contaminating the tap water of 300,000 persons in southern West Virginia (Whelton et al., 2015).

Following the incident, state legislators revised West Virginia above-ground storage regulations into the law SB 373 (Manuel, 2014). While this event was of particular importance, and drew intense media discussion, the Appalachia region has been long known for its coal mining activities and its impacts on water quality (Sams and Beer, 2000; Underwood et al., 2014). In 2015, the state legislators amended the law SB 373, lifting part of the regulations imposed by the bill passed after the spill (West Virginia Legislature, 2015). This example highlights conflicts between economic development alternatives and natural resources management in West Virginia. At the heart of water quality management in West Virginia lays conflicts over environmental regulations (Höök and Aleklett, 2009).

At the federal level, the recent change in the US administration favors energy development over environmental regulations (Anderson et al., 2017). Specifically, the Trump administration has sought to decrease funding for the Environmental Protection Agency, which is responsible for protecting water resources through the Clean Water Act or the Safe Drinking Water Act (Bomberg, 2017). As a result, there is uncertainty in terms of regulations, either for energy companies or for environmental organizations (Anderson et al., 2017; Bomberg, 2017).

1.2. Gas development in West Virginia

Simultaneous to water management difficulties, West Virginia is seeing an increase in the development of natural gas extraction, notably with unconventional drilling (Higginbotham et al., 2010). In November 2017, U.S. President Trump announced the signature of an intended 83-billion-dollar contract with Chinese companies to develop unconventional gas drilling in West Virginia (Reuters, 2017).

The literature has been divided about the potential environmental risks of gas development. On one hand, the environmental science community opposes contradictory views on the likelihood of groundwater aquifer contamination, arguing that the risk is minimal in one case and high in another (Engelder et al., 2014; Harkness et al., 2017; Osborn et al., 2011). For instance, Osborn et al. (2011) found higher

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https://doi.org/10.1016/j.jenvman.2018.11.126
Received 30 September 2017; Received in revised form 24 January 2018; Accepted 26 November 2018

concentrations of methane in tap water within a one kilometer radius of gas wells, compared to areas without wells. In contrast, Harkness et al. (2017) found no evidence of well water contaminated as a result of underground aquifers contaminated by gas drilling operations in their study in West Virginia.

On the other hand, regarding surface contamination, there is greater consensus on the existing risks of spills from waste disposal and water flowbacks during the extraction process (Engelder et al., 2014; Kharaka et al., 2013; Harkness et al., 2017; Osborn et al., 2011; Vengosh et al., 2013; Vidic et al., 2013). Harkness et al. (2017) found water well contaminations linked to surface contamination, in West Virginia.

1.3. Unconventional gas drilling and geographic location

Building on environmental risk perceptions, several studies investigated communities located near extraction sites (coal mines, gas/oil wells). For instance, when comparing two counties in Pennsylvania, Kriesky et al. (2013) found that residents who lived in the county with a higher density of wells perceived less environmental risks associated with unconventional gas drilling and were more supportive of the practice in general. The authors suggested attraction to positive economic impacts from gas drilling and increased knowledge to explain this difference (Kriesky et al.). Boudet et al. (2014, 2016) explored support for oil and gas unconventional drilling at the national level. Their results indicated that respondents who lived in areas where employment in natural extraction industries was higher and in "shale play areas" were more supportive of unconventional gas drilling (Boudet et al., 2016, p.603). Older respondents were found to be more supportive of the practice than younger respondents (Boudet et al., 2014). In contrast, they did not find significant differences for residents who lived in active and historically mining/oil and gas drilling areas (Boudet et al., 2016). Comparing four counties of Pennsylvania and New York, Brasier et al. (2011) conducted focus group research to understand perceived impacts of unconventional gas drilling. These authors showed that some landowners feared water quality changes for both drinking water and recreational water (based on experiences with coal mining), negatively impacting their environment and tourism (Brasier et al., 2011). To the contrary, Brasier et al. (2011) illustrated other landowners being attracted to the positive economic impacts of gas drilling development, regardless of environmental issues. Similarly, Dogaru et al. (2009) described a certain acceptance of polluted water in coal-mining communities in Romania, favoring job security over health and environmental concerns.

1.4. Environmental concern

Past research on environmental concern has shown that respondents who have lower perceptions of their local water quality have lower environmental concern and lower desire for action (Stough-Hunter et al., 2014; Story and Forsyth, 2008). The literature ties environmental concern to cultural orientations and notably how individual values are correlated to environmental concern and behavior (Dutcher et al., 2007; Thompson et al., 1990). Diverse theories and frameworks have been used to describe environmental concern (for discussions, see Dutcher et al., 2007; Fransson and Gärling, 1999; Schultz, 2001). Specifically, people who hold more egalitarian/altruistic values are more concerned about the environment than persons who hold individualistic/egoistic values (Dutcher et al., 2007; Thompson et al., 1990). In that regard, local contexts are different from each other as some values may vary across geographical locations. Consequently, several studies, including Brody et al. (2004), examined the link between places and attitudes towards the environment. An important theoretical addition to environmental concern is how place attachment and items such as residency length affect environmental perceptions (Brehm et al., 2006; Brody et al., 2004; Stough-Hunter et al., 2014). Brehm et al. (2006) demonstrated with samples from Utah and Wyoming that residents who had lived longer in their community cared less for the environment. At the opposite, Brody et al. (2004) found that residents who had lived longer in the study location were more concerned about water quality.

1.5. Proximity and water quality

Brody et al. (2004) compared driving distances from the place of residence to two different creeks in Texas to understand the relationship between proximity, knowledge and water quality perceptions. These authors join a body of research that assessed the relationship between proximity to water, environmental concern and water quality perceptions (Brody et al., 2004; Larson and Santelmann, 2007; Sutherland and Walsh, 1985). These studies demonstrated negative correlations between environmental protection and distance from the body of water under study. This suggests that respondents who lived closer to a lake or river under study were more sensitive to the protection of this resource. These studies highlight the importance of proximity factors for water quality management and for policies aimed at resource protection (Brody et al., 2004; Larson and Santelmann, 2007). Using another perspective, housing market studies demonstrated that water quality impacts sale prices, confirming the importance of proximity to bodies of water and the quality of these (Mahan et al., 2000; Muehlenbachs et al., 2015).

1.6. Contribution to water management

This study addresses the need to understand residents' water quality perceptions. While this study is preliminary in scale, implications of the results are relevant for water quality management in the current context of legislation and proposed increases in unconventional gas drilling. Although legislation on water quality management is a sensitive issue, it is necessary to understand residents' water quality perceptions. By doing so, it is possible to give data to decision-makers to take the right decisions. Results of this study will determine whether there are perceived risks related to gas drilling affecting perceptions of water quality.

Besides, from a methodological point of view, no study has empirically evaluated how proximity to water resources and natural resource extraction sites, and how density of natural resource extraction sites correlate with public perceptions of water quality and environmental concern. The goal is to replicate this method at a larger scale to better identify areas and communities that are more sensitive to perceived risks.

Results of this study can also benefit oil and gas companies in targeting communication in areas that might be more concerned to water quality issues.

2. Study purpose

Much recent literature suggests a link between proximity factors, environmental concern, and water quality perceptions. Accordingly, the goal of our study was to understand whether residents' proximity to wells (oil/gas), coal mines, or bodies of water influence water quality perceptions and environmental concern in West Virginia. Since the proximity is not necessarily a function of the density, the role of density of extraction sites within a certain area, and the absence vs. presence of sites within a specific area were also investigated. In a period of environmental regulation changes in the US, investigating the existence of a link between density and distance to natural resource extraction sites, and water quality perceptions and environmental concern is relevant. Four constructs were of particular interest when analyzing water quality perceptions: organoleptic perceptions (odor, color and taste) (based on Doria et al., 2009), perceived surface water quality (streams, rivers and lakes) (based on Hu et al., 2011), perceived health risks from drinking from the tap (based on Doria et al., 2009) and environmental concern (based on Dutcher et al., 2007). All of these items were measured using five-point Likert scales: 1 "strongly disagree," 5 "strongly agree" (for a full description of the items and variable building, see Levêque & Burns, 2017b). Higher scores in organoleptic perceptions meant better odor, color, and taste; higher scores in perceived water quality meant better water quality; higher scores in perceived health risks meant higher fears of becoming sick from drinking tap water; and higher scores in environmental concern meant higher care for general environmental problems. Proximity was defined as the nearness or distance between respondents' residence and water resources, and natural resource extraction sites (wells, mines), based on Larson and Santelmann (2007).

The following hypotheses were formulated:

Hypothesis 1. people who live closer to or have a higher density of active and abandoned mines have lower scores for environmental concern and perceived health risks, but have higher scores for organoleptic perceptions and lower scores for perceived surface water quality, based on Dogaru et al. (2009) and expanding from Kriesky et al. (2013).

Hypothesis 2. people who live closer to or have a high density of conventional, unconventional and abandoned gas and oil wells have lower environmental concern and perceived health risks, and show higher scores for organoleptic perceptions and perceived surface water quality, based on Kriesky et al. (2013).

Hypothesis 3. people who live closer to bodies of water (streams, rivers and lakes) show higher levels of environmental concern and perceived health risks, and have lower scores for organoleptic perceptions and the perceived surface water quality, based on Sutherland and Walsh (1985) and Brody et al. (2004).

Hypothesis 4. differences will appear between people who live in an area where there is either a mine, an oil/gas well or a body of water and people who live in an area deprived of these.

3. Methods

3.1. Study area

The area selected for this study was in Monongalia County, West Virginia (US) (see Fig. 1). Water is pumped from the county's major river, the Monongahela River, to be treated and distributed to the drinking water network by Morgantown Utility Board (MUB, 2015). MUB is responsible for distributing the water throughout the entire County and is the largest public water provider in West Virginia (MUB, 2015). Morgantown is the main city in the area, and is one of the largest cities in West Virginia.

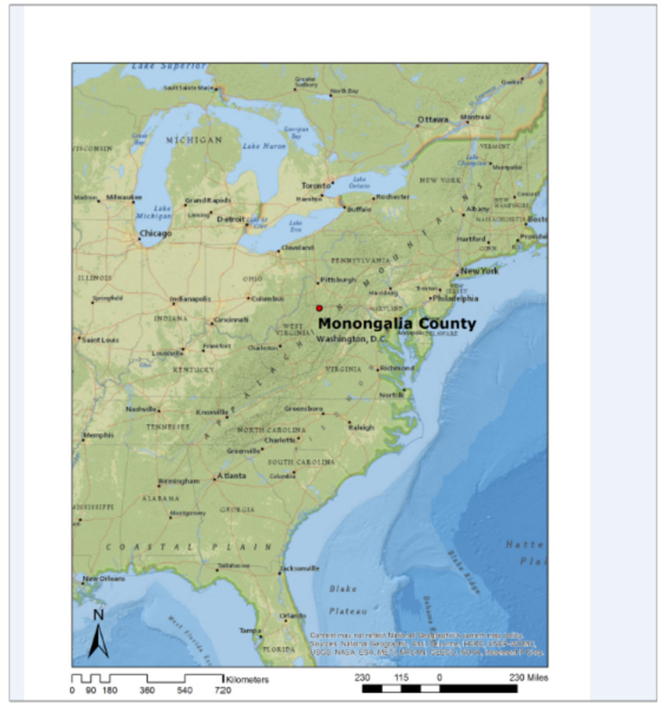

Fig. 1. Map of the study location.

3.2. Data collection

An online survey was conducted during the winter season of 2015–2016, targeting residents who lived in Morgantown and its surrounding areas within Monongalia County. Morgantown can be considered as a semi-urban city within one of the most rural states in the U.S. Surveys were distributed online using 5492 residents' email addresses. A database containing those was purchased from a commercial company. The sample was randomly selected from Monongalia County residents who had an email address. A total of 557 respondents answered the online questionnaire. Due to the impossibility to match P.O. box addresses with real residential addresses, the answers of 22 respondents had to be dropped for proximity analyses. As such, a total of 535 responses were used for the following analyses After matching responses to residential addresses, the data indicated that a total of 90% of the respondents lived in the vicinity of Morgantown (see Fig. 2). Non-response bias check was conducted using early and late respondents

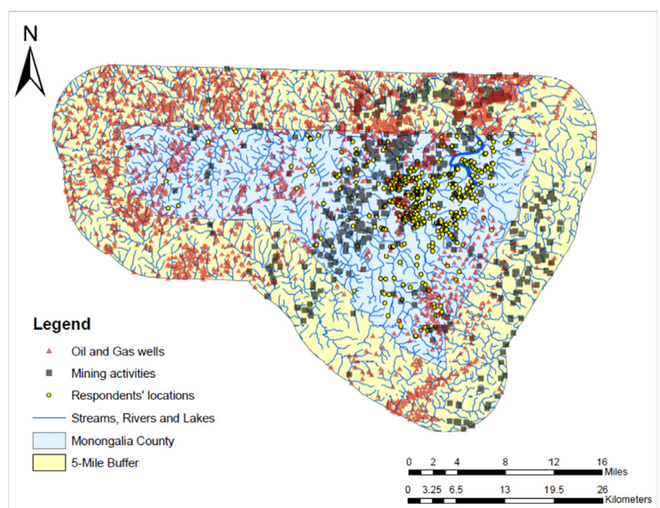

Fig. 2. Locations of the different sites and residents' locations.

and no differences were significant (for a larger discussion, see Levêque & Burns, 2017a). Comparisons of our sample with the Census data showed that our sample was relatively coherent with the general population of Morgantown and its surrounding area, reflecting the presence of a University, a regional hospital, and a chemical company (U.S. Census Bureau, 2017). Accordingly, respondents had a higher level of education, higher incomes, were older than the general population, and more women answered the survey, which is typical of email survey research (Dillman et al., 2014). When comparing our sample to the Census data for income, our sample matches the families and the married-couple families' income data (see Table 1). A total of 70% of the respondents indicated being married. As a consequence, this study should be replicated in other locations and at a larger scale in order to increase the validity and the reliability of these results.

Table 1
Demographic characteristics of participants (N = 535).

Characteristic	Sample				Census data		
	N	%	M	SD	%	M	SD
Gender	519						
Male	219	40.9			56.3		
Female	300	56.1			43.7		
Age	521		51	13.9	N/A		
Highest Level of Education	523						
Some high school	3	0.6			6.3		
High school graduate	40	7.6			20.2		
Some college	88	16.8			17.5		
Two-year college	48	9.2			6.1		
Four-year college	149	28.5			25.9		
Graduate or professional degree	195	37.3			24		
Income ($)	467		$87,580	/		$90,493	/
0–24,999	25	5.4			12		
25,000–49,999	88	18.8			15		
50,000–74,999	92	19.7			20.2		
75,000–99,999	79	16.9			15.3		
100,000–149,999	113	24.2			16.1		
150,000 or more	70	15			13.5		
Length of residency in Monongalia County (years)	525		27.36	18.69			
0-5	41	7.8			N/A		
6-10	83	15.8			N/A		
11-20	109	20.8			N/A		
21-30	83	15.8			N/A		
31-40	88	16.8			N/A		
41-50	59	11.2			N/A		
51 or more	62	11.8			N/A		

3.3. Variables

Our questionnaire focused on four variables: environmental concern (EC, combining 5 items, α = 0.870), perceived health risks (PHR, combining 4 items, α = 0.836), organoleptic perceptions (OR, 3 items: odor, color and taste, α = 0.875) and perceived surface water quality (PSWQ, streams, rivers and lakes as a single item). Demographic variables were used to control for the proximity variables.

3.4. Geolocalization

Online Geographic Information Systems (GIS) datasets were used to create the different maps. The software package ArcMap 10.4.1 was utilized to organize and map the different locations such as residents' addresses, oil and gas wells, mining activities, streams, rivers and lakes. Respondents' addresses were converted into geo-spatial data points and added to the maps. A buffer of five miles (eight kilometers) was drawn surrounding Monongalia County to include sites (wells, mines, rivers …) outside the County limits. As a result, GIS data from both the Department of Environmental Protection of West Virginia (2017) and Pennsylvania (2017) were downloaded and mapped (Monongalia County borders Pennsylvania). More specifically, the two different oil and gas well datasets were merged and refined to exclusively reflect wells that were active and abandoned during the data collection period. Plugged wells were not included within the dataset. A total of 2453 wells were mapped. Similarly, mining datasets were merged to include only active and abandoned mining sites (including sites that had not completed their reclamation by the time of the survey). A total of 641 mining sites were mapped. Streams, rivers and lakes were merged into a single dataset. Fig. 2 represents all of these sites in one map. In order to obtain a more precise picture of these sites for analysis, we created six different site categories: a) active mines, b) abandoned mines (including in reclamation), c) active conventional oil and gas wells, d) active unconventional oil and gas wells, e) abandoned oil and gas wells,

Table 2
Descriptive statistics of the nearest distances and densities, per site category.

N = 535	Nearest Distance[a]		Density[b]	
	Mean	Std. Deviation	Mean	Std. Deviation
Active mines	4292	2119	1.92	0.10
Abandoned mines	1631	791	23.94	0.85
Active conventional wells	1978	1194	21.37	0.88
Active unconventional wells	5605	2138	2.15	0.13
Abandoned wells	2314	1859	14.09	0.46
Streams, rivers or lakes	292	180	N/A	N/A

Note 1.
[a] Displayed distances are measured in meters.
[b] Density is measured within a radius of 5 km for all sites, but unconventional wells: 6 km.

and f) streams, rivers, and lakes.

3.5. Data analysis

To test proximity, we used ArcMap version 10.4.1 to analyze distances between sites and respondents' residence by using the "generate near table" command providing the nearest distances (in meters) from residents' addresses to the closest site (one site per category). For density, we first selected buffer zones to calculate the density within specific distances of the respondents' residence (Deng et al., 2008). Then, we used ArcMap and the "generate near table" command again but specified a distance of 1 km, 2 km, 3 km, 4 km and 5 km from the respondents' residence in order to calculate the frequencies for each type of site, for each buffer zone (we added 6 km for unconventional wells, based on descriptive analyses: see Table 2). These distances were selected based on the 1-km used by researchers on wells (Harkness et al., 2017; Osborn et al., 2011). The other distances were added for sensitivity (Deng et al., 2008). Frequency was not captured for streams, rivers, or lakes as they are continuous lines and not unique points. As a result, we used absence or presence of a stream, river or lake within 100 m, 200 m, 300 m and 400 m of a respondent's residence location. These distances were chosen based on the descriptive statistics (see Table 2). We also included a presence variable for wells and mines, based on the same buffer distances (1 km–6 km).

All of the tables created in ArcMap were then transferred to Excel and pasted into IBM Statistical Package for Social Sciences (SPSS) version 24 for analysis. For absence/presence analyses, dichotomous variables were created with 0 indicating the absence of a site (oil/gas well or mine) within a specific distance of a residence, and 1 indicating the presence of at least one site within this distance.

Outliers were identified using the 3-interquartile range rule for excessive distances and for excessive densities. Only mild outliers were detected for the nearest distance to a site (gas/oil well or mine) and were kept in the dataset. There were no outliers for streams, rivers, and lakes. However, there were extreme outliers for densities. Following Vaske's (2008) recommendation, we winsorized the extreme values and replaced them with the highest mild outlier values.

Using SPSS, linear regressions were selected to test the different hypotheses. For the regression analyses, we controlled for gender, income, education, age, and length of residency in the County. Independent t-tests were conducted to identify differences for the absence/presence dichotomous variables. Sample sizes were especially of interest to decide which buffer zones to select for analyses. Hedge's g was calculated instead of Cohen's d for effect sizes, as sample sizes were unequal.

Table 3
Regression analysis summary for proximity variables predicting organoleptic perceptions, perceived surface water quality, perceived health risks and environmental concern, controlling for residents' demographics.

	Organoleptic perceptions		Perceived surface water quality		Perceived health risks		Environmental concern	
	β	t	β	t	β	t	β	t
Active mine								
Abandoned mine								
Active conventional well							−0.11	−2.18*
Active unconventional well	0.14	2.88**	0.10	1.98*				
Streams, rivers, lakes								
Gender							0.22	4.89***
Age	0.12	2.36*			−0.16	−2.99**		
Length of residency	0.12	2.25*	0.14	2.51**			−0.16	−3.00**
Education								
Income	0.10	2.11*			−0.11	−2.13*	−0.15	−3.10**
	Adjusted R^2 = .06; N = 455, F (10, 444) = 4.03; p < .001. R = .29		*Adjusted R^2 = .03; N = 456, F (10, 445) = 2.34; p = .011. R = .22*		*Adjusted R^2 = .05; N = 456, F (10, 445) = 3.33; p < .001. R = .26*		*Adjusted R^2 = .10; N = 453, F (10, 442) = 6.19; p < .001. R = .35*	

Note 2: Empty cells indicate non-significant results. *p = .05, **p = .01, ***p < .001.

4. Results

4.1. Proximity

Due to multicollinearity with conventional wells, abandoned wells were dismissed from the models for proximity regressions. Regression analyses were conducted for each of the variables:

As noted in Table 3, the multiple correlation coefficients (R) indicate small effect sizes. For perceived surface water quality, the significance of the model is trivial. The model for environmental concern approaches a moderate effect size.

4.2. Density

Due to multicollinearity with active mines, abandoned mines were dismissed from the models for density regressions.

Similar to proximity, the effect sizes of the models are rather small, except for environmental concern (Table 4).

4.3. T-tests

4.3.1. Active mines

There were no significant differences in water quality perceptions or environmental concern between respondents who lived within 1, 2, 3, 4 or 5 km of an active mine and respondents who did not reside within 1, 2, 3, 4 and 5 km of a mine (respectively).

4.3.2. Abandoned mines

Similar to active mines, we did not find significant differences for any of the distances for abandoned mines (1–5 km).

4.3.3. Conventional wells

Respondents who lived within 3 km of a conventional well (N = 118, M = 3.23) had significantly higher environmental concern (t = −3.49, p < .001) than people who lived further away from a conventional well (N = 412, M = 3.55). Hedge's g indicated a small effect size (Hedge's g = 0.36). There were no significant differences for water quality perceptions. Other distances were tested but results did not prove significant.

4.3.4. Unconventional wells

According to Table 5, environmental concern was the only variable for which the difference between the two groups was not significant. For the significant differences, Hedge's g indicated small effect sizes (Table 5). Similar results were found for a distance of 5 km with larger differences in sample sizes: 336 (absence)/195 (presence). A distance of 4 km resulted in significant similar results for perceived surface water quality only, with unequal sample sizes: 399 (absence)/132 (presence). Other distances did not show significant results.

4.3.5. Abandoned wells

According to Table 6, there were significant differences for all of the independent variables between respondents who lived within 3 km of an abandoned well and respondents who resided further away from an

Table 4
Regression analysis summary for density variables predicting organoleptic perceptions, perceived surface water quality, perceived health risks and environmental concern, controlling for residents' demographics.

	Organoleptic perceptions		Perceived surface water quality		Perceived health risks		Environmental concern	
	β	t	β	t	β	t	β	t
Active mine	0.11	2.02*						
Active conventional well								
Active unconventional well			−0.11	−2.28*				
Abandoned wells			−0.10	−1.98*			0.14	2.83**
Gender							0.22	4.94***
Age	0.12	2.32*			−0.16	−2.98**		
Length of residency	0.11	2.06*	0.14	2.59**			−0.17	−3.20**
Education								
Income	0.10	2.07*			−0.10	−1.98*	−0.13	−2.67**
	Adjusted R^2 = .05; N = 455, F (9, 445) = 3.71; p < .001. R = .26		*Adjusted R^2 = .04; N = 457, F (9, 447) = 2.97; p = .002. R = .24*		*Adjusted R^2 = .05; N = 456, F (9, 446) = 3.61; p < .001. R = .26*		*Adjusted R^2 = .11; N = 453, F (9, 443) = 7.23; p < .001. R = .36*	

Note 3: Empty cells indicate non-significant results. *p = .05, **p = .01, ***p < .001.

Table 5
Group differences for water quality perceptions and environmental concern between residents who had an unconventional well within 6 km of their house and residents who did not.

Variable	Absence of site within 6 km			Presence of site within 6 km			t	p	Hedge's g
	N	*M*	*SD*	*N*	*M*	*SD*			
Organoleptic perceptions	244	3.57	0.88	287	3.39	1.02	2.18	.030	0.19
Perceived surface water quality	246	3.30	0.80	289	3.10	0.86	2.84	.005	0.24
Perceived health risks	246	2.57	0.84	288	2.74	0.92	−2.30	.022	0.19

abandoned well. These results were comparable and significant with a 4-km distance: N (absence) = 135, N (presence) = 396, except for organoleptic perceptions. With distances of 1 and 2 km, there were no differences. For 5 km, there were significant differences for perceived surface water quality and environmental concern, though the samples sizes were very unequal. It is worth noting that Hedge's g indicated small effect sizes for all of these t-tests (Table 6).

4.3.6. Streams, rivers and lakes

No differences were found for the different distances.

5. Interpretation

Our results suggest that there exist differences in water quality perceptions and environmental concern, based on the type of natural resource extraction sites, the proximity to those, and on the density and presence of these sites. However, the magnitude of these differences is rather small, reflected by small effect sizes. This means that our results add small evidence for proximity, density and presence as important factors to influence water quality perceptions and environmental concern. Nonetheless, these results are worth discussing:

5.1. Mines

Our results indicate that an increase in active mine density increases organoleptic perceptions. This result is the opposite of many studies (Morrice and Colaguiri, 2013; Shi and He, 2012). Based on Dogaru et al. (2009), we suggest that local communities that have been affected by mining in the past are aware of the quality of their water and that coping effects are at play here, noting that age and length of residency are also significant factors in influencing organoleptic perceptions. Shi and He (2012) indicated that age increased the perceptions of water quality: an interaction between age and proximity might be at play. Another explanation could be the fact that rivers that are impaired may receive treatment. It can also be a combination of better water policies and treatment technologies. Future studies should determine reasons for this result or this was an artifact. Nevertheless, this is the only significant result for mines, as proximity to or presence of active or abandoned mines did not prove significant for the different variables tested.

5.2. Wells

The different types of wells provided dissimilar results. For instance, for proximity, an increase in the distance between a respondent's residence and a conventional well led to a decrease in environmental concern. This result ruled out part of our second hypothesis, that people closer to a conventional well were less concerned about the environment. The presence of this variable indicated the same result; those respondents with a well within 3 km of their house were more environmentally concerned. Density was not significant.

In terms of proximity, as the distance between an unconventional well and a respondent's residence increased, organoleptic perceptions and perceived surface water quality increased as well. In terms of density, an increase of the number of unconventional wells within 6 km of a respondent's house significantly decreased the perceived surface water quality. Using the presence variable with a distance of 6 km, we found similar results with the addition of perceived health risks: respondents who had an unconventional well within 6 km of their house were significantly more worried about their tap water quality. These results can be compared to Brasier et al. (2011), where some landowners feared impacts of unconventional wells on water quality. We suggest that future studies compare actual water quality and respondents' level of knowledge of unconventional drilling to the water quality perceptions of these respondents (Boudet et al., 2016; Kriesky et al., 2013; Ochoo et al., 2017). Our results indicate the need for more information regarding wells and water quality monitoring, especially for residents who live closer to these wells (up to 6 km). The density of unconventional wells, proximity, or presence did not influence environmental concern, refuting part of Hypothesis 2.

Similar to the results of Brasier et al. (2011), for abandoned wells, an increase in density within 5 km decreased the perceived surface water quality and increased environmental concern. People who had an abandoned well within 3 km of their house were less satisfied with the organoleptic quality of their water, had lower scores in perceived surface water quality, had higher scores in perceived health risks, and were more concerned about the environment. These results are the opposite of our second hypothesis. This suggests that Kriesky et al.'s results may not extrapolate to abandoned wells.

5.3. Streams, rivers and lakes

While we described several studies looking at the effects of proximity to bodies of water and environmental concern and water quality,

Table 6
Group differences for water quality perceptions and environmental concern between residents who had an abandoned well within 3 km of their house and residents who did not.

Variable	Absence of site within 3 km			Presence of site within 3 km			t	p	Hedge's g
	N	M	SD	N	M	SD			
Organoleptic perceptions	172	3.60	0.86	359	3.41	1.00	2.13	.033	0.20
Perceived surface water quality	174	3.36	0.79	361	3.11	0.85	3.20	.001	0.30
Perceived health risks	174	2.49	0.78	360	2.74	0.92	−3.31	.001	0.29
Environmental concern	173	3.33	0.88	357	3.55	0.88	−2.60	.010	0.25

our results did not prove significant, challenging our third hypothesis and these studies (Brody et al., 2004; Larson and Santelmann, 2007; Ryan, 1998; Sutherland and Walsh, 1985). Perhaps this is a consequence of the methodology used (straight line, sensitivity of the distance used as buffer (Deng et al., 2008)). In addition, these studies asked specifically about the protection of certain rivers and named them in their survey. Our methods were different in this regard as we did not ask respondents about resource protection. Similar to our results, Brody et al. (2004) indicated small effect sizes and R^2 in studying spatial locations of residents and rivers. Our results confirm these small effects.

5.4. Demographics

Demographic variables proved to be of importance in determining water quality perceptions and environmental concern, confirming previous work (Brehm et al., 2006; Brody et al., 2004; Ochoo et al., 2017). Specifically, respondents who were older, resided longer in the County and had a higher income had perceived less health risks from tap water consumption and had lower environmental concern, while they had higher scores in organoleptic perceptions and perceived surface water quality, similar to earlier studies (Boudet et al., 2014; Ryan, 1998; Shi and He, 2012).

6. Discussion

In times of environmental laws change in the U.S., these results demonstrate that there is variation in water quality perceptions and environmental concern based on geographical data: residential location and mining/drilling activities. Though the effect sizes are small, our case study encourages the replication of this study at other locations in the Appalachia region.

Our results indicate that water managers should take residents' water quality perceptions into account for communication on unconventional oil/gas drilling. Specifically, there needs to be higher transparency about the water quality distributed to people's houses. This is especially important for residents who live closer to these sites: in terms of risks, and content of salts used during the extraction process. At the governing level, decision-makers should seek to protect water quality through the enforcement of best management practices and should inform residents about the laws that are currently in place for water protection and public safety. For instance, the U.S. EPA has created a framework to assess human health risk as a tool to guide decision-makers (Fitzpatrick et al., 2018). The implementation of such frameworks is important because it creates conditions for successful planning and the possibility for citizens to have their voices heard through public involvement.

While communicating on unconventional gas/oil drilling, it is necessary for agencies and water managers to disseminate more information about water quality in general. In that matter, Via (2017, p.88) suggested that modernization of monitoring systems under the “national Safe Drinking Water Act” would enable the U.S. EPA to deliver better data to the public. It is worth noting that these data need to be delivered in understandable and non-specialist ways. As such, educational programs are also needed.

In the context of West Virginia, these results indicate that there are objective differences in water quality perceptions depending on the proximity and density of natural resource extraction sites. While some of these activities have occurred for a long period of time in this region, there might be sensitivity for the upcoming development of unconventional wells. This sensitivity highlights a need to be addressed by water managers and professionals (i.e. communication). In terms of water management, there has to be a larger discussion on the balance between resource protection and economic development, and further involvement of the public in the decision-making. Last but not least, there needs to be a higher role of science in the decision-making process in West Virginia.

7. Limitations and future studies

Our study presented several limitations. First, we did not use driving distances or driving time to mines, wells, or rivers that could affect the results. We solely used planar methods. We also did not ask respondents about perceived proximity from the river, coal mines, or oil/gas wells. This could be used for comparison. Additionally, we did not differentiate between the quality of the rivers utilized in our analyses. As such, further studies could segment between proximity to impaired or non-impaired streams. A final limitation is the fact that we did not ask whether residents received royalties from resource extraction activities or worked for drilling or mining companies. Future studies could pair water well contamination research together with residents' risk perceptions of water quality contamination.

8. Conclusions and implications

Changing environmental regulations in the context of an unconventional drilling boom and aging coal mines intensifies concern over water quality management. Understanding how proximity, density and presence of natural resource extraction sites can affect residents is important, as there is uncertainty regarding risks that can affect the general public. Our results indicate the need for future studies in perceived water quality risk assessment, especially for unconventional wells, at larger scales, and in other places in the U.S. Different places may have different contexts and results. In addition, there needs to be more and better general communication to the public about the factors which may pose risks to water quality. These are increasingly important as decisions on environmental protection can directly impact communities. As such, there needs to be more scientific communication between the public, scientists, regulators, and companies.

Disclaimer

The funding source had no involvement in 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. Free and informed consent was asked from participants or their legal representatives was obtained. Our study protocol was approved by West Virginia University Institutional Review Board IRB, by West Virginia University, West Virginia, United States, protocol No.1510895135, November 2015.

Acknowledgements

We would like to thank the US National Science Foundation-Experimental Program to Stimulate Competitive Research (through WV-HEPC-Division of Science and Research) under the Award Number 145852 and the National Institute of Food and Agriculture (NIFA) for the funding of this study. We would also like to thank Dr. Jinyang Deng and Dr. Mike Strager for their help and advices for using ArcMap.

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