



## Short communication

## Health symptoms in residents living near shale gas activity: A retrospective record review from the Environmental Health Project

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## ABSTRACT

Increasing evidence demonstrates an association between health symptoms and exposure to unconventional natural gas development (UNGD). The purpose of this study is to describe the health of adults in communities with intense UNGD who presented for evaluation of symptoms. Records of 135 structured health assessments conducted between February 2012 and October 2015 were reviewed retrospectively. Publicly available data were used to determine proximity to gas wells. Analysis was restricted to records of adults who lived within 1 km of a well in Pennsylvania and denied employment in the gas industry ( $n = 51$ ). Symptoms in each record were reviewed by a physician. Symptoms that could be explained by pre-existing or concurrent conditions or social history and those that began or worsened prior to exposure were excluded. Exposure was calculated using date of well drilling within 1 km. The number of symptoms/participant ranged from 0 to 19 (mean = 6.2; SD = 5.1). Symptoms most commonly reported were: sleep disruption, headache, throat irritation, stress or anxiety, cough, shortness of breath, sinus problems, fatigue, nausea, and wheezing. These results are consistent with findings of prior studies using self-report without physician review. In comparison, our results are strengthened by the collection of health data by a health care provider, critical review of symptoms for possible alternative causes, and confirmation of timing of exposure to unconventional natural gas well relative to symptom onset or exacerbation. Our findings confirm earlier studies and add to the growing body of evidence of the association between symptoms and exposure to UNGD.

## 1. Background

The public's health should be a consideration when there is widespread adoption of new industrial activity such as extraction of natural gas through hydraulic fracturing, commonly referred to as “fracking”. Hydraulic fracturing, the injection of pressurized water, chemicals and sand into a well bore to increase production of oil or gas, was first used in conventional vertical wells drilled into discrete oil or gas reservoirs. In recent years, the development of high volume, high pressure hydraulic fracturing, combined with directional drilling, has facilitated the extraction of oil and gas from unconventional reservoirs, such as shale and other “tight” geologic formations, where the oil and gas is distributed throughout the formation rather than in defined reservoirs. Proponents of hydraulic fracturing cite benefits such as reduced dependence on foreign oil and job creation in local communities. Public health professionals and others have raised concerns about short- and long-term health and environmental impacts.

Hydraulic fracturing is part of a larger process of extracting, processing and transporting natural gas. Taken together, it is referred to as unconventional natural gas development (UNGD). UNGD sites include well pads, where the hydraulic fracturing occurs, compressor stations, metering stations, and processing plants, all of which release emissions.

Air and water monitoring near well pads have documented the presence of multiple compounds with known human health effects, both short- and long-term. Compounds of concern are volatile organic compounds including benzene, associated with short-term effects of headache and dizziness and long-term effects of aplastic anemia and leukemia (ATSDR, 2015); toluene, associated with headaches, sleepiness, confusion, and possible permanent neurological damage (ATSDR, 2011a) ethylbenzene, associated with symptoms of eye and throat irritation and a possible carcinogen (ATSDR, 2011b) and xylene, associated with eye, nose, throat, and skin irritation and possible long-term neurologic effects (CCOHS, 2017).

Other compounds with documented adverse health outcomes

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include particulate matter, associated with asthma attacks, acute bronchitis, and reduced lung function (OSHA, 2013), methylene chloride, associated with cancer (ATSDR, 2011c), and hydrogen sulfide, associated with eye, nose, and throat irritation and asthma (ATSDR, 2011d). Our understanding of the human health impacts of exposure, however, is hampered by the absence of human toxicity information on 75–80% of the chemicals used in this process (Elliott et al., 2016). In addition to chemical emissions, UNGD produces noise and light exposures at levels that may increase the risk of adverse health outcomes, including annoyance, sleep disturbance, and cardiovascular symptoms (Hays et al., 2017).

Self-report studies have consistently documented skin irritation and rash; respiratory symptoms including difficulty breathing; nose, throat, and sinus problems; gastrointestinal disturbances; headache; sleep disruption; and psychological symptoms including stress (Saber, 2013; Ferrar et al., 2013; Rabinowitz et al., 2015; Steinzor et al., 2013). These studies relied on self-report of symptoms, obtained either through a survey “check-list” that was self-administered (Saber, 2013; Steinzor et al., 2013) or administered by a research assistant (Rabinowitz et al., 2015). In one study a semi-structured interview was used (Ferrar et al., 2013). With the exception of the study conducted by Rabinowitz and colleagues (Rabinowitz et al., 2015), these studies used convenience samples that ranged in size from 33 to 108. Rabinowitz et al. used randomized subject selection and did not refer explicitly to UNGD in the survey process. Two studies included an estimate of exposure. Steinzor et al. demonstrated compounds with known human health effects in air and water samples; symptoms reported by participants were consistent with these effects. Rabinowitz et al. found increased prevalence of skin and respiratory symptoms was associated with increased proximity to natural gas wells.

Limitations of the self-report studies include the use of convenience samples and possible recall bias on the part of the participant. Onset and/or exacerbation of self-reported symptoms may be subject to recall bias on the part of the participant, particularly if the participants have a high level of awareness of the risks associated with exposure and/or understand the purpose of the study. None of the self-report studies incorporated review of data by a health care provider.

More recently, several population-based studies using publicly available or health system data have documented an association with poor birth outcomes (Casey et al., 2015; McKenzie et al., 2014; Stacy et al., 2015) asthma exacerbation (Rasmussen et al., 2016), infant mortality (Busby and Mangano, 2017), and childhood acute lymphocytic leukemia (McKenzie et al., 2017). One other study demonstrated an association with migraine, chronic rhinosinusitis, and fatigue, symptoms previously documented in the other self-report studies. (Tustin et al., 2016)

The purpose of the present study is to describe the symptoms reported in a sample of Pennsylvania residents who lived in close proximity to unconventional gas wells. We conducted a retrospective review of 135 health assessment records of individuals who live in the Marcellus Shale region of the United States. The health assessments had been conducted by family nurse practitioners in collaboration with an occupational medicine physician. Because available evidence suggests that health impacts are related to proximity to wells, with symptoms more likely in individuals who live in closer proximity to gas wells (Rabinowitz et al., 2015; Casey et al., 2015; McKenzie et al., 2014; Stacy et al., 2015; Rasmussen et al., 2016; McKenzie et al., 2017; Tustin et al., 2016), this review was restricted to the records of individuals who lived within 1 km of at least one gas well. The study was reviewed and approved by the Duquesne University Institutional Review Board.

## 2. Method

Family nurse practitioners at the Southwest Pennsylvania Environmental Health Project (EHP) have been systematically collecting health data from residents of communities located near UNGD

sites since 2012. This service was developed to meet the needs of residents who were concerned about health impacts and who sought evaluation by a health care professional. Services are advertised on the EHP website, local media, community meetings, and word-of-mouth and are offered at no charge. The health records of these clients provide a dataset of health symptoms reported by those living in proximity to UNGD sites.

Between February 1, 2012 and October 31, 2015, 135 children and adults completed the standardized health assessment, typically conducted face-to-face by a family nurse practitioner. The health assessments were conducted according to standard clinical practice for collecting a medical history and included current problems, review of systems, past medical history, family history, and social history. When indicated by the interview, a targeted physical examination was conducted. Individuals who completed this health assessment did so for their own personal health information.

All 135 records were reviewed by a team of health care providers that included a physician who is board certified occupational medicine (LW) and at least one nurse practitioner. Records were excluded if they were incomplete at the time of the review ( $n = 2$ ); the client was < 18 years of age ( $n = 21$ ); the client reported employment in the gas industry ( $n = 7$ ); client resided in a state other than Pennsylvania ( $n = 28$ ); client did not report any symptoms at the time of the health assessment ( $n = 3$ ). After these exclusion criteria were applied, 74 records remained.

### 2.1. Proximity to unconventional natural gas wells

One author (BW) used publicly available data to determine the number of unconventional natural gas wells located within 1 km of each residence for the 74 records. Publicly available data includes location and “SPUD” date, or date drilling began. Using ArcGIS, the home address was used to calculate the distance from the home to the nearest well(s). Records were excluded if it was not possible to verify at least one gas well within 1 km of the residence ( $n = 23$ ). After this criterion was applied, 51 records remained.

### 2.2. Symptom inclusion criteria

Prior to review of the records, the physician (LW) and nurse practitioner developed and implemented the symptom inclusion criteria. Each symptom recorded in the health assessment was reviewed in the context of past medical and surgical history, concurrent medical conditions, family and social history, and environmental exposures unrelated to UNGD. If a plausible cause for the symptom was identified, the symptom was not included in the analysis. For example, if the social history indicated a ½ pack/day smoking history, the symptom of “difficulty breathing” was not included. Symptoms were included only when there was no possible cause evident in the health assessment record. The records were not reviewed with the intent of establishing or confirming a diagnosis, but to determine if a plausible explanation for the symptom could be identified.

Independently, BW determined timing of the exposure for each symptom that met the inclusion criteria, using the SPUD date for each unconventional natural gas well within 1 km. The earliest SPUD date for wells within 1 km of the residence was considered the beginning of exposure to UNGD. The date of onset/exacerbation of each symptom was available in the health assessment record. If the date of onset/exacerbation of a symptom occurred prior to the earliest SPUD date for wells within 1 km, that symptom was not included in the analysis. Symptoms were included only if the onset/exacerbation occurred after the date of first exposure, estimated by the earliest SPUD date.

Descriptive statistics were used to determine frequency, distribution, and variance.



**Table 1**

Symptoms meeting inclusion criteria that were reported between February 2012 and October 2015 by 51 adults who lived within 1 km of an unconventional natural gas well in Pennsylvania.

Symptoms	# Reporting	% Reporting
Sleep disruption	22	43.1%
Headache	21	41.2%
Throat irritation	20	39.2%
Stress/anxiety	19	37.3%
Cough	17	33.3%
Shortness of breath	15	29.4%
Sinus problems	15	29.4%
Fatigue	12	23.5%
Nausea	12	23.5%
Wheezing	11	21.6%
Itchy eyes	11	21.6%
Weak/drowsy	9	17.6%
Abdominal pain	9	17.6%
Irritable moody	9	17.6%
Painful/dry eyes	8	15.7%
Painful joints	8	15.7%
Rash	8	15.7%
Dizziness	8	15.7%
Nose bleeds	7	13.7%
Tinnitus	7	13.7%
Aches	7	13.7%
Memory - short term	7	13.7%
Numbness	7	13.7%
Chest pain	6	11.8%
Hair loss	6	11.8%
Itchy skin	6	11.8%
Worry	6	11.8%
Palpitation	5	9.8%
Skin lesions/blisters	5	9.8%

### 3. Results

The 51 adults included in this record review had reported at least one symptom on their health assessment, denied occupation exposure related to natural gas extraction and lived in Pennsylvania within 1 km of an unconventional natural gas well. The average age of this sample was 57 (SD = 12.3), with a range of 24–85. More than half (56.8%) were female and the majority (83%) were married. Each individual lived within 1 km of a gas well; the number of wells ranged from 1 to 16, (mean 5.7, SD 3.6). A total of three counties in Pennsylvania are represented in this sample: Washington ( $n = 47$ ), Butler ( $n = 3$ ), and Bedford ( $n = 1$ ) counties.

In this sample, all individuals reported at least one symptom at the time of the health assessment. The number of symptoms reported ranged from 1 to 19, with an average of 7.2 (SD = 4.9). Not all of the symptoms reported met the inclusion criteria (i.e., symptoms began or worsened after exposure to UNGD and could not be explained by a pre-existing or concurrent health condition). Some symptoms reported by 19 individuals (37%) did not meet inclusion criteria and were excluded, although the individuals remained in the analysis. The number of symptoms excluded/individual ranged from 1 to 7, with an average of 2.4 symptoms. For five of the 19 individuals, all reported symptoms were excluded.

The number of symptoms meeting inclusion criteria ranged from 0 to 19 with a mean of 6.2 (SD = 5.1) symptoms/individual. The most frequently reported symptoms that met inclusion criteria were sleep disturbance, headache, throat irritation, stress/anxiety, cough, shortness of breath, sinus, fatigue, wheezing, nausea (> 20% of sample).

Symptoms shown in Table 1 were reported by at least 10% of the sample. Symptoms not shown on Table 1, reported by < 10% of the sample were: weight change, hearing loss, vomiting, burning skin, and depression.

### 4. Discussion

The symptoms reported by residents of southwestern Pennsylvania who live within 1 km of an unconventional natural gas well are consistent with those reported in other self-report studies. The most commonly reported symptoms in this sample of adults were sleep disruption, headache, throat irritation, stress/anxiety, cough, shortness of breath, sinus problems, fatigue, nausea, and wheezing.

Limitations of this study include use of self-report data and a convenience sample. However, our methodology mitigates some of the limitations typically associated with this type of data and strengthens our results. Reported symptoms were abstracted from health records obtained by a nurse practitioner in consultation with a physician. Each symptom was evaluated using criteria to establish onset or exacerbation of the symptom relative to exposure to UNGD and to rule out other plausible explanations for the symptom. Only those symptoms that could not be explained by evidence in the health record (i.e., medical, surgical, or social history) and had a date of onset or exacerbation after exposure to UNGD began were included in the analysis.

Both the collection of symptom data, and the inclusion criteria used, distinguish this study from others that rely only on self-report. In comparison to such studies, our results are strengthened by the collection of health assessment data by a health care provider, critical review of symptoms for possible alternative causes, and confirmation of timing of exposure relative to symptom onset or exacerbation.

Health care providers whose clients live or work in communities where unconventional techniques are used to extract natural gas and/or oil should be alert to the possibility of environmental exposures. Symptoms, particularly those that are unexplained by concurrent medical conditions, may be related to environmental exposures.

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### Conflict of interest

The authors declare no conflict of interest.

### References

- ATSDR, 2011a. Toluene. Available at: Agency for Toxic Substances and Disease Registry Toxic Substances Portal <http://www.atsdr.cdc.gov/substances/toxsubstance.asp?toxid=29>, Accessed date: 13 February 2017.
- ATSDR, 2011b. Ethylbenzene. Available at: Agency for Toxic Substances and Disease Registry Toxic Substances Portal <https://www.atsdr.cdc.gov/substances/toxsubstance.asp?toxid=66>, Accessed date: 13 February 2017.
- ATSDR, 2011c. Methylene chloride. Available at: Agency for Toxic Substances and Disease Registry Toxic Substances Portal <http://www.atsdr.cdc.gov/substances/toxsubstance.asp?toxid=42>, Accessed date: 13 February 2017.
- ATSDR, 2011d. Hydrogen sulfide carbonyl sulfide. Available at: Agency for Toxic Substances and Disease Registry Toxic Substances Portal <http://www.atsdr.cdc.gov/substances/toxsubstance.asp?toxid=67>, Accessed date: 13 February 2017.
- ATSDR, 2015. ToxFaqSTM for benzene. Available at: Agency for Toxic Substances and Disease Registry Toxic Substances Portal <https://www.atsdr.cdc.gov/toxfaqs/faq.asp?id=38&tid=14>, Accessed date: 13 February 2017.
- Busby, C., Mangano, J., 2017. There's a world going on underground—infant mortality and fracking in Pennsylvania. *J. Environ. Prot.* 8, 381–393.
- Casey, J.A., et al., 2015. Unconventional natural gas development and birth outcomes in Pennsylvania, USA. *Epidemiology*. <http://dx.doi.org/10.1097/EDE.0000000000000387>.
- CCOHS, 2017. Xylene. Available at: Canadian Centre for Occupational Health and Safety OSH Answers Fact Sheet [http://www.ccohs.ca/oshanswers/chemicals/chem\\_profiles/xylene.html](http://www.ccohs.ca/oshanswers/chemicals/chem_profiles/xylene.html), Accessed date: 13 February 2017.
- Elliott, E.G., Ettinger, A.S., Leaderer, B.P., Bracken, M.B., Deziel, N.C., 2016. A systematic evaluation of chemicals in hydraulic-fracturing fluids and wastewater for reproductive and developmental toxicity. *J. Expo. Sci. Environ. Epidemiol.* <http://dx.doi.org/10.1038/jes.2015.81>.
- Ferrar, K.J., et al., 2013. 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* 19, 104–112.
- Hays, J., McCawley, M., Shonkoff, S.B.C., 2017. Public health implications of environmental noise associated with unconventional oil and gas development. *Sci. Total Environ.* 580, 448–456.
- McKenzie, L.M., et al., 2014. Birth outcomes and maternal residential proximity to natural gas development in rural Colorado. *Environ. Health Perspect.* 122, 412–417.
- McKenzie, L.M., et al., 2017. Childhood hematologic cancer and residential proximity to oil and gas development. *PLoS One* 12, e0170423.
- OSHA, 2013. Diesel exhaust. Available at: **Occupational Health and Safety Administration Safety and Health Topics**<https://www.osha.gov/SLTC/dieselexhaust/>.
- Rabinowitz, P.M., et al., 2015. Proximity to natural gas wells and reported health status: results of a household survey in Washington County, Pennsylvania. *Environ. Health Perspect.* 123, 21–26.
- Rasmussen, S.G., et al., 2016. Association between unconventional natural gas development in the Marcellus Shale and asthma exacerbations. *JAMA Intern. Med.* <http://dx.doi.org/10.1001/jamainternmed.2016.2436>.
- Saberi, P., 2013. Navigating medical issues in shale territory. *New Solut. J. Environ. Occup. Health Policy* 23, 209–221.
- Stacy, S.L., et al., 2015. Perinatal outcomes and unconventional natural gas operations in Southwest Pennsylvania. *PLoS One* 10, e0126425.
- Steinzor, N., Subra, W., Sumi, L., 2013. Investigating links between shale gas development and health impacts through a community survey project in Pennsylvania. *New Solut. J. Environ. Occup. Health Policy* 23, 55–83.
- Tustin, A.W., et al., 2016. Associations between unconventional natural gas development and nasal and sinus, migraine headache, and fatigue symptoms in Pennsylvania. *Environ. Health Perspect.* <http://dx.doi.org/10.1289/EHP281>.