

**Compilation of UNGD Health Studies Using Pennsylvania Data  
December 17, 2018**

*Abstracts for articles were provided by the authors of those articles and accessed through The Endocrine Disruption Exchange FrackHealth Database.*

**Beleche T, Cintina I. 2018. Fracking and risky behaviors: Evidence from Pennsylvania. Econ Hum Biol 31:69-82, doi: [10.1016/j.ehb.2018.08.001](https://doi.org/10.1016/j.ehb.2018.08.001).** In the past decade, the technological developments in the oil and natural gas extraction industry made the extraction of shale gas economically feasible and prompted local economic booms across the US. Anecdotal evidence suggests that areas with unconventional gas development experience a disproportionate increase in the young male population who are more likely to be involved in risk-taking behavior. Moreover, the sudden income gains or demographic shifts might increase the demand for various goods and services, including entertainment and illegal activities provided by the adult entertainment industry. We investigate the relationship between unconventional gas development and a variety of risk-taking outcomes such as sexually transmitted infections, and prostitution-related arrests. Our identification strategy exploits the variation in shale gas or unconventional well drilling across time and counties in conjecture with a number of datasets that allow us to investigate the potential mechanisms. Our findings indicate that Pennsylvania counties with fracking activities have higher rates of gonorrhea and chlamydia infections (7.8% and 2.6%, respectively), as well as higher prostitution related arrests (19.7%). We posit that changes in the labor market and associated impacts to income or composition of workers may play a role in the estimated effects, but we do not find evidence in support of these hypotheses.

**Casey JA, Wilcox HC, Hirsch AG, Pollak J, Schwartz BS. 2018. Associations of unconventional natural gas development with depression symptoms and disordered sleep in Pennsylvania. Sci Rep 8(1):11375, doi: [10.1038/s41598-018-29747-2](https://doi.org/10.1038/s41598-018-29747-2).** Environmental and community factors may influence the development or course of depression and sleep problems. We evaluated the association of unconventional natural gas development (UNGD) with depression symptoms and disordered sleep diagnoses using the Patient Health Questionnaire-8 and electronic health record data among Geisinger adult primary care patients in Pennsylvania. Participants received a retrospective metric for UNGD at their residence (very low, low, medium, and high) that incorporated dates and durations of well development, distance from patient homes to wells, and well characteristics. Analyses included 4,762 participants with no (62%), mild (23%),

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**SW Pennsylvania Office**

2001 Waterdam Plaza Suite 201, McMurray, PA 15317  
Office: 724.260.5504 • Cell: 724.249.7501

**Connecticut Office**

470 James Street, Suite 007, New Haven, CT 06513  
Cell: 724.263.5925

moderate (10%), and moderately severe or severe (5%) depression symptoms in 2014–2015 and 3,868 disordered sleep diagnoses between 2009–2015. We observed associations between living closer to more and bigger wells and depression symptoms, but not disordered sleep diagnoses in models weighted to account for sampling design and participation. High UNGD (vs. very low) was associated with depression symptoms in an adjusted negative binomial model (exponentiated coefficient = 1.18, 95% confidence interval [CI]: 1.04–1.34). High and low UNGD (vs. very low) were associated with depression symptoms (vs. none) in an adjusted multinomial logistic model. Our findings suggest that UNGD may be associated with adverse mental health in Pennsylvania.

**Hill EL. 2018. Shale gas development and infant health: Evidence from Pennsylvania. *J Health Econ* 61:134-150, doi: [10.1016/j.jhealeco.2018.07.004](https://doi.org/10.1016/j.jhealeco.2018.07.004).** This research exploits the introduction of shale gas wells in Pennsylvania in response to growing controversy around the drilling method of hydraulic fracturing. Using detailed location data on maternal addresses and GIS coordinates of gas wells, this study examines singleton births to mothers residing close to a shale gas well from 2003 to 2010 in Pennsylvania. The introduction of drilling increased low birth weight and decreased term birth weight on average among mothers living within 2.5 km of a well compared to mothers living within 2.5 km of a permitted well. Adverse effects were also detected using measures such as small for gestational age and APGAR scores, while no effects on gestation periods were found. In the intensive margin, an additional well is associated with a 7 percent increase in low birth weight, a 5 g reduction in term birth weight and a 3 percent increase in premature birth. These results are robust to other measures of infant health, many changes in specification and falsification tests. These findings suggest that shale gas development poses significant risks to human health.

**Koehler K, Ellis JH, Casey J, Manthos D, Bandeen-Roche K, Platt R, Schwartz B. 2018. Exposure assessment using secondary data sources in unconventional natural gas development and health studies. *Environ Sci Technol* 52(10):6061-6069, doi: [10.1021/acs.est.8b00507](https://doi.org/10.1021/acs.est.8b00507).** Studies of unconventional natural gas development (UNGD) and health have ranked participants along a gradient of geographic information system (GIS)-based activity that incorporated distance between participants' home addresses and unconventional natural gas wells. However, studies have used different activity metrics, making results comparisons across studies difficult. Existing studies have only incorporated wells, without accounting for other components of development (e.g., compressors, impoundments, flaring events), for which it is often difficult to obtain reliable data, but may have relevance to health. Our aims were to: (1) describe, in space and time, UNGD-related compressors, impoundments, and flaring events, (2) evaluate whether and how to incorporate these into UNGD activity assessment, (3) evaluate associations of these different approaches with mild asthma exacerbations. We identified 361 compressor stations, 1,218 impoundments, and 216 locations with flaring events. A principal component analysis identified a single component that was approximately an equal mix of the metrics for compressors, impoundments, and four phases of well development (pad preparation, drilling, stimulation, and production). However, temporal coverage for impoundments and flaring data was sparse. Ultimately, we evaluated three UNGD activity metrics, including two based on existing studies and a novel metric that included well pad development, drilling, stimulation,

production and compressor engine aspects of UNGD. The three metrics had varying magnitudes of association with mild asthma exacerbations, although the highest category of each metric (vs. the lowest) was associated with the outcome.

**Peng L, Meyerhoefer C, Chou SY. The health implications of unconventional natural gas development in Pennsylvania. Health Econ, doi: [10.1002/hec.3649](https://doi.org/10.1002/hec.3649).** We investigate the health impacts of unconventional natural gas development of Marcellus shale in Pennsylvania between 2001 and 2013 by merging well permit data from the Pennsylvania Department of Environmental Protection with a database of all inpatient hospital admissions. After comparing changes in hospitalization rates over time for air pollution-sensitive diseases in counties with unconventional gas wells to changes in hospitalization rates in nonwell counties, we find a significant association between shale gas development and hospitalizations for pneumonia among the elderly, which is consistent with higher levels of air pollution resulting from unconventional natural gas development. We note that the lack of any detectable impact of shale gas development on younger populations may be due to unobserved factors contemporaneous with drilling, such as migration.

**Willis MD, Jusko TA, Halterman JS, Hill EL. 2018. Unconventional natural gas development and pediatric asthma hospitalizations in Pennsylvania. Environ Res 166:402-408, doi: [10.1016/j.envres.2018.06.022](https://doi.org/10.1016/j.envres.2018.06.022).** Background: Pediatric asthma is a common chronic condition that can be exacerbated by environmental exposures, and unconventional natural gas development (UNGD) has been associated with decreased community air quality. This study aims to quantify the association between UNGD and pediatric asthma hospitalizations. Methods: We compare pediatric asthma hospitalizations among zip codes with and without exposure to UNGD between 2003 and 2014 using a difference-in-differences panel analysis. Our UNGD exposure metrics include cumulative and contemporaneous drilling as well as reported air emissions by site. Results: We observed consistently elevated odds of hospitalizations in the top tertile of pediatric patients exposed to unconventional drilling compared with their unexposed peers. During the same quarter a well was drilled, we find a 25% increase (95% CI: 1.07, 1.47) in the odds of being hospitalized for asthma. Ever-establishment of an UNGD well within a zip code was associated with a 1.19 (95% CI: 1.04, 1.36) increased odds of a pediatric asthma hospitalization. Our results further demonstrate that increasing specific air emissions from UNGD sites are associated with increased risks of pediatric asthma hospitalizations (e.g. 2,2,4-trimethylpentane, formaldehyde, x-hexane). These results hold across multiple age groups and sensitivity analyses. Conclusions: Community-level UNGD exposure metrics were associated with increased odds of pediatric asthma-related hospitalization among young children and adolescents. This study provides evidence that additional regulations may be necessary to protect children's respiratory health from UNGD activities.

**Busby C, Mangano JJ. 2017. There's a world going on underground —infant mortality and fracking in Pennsylvania. J Environ Prot 8(4):381-393, doi: [10.4236/jep.2017.84028](https://doi.org/10.4236/jep.2017.84028).** Background: There has been a rapid global development of the horizontal drilling and hydraulic fracturing process termed fracking. This involves the dispersion of “produced water” which contains naturally occurring radioactive material (NORM) which may contaminate surface

water and pose a health risk. Objectives: To investigate association between early (0-28 days) infant mortality by county in Pennsylvania and fracking. Methods: We compared early infant mortality for 2007-2010 after fracking developed with a control period 2003-2006, contrasting a group of the 10 most heavily fracked counties with the rest of Pennsylvania. Results: Whilst early infant deaths decreased by 2.4% in the State over the period, in the 82,558 births in the 10 fracked counties there was a significant increase in mortality (238 vs 193; RR = 1.29; 95% CI 1.05, 1.55; p = 0.011). For the five north east fracked counties Bradford, Susquehanna, Lycoming, Wyoming and Tioga the combined early infant mortality increased from 34 deaths to 60 (RR 1.66; 1.05, 2.51; p = 0.014), whereas in the south western 5 counties Washington, Westmoreland, Fayette, Butler and Greene the increase was modest, 157 to 178 (RR 1.18; 0.95, 1.46; p = 0.13). Increased risk was associated with exposure to groundwater, expressed as the county ratio of water wells divided by the number of births. Conclusions: Fracking appears to be associated with early infant mortality in populations living in counties where the process is carried out. There is some evidence that the effect is associated with private water well density and/or environmental law violations.

**Hirsch JK, Bryant Smalley K, Selby-Nelson EM, Hamel-Lambert JM, Rosmann MR, Barnes TA, Abrahamson D, Meit SS, GreyWolf I, Beckmann S, et al. 2017. Psychosocial impact of fracking: a review of the literature on the mental health consequences of hydraulic fracturing. *Int J Ment Health Addict* 16(1):1-15, doi: [10.1007/s11469-017-9792-5](https://doi.org/10.1007/s11469-017-9792-5).** The process of natural gas extraction known as hydraulic fracturing, or fracking, is a controversial energy acquisition technique often viewed with disdain by the public, due to its potential for environmental harm. However, the mental health and psychological well-being of fracking communities, including potential benefits and detriments, are often overlooked. We reviewed the literature on the association between fracking and psychological functioning, finding that although persons living in fracking communities may experience some minimal, initial benefits such as land lease income or infrastructure development, they may also experience worry, anxiety, and depression about lifestyle, health, safety, and financial security, as well as exposure to neurotoxins and changes to the physical landscape. Indeed, entire communities can experience collective trauma as a result of the “boom/bust” cycle that often occurs when industries impinge on community life. Impacted communities are often already vulnerable, including poor, rural, or indigenous persons, who may continue to experience the deleterious effects of fracking for generations. An influx of workers to fracking communities often stokes fears about outsiders and crime, yet, it must be recognized that this population of mobile workers is also vulnerable, often ostracized, and without social support. Practitioners, researchers, and policy makers alike should continue to investigate the potential psychological ramifications of fracking, so that effective and targeted intervention strategies can be developed, disseminated, and implemented to improve mental health in fracking communities.

**Komarek T, Cseh A. 2017. Fracking and public health: Evidence from gonorrhoea incidence in the Marcellus Shale region. *J Public Health Policy* 38(4):464-481, doi: [10.1057/s41271-017-0089-5](https://doi.org/10.1057/s41271-017-0089-5).** The United States (US) began to experience a boom in natural gas production in the 2000s due to the advent of hydraulic fracturing (fracking) and horizontal drilling technology. While the natural gas boom affected many people through lower energy prices, the strongest

effects were concentrated in smaller communities where the fracking occurred. We analyze one potential cost to communities where fracking takes place: an increase of sexually transmitted diseases. We use a quasi-natural experiment within the Marcellus shale region plus panel data estimation techniques to quantify the impact of fracking activity on local gonorrhea incidences. We found fracking activity to be associated with an increase in gonorrhea. Our findings may be useful to public health officials. To make informed decisions about resource extraction, policy makers as well as regulators and communities need to be informed of all the benefits as well as the costs.

**McCawley MA. 2017. Does increased traffic flow around unconventional resource development activities represent the major respiratory hazard to neighboring communities? knowns and unknowns. *Current Opinion in Pulmonary Medicine* 23(2):161-166, doi:**

**[10.1097/MCP.0000000000000361](https://doi.org/10.1097/MCP.0000000000000361).** McCawley has conducted a review of research on air emissions and respiratory effects. He suggests that respiratory effects may not only be the result of activities on the well pad. Instead he says that the most recent publications on the health effects of hydraulic fracturing operations are similar to studies of diesel particulate exposure near roadways and the health effects associated with those exposures. It seems at least possible that some, if not all, of the respiratory effects associated with unconventional resource development may be traffic-related. Road traffic generated by hydraulic fracturing operations is one possible source of environmental impact whose significance has, until now, been largely neglected in the available literature with 4000 to 6000 vehicles visiting the well pad.

**Weinberger B, Greiner LH, Walleigh L, Brown D. Health symptoms in residents living near shale gas activity: a retrospective record review from the Environmental Health Project. *Prev Med Rep* 8:112-115, doi: [10.1016/j.pmedr.2017.09.002](https://doi.org/10.1016/j.pmedr.2017.09.002).** 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 - 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.

**Carpenter DO. 2016. Hydraulic fracturing for natural gas: impact on health and environment. Rev Environ Health 31(1):47-51; doi: [10.1515/reveh-2015-0055](https://doi.org/10.1515/reveh-2015-0055).** Carpenter discusses the threats to human health from the extraction process as currently practiced. There are immediate threats to health resulting from air pollution from volatile organic compounds, which contain carcinogens such as benzene and ethyl-benzene, and which have adverse neurologic and respiratory effects. Hydrogen sulfide, a component of natural gas, is a potent neuro- and respiratory toxin. In addition, levels of formaldehyde are elevated around well sites due to truck traffic and conversion of methane to formaldehyde by sunlight. There are major concerns about water contamination because the chemicals used can get into both ground and surface water. Much of the produced water (up to 40% of what is injected) comes back out of the gas well with significant radioactivity because radium in subsurface rock is relatively water soluble.

**Finkel ML. 2016. Shale gas development and cancer incidence in southwest Pennsylvania. Public Health 141:198-206, doi: [10.1016/j.puhe.2016.09.008](https://doi.org/10.1016/j.puhe.2016.09.008).** Finkel studied the extent to which unconventional gas development leads to an increase in cancer incidence in Southwest Pennsylvania. She used data on urinary bladder and thyroid cancer and leukemia, evaluating their incidence among counties with high, moderate and minimal number of producing wells. She also compared the cancer incidence before and after drilling activity. Data are evaluated for the years 2000-2004, 2004-2008 and 2008-2012. The number of urinary bladder cases diagnosed was higher than expected in both sexes in counties with shale gas activity. In counties with the fewest number of producing wells, the increase in cases was essentially non-existent. The number of observed cases of thyroid cancer increased substantially among both sexes over the time period in all counties regardless of the number of wells drilled. The pattern for leukemia was mixed among males and females and among the counties regardless of the extent of shale gas development activities. It will take more research to understand the extent to which there is a causal relationship between different forms of cancer and producing wells.

**Ma Z, Sneeringer K, Liu L, Kuller L. 2016. Time series evaluation of birth defects in areas with and without unconventional natural gas development. J Public Health Epidemiol 1(2); doi: [10.16966/2471-8211.107](https://doi.org/10.16966/2471-8211.107).** Ma, Lui and Kuller evaluated the association of unconventional natural gas development (UNGD) and birth defects using 2003-2012 Pennsylvania birth registry data. The researchers found that in areas with UNGD, birth defects prevalence rate was 6.3/1,000 live births before UNGD and 5.0/1,000 live births after UNGD, a 20.6% drop, while birth defects prevalence rate in zip code areas without UNGD was 4.7/1,000 live births. We conclude UNGD was not associated with birth defects prevalence rate trend and level changes. Further studies are needed to address why birth defects prevalence rate in UNGD areas were consistently 22% higher than in non-UNGD areas.

**McDermott-Levy R, Garcia V. 2016. Health concerns of northeastern Pennsylvania residents living in an unconventional oil and gas development county. Public Health Nurs 33(6):502-510, doi: [10.1111/phn.12265](https://doi.org/10.1111/phn.12265).** This study was conducted to describe the health concerns of residents of an unconventional oil and natural gas development (UOGD) community and identify methods to best disseminate health information to the residents. It was a study of 27

residents of Wyoming County, Pennsylvania. Residents described their health concerns in terms of their changing community, their feelings of stress and powerlessness related to these changes, and the limited response of their local policymakers and protective agencies. There were indications of misinformation related to routine environmental health and UOGD environmental risks. Web-based educational programs with downloadable printed materials to bridge the knowledge gaps of residents and health professionals are recommended. The researchers recommend that public health nurses provide education to communities and other health professionals regarding environmental health risks, work with communities to advocate for health-protective regulations, and adopt a community-based participatory approach to meet the needs of community members.

**Rasmussen SG, Ogburn EL, McCormack M, Casey JA, Bandeen-Roche K, Mercer DG, Schwartz BS. 2016. Association between unconventional natural gas development in the Marcellus Shale and asthma exacerbations. *JAMA Intern Med* 176(9):1334-1343, doi:**

**[10.1001/jamainternmed.2016.2436](https://doi.org/10.1001/jamainternmed.2016.2436).** Rasmussen and her colleagues evaluated associations between UNGD and asthma exacerbations by comparing patients with asthma with and without exacerbations from 2005 through 2012 treated at the Geisinger Clinic, which provides primary care services to over 400 000 patients in Pennsylvania. They found that living near UNGD operations significantly increases asthma attacks, according to a study of 35,000 medical records of people with asthma in north and central PA from 2005-2012. The data show that those who live near a higher number of, or larger, active gas wells were 1.5-4 times more likely to suffer from asthma attacks compared to those who live farther away, with the closest group having the highest risk. There was increased risk in all three types of exacerbations defined: mild (new oral corticosteroid medication order), moderate (emergency department encounter), or severe (hospitalization). In addition, researchers identified increased risk during all four phases of well development: pad preparation, drilling, stimulation (UNGD), and production.

**Tustin AW, Hirsch A, Rasmussen S, Casey J, Bandeen-Roche K, Schwartz B. 2016. Associations between unconventional natural gas development and nasal and sinus, migraine headache, and fatigue symptoms in Pennsylvania. *Environ Health Perspect* 125:189-197, doi:**

**[10.1289/EHP281](https://doi.org/10.1289/EHP281).** This study provides evidence that UNGD is associated with nasal and sinus, migraine headache, and fatigue symptoms in a general population representative sample. Researchers mailed a self-administered questionnaire to 23,700 adult patients of the Geisinger Clinic. They created a summary UNGD activity metric that incorporated well phase, location, total depth, daily gas production and inverse distance-squared to patient residences. Those who met criteria for two or more of the health conditions were nearly twice as likely to live closer to more or larger wells.

**Webb, E., Hays, J., Dyrzka, L., Rodriguez, B., Cox, C., Huffling, K., & Bushkin-Bedient, S. (2016). Potential hazards of air pollutant emissions from unconventional oil and natural gas operations on the respiratory health of children and infants. *Reviews on Environmental Health*, 31(2), 225-243. doi: [10.1515/reveh-2014-0070](https://doi.org/10.1515/reveh-2014-0070).** [This study examined potential respiratory effects from exposure to known emissions from UNGD. It is not specific to PA.] Researchers focused on exposures to ozone, particulate matter, silica dust, benzene, and

formaldehyde—all of which are associated with drilling and UNGD operations—noting that all are linked to adverse respiratory health effects, particularly in infants and children. Benzene, for example, emitted from gas wells, production tanks, compressors, and pipelines, is a carcinogen also linked to serious respiratory outcomes in infants and children, including pulmonary infections in newborns. As the authors emphasized, this review did not consider other air pollutants commonly associated with drilling and UNGD activities, namely hydrogen sulfide, polycyclic aromatic hydrocarbons, and oxides of nitrogen. Although improved exposure assessment, air monitoring, and long-term studies are still lacking, existing evidence was sufficient for the authors to “strongly recommend precautionary measures at this time.”

**Bamberger, M. & Oswald, R. E. (2015). Long-term impacts of unconventional drilling operations on humans and animal health. *Journal of Environmental Science and Health, Part A: Toxic/Hazardous Substances and Environmental Engineering*, 50, 447-59. doi:**

**[10.1080/10934529.2015.992655](https://doi.org/10.1080/10934529.2015.992655).** A follow-up study of 21 case studies from five states found that the distribution of symptoms in animals and humans affected by nearby UNGD operations was, since 2012, unchanged for humans and companion animals. In food animals, reproductive problems decreased over time while respiratory problems and growth problems increased. This longitudinal case study illustrates the importance of obtaining detailed epidemiological data on the long-term health effects of multiple chemical exposures and multiple routes of exposure that are characteristic of the environmental impacts of unconventional drilling operations.

**Stacy SL., Brink, L. L, Larkin, J. D., Sadoski, Y, Goldstein, B. C., Pitt, B. R., & Talbott, E. O. (2015). Perinatal outcomes and unconventional natural gas operations in southwest Pennsylvania. *PLoS One*, 10, e0126425. doi: [10.1371/journal.pone.0126425](https://doi.org/10.1371/journal.pone.0126425).** In this study, researchers looked at birth outcomes for 15,451 babies born in Washington, Westmoreland, and Butler counties from 2007 through 2010. Exposure was determined as proximity and density of wells in relation to the residence of the pregnant woman. Researchers divided the data into four groups, based upon the number and proximity of wells within a 10-mile radius of the mothers’ homes. Mothers whose homes fell in the top group for proximity to a high density of such wells were 34 percent more likely to have babies who were “small for gestational age” than mothers whose homes fell in the bottom 25 percent. “Small for gestational age” refers to babies whose birth weight ranks them below the smallest 10 percent when compared to their peers. Comparison of the most to least exposed also had higher incidence of low birth weight.

**Casey JA, Savitz DA, Rasmussen SG, Ogburn EL, Pollak J, Mercer DG, Schwartz BS. 2015. Unconventional natural gas development and birth outcomes in Pennsylvania, USA. *Epidemiology* 27(2):163-172, doi: [10.1097/ede.0000000000000387](https://doi.org/10.1097/ede.0000000000000387).** Casey found birth that pregnant women who live near active UNGD operations in Pennsylvania were at a 40 percent increased risk of giving birth prematurely and at a 30 percent increased risk for having obstetrician-labeled high-risk pregnancies, than those not living near UNGD operations. High-risk pregnancies were those that included hypertension, high pre-pregnancy body mass index, and asthma. The study used data from the Geisinger Health System on 9,384 pregnant women and their 10,496 newborns between January 2009 and January 2013; Geisinger covers 40

counties in north and central Pennsylvania. Researchers developed an index for proximity to UNGD wells based on distance from the women's homes, stage of drilling and depth of wells dug, and the amount of gas that was produced at those wells during the pregnancies. The highest-activity quartile had the highest rates of premature births and high-risk pregnancies.

**Jemielita T, Gerton GL, Neidell M, Chillrud S, Yan B, Stute M, Howarth M, Saberi P, Fausti N, Penning TM, et al. 2015. Unconventional gas and oil drilling is associated with increased hospital utilization rates. PloS One 10(7):e0131093, doi: [10.1371/journal.pone.0131093](https://doi.org/10.1371/journal.pone.0131093).**

This study by University of Pennsylvania and Columbia University researchers found that drilling and UNGD activity was associated with increased rates of hospitalization in Pennsylvania. During a period of intensive increase in drilling and hydro-fracturing activity between 2007 and 2011, inpatient prevalence rates surged for people living near shale gas wells. Cardiology inpatient prevalence rates were significantly associated with number of wells per zip code and their density, while neurology inpatient prevalence rates were significantly associated with density of wells. Hospitalizations for cancer, skin conditions, and urological problems also rose significantly. During the same time period, no such increase in health problems was observed in a control Pennsylvania county without any drilling and UNGD activity. In communities with the most wells, the rate of cardiology hospitalizations was 27 percent higher than in control communities with no UNGD.

**Slizovskiy, I. B., Conti, L. A., Trufan, S. J., Reif, J. S., Lamers, V. T., Stowe, M. H., Dziura, J., & Rabinowitz, P. M. (2015). Reported health conditions in animals residing near natural gas wells in southwestern Pennsylvania, *Journal of Environmental Science and Health, Part A: Toxic/Hazardous Substances and Environmental Engineering*, 50(5), 473-481, doi: [10.1080/10934529.2015.992666](https://doi.org/10.1080/10934529.2015.992666).**

A cross-sectional study by Yale University School of Medicine researchers using companion animals as sentinels of human exposure to UNGD-related chemicals investigated possible associations between reported health conditions of companion and backyard animals in Southwest Pennsylvania and household proximity to drilling and UNGD operations. Among dogs living in households located less than one kilometer from a gas well, risks for health problems were elevated, especially for dermal conditions, compared to animals living more than two kilometers from a well.

**Rabinowitz PM, Slizovskiy IB, Lamers V, Trufan SJ, Holford TR, Dziura JD, Peduzzi PN, Kane MJ, Reif JS, Weiss TR, 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(1):21-26, doi: [10.1289/ehp.1307732](https://doi.org/10.1289/ehp.1307732).** Rabinowitz and colleagues surveyed approximately 200 randomly selected households in Washington County. They found that health symptoms reported by residents increased in frequency as distance between household and gas wells decreased. Among persons living less than one kilometer from drilling and UNGD operations, rashes and upper respiratory problems were significantly more prevalent. The authors also cite literature demonstrating the biological plausibility of a link between oil and gas extraction activities and both categories of health effects reported.

**Saberi P, Propert K, Powers M, Emmett E, Green-McKenzie J. 2014. Field survey of health**

**perception and complaints of Pennsylvania residents in the Marcellus Shale region. *Int J Environ Res Public Health* 11(6):6517-6527, doi: [10.3390/ijerph110606517](https://doi.org/10.3390/ijerph110606517).** The objective of this descriptive study is to explore whether shale region Pennsylvania residents perceive UNGD as a health concern and whether they attribute health symptoms to UNGD exposures. A questionnaire was administered to adult volunteers with medical complaints in a primary-care medical office in a county where UNGD was present. There were 72 respondents, 22% perceived UNGD as a health concern and 13% attributed medical symptoms to UNGD exposures. Overall, 42% attributed one or more of their medical symptoms to environmental causes, of which UNGD was the most frequent. A medical record review conducted on six participants who attributed their medical symptoms to UNGD revealed that only one of these records documented both the symptoms in question and the attribution to UNGD.

**Shonkoff SB, Hays J, Finkel ML. 2014. Environmental public health dimensions of shale and tight gas development. *Environ Health Perspect* 122:787-795; doi: [10.1289/ehp.1307866](https://doi.org/10.1289/ehp.1307866).** Jake Hayes and Seth Shonkoff, of Physicians, Scientists and Engineers for Health Energy assessed the peer-reviewed scientific literature from 2009 to 2015, as it relates to the potential impacts of UNGD on public health, water and air quality. They state that at least 685 papers (including reviews) have been published in a peer-reviewed scientific journals that are relevant to assessing the impacts of UNGD. None invalidate health findings associated with UNGD.

**Ferrar KJ, Kriesky J, Christen CL, Marshall LP, Malone SL, Sharma RK, Michanowicz DR, Goldstein BD. 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 Env Health* 19(2):104-112, doi: [10.1179/2049396713Y.0000000024](https://doi.org/10.1179/2049396713Y.0000000024).** Two sets of interviews were conducted with a small sample of community members living near Marcellus shale gas development. The interviews were intended to elicit information on the health and stressor impacts individuals had experienced during the period of gas extraction activities. Participants in the study attributed 59 unique health impacts and 13 stressors to Marcellus Shale development; with stress being the most frequently-reported symptom. Among the leading causes of stress reported by the participants were feelings of being taken advantage of, having their concerns and complaints ignored, and being denied information or misled. In addition to stress, frequently identified health concerns included rashes, headaches, shortness of breath, nausea and sore throats. Over time, perceived health impacts increased, while stressors remained constant.

**Fryzek J, Pastula S, Jiang X, Garabrant DH. 2013. Childhood cancer incidence in Pennsylvania counties in relation to living in counties with hydraulic fracturing sites. *J Occup Environ Med* 55(7):796-801, doi: [10.1097/JOM.0b013e318289ee02](https://doi.org/10.1097/JOM.0b013e318289ee02).** The authors compared cancer incidence in children in Pennsylvania counties before and after hydrofracturing began. They looked at publicly available data on wells drilled and cancer records, between 1990 and 2009. The data was compared to cancer rates for the general population. The total number of cancers observed was close to the expected outcome both before drilling began and after drilling for counties with oil and natural gas wells. Analyses for childhood leukemia were also similar. A slightly elevated incidence was found for central nervous system tumors after drilling.

Note: The authors do not address the latency period between exposures to cancer agents and the development of cancer, the findings of this study are likely affected by that.

**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* 23(1):55-83, doi: [10.2190/NS.23.1.e](https://doi.org/10.2190/NS.23.1.e).** Steinzor's community-based participatory research study in Pennsylvania tested air and water quality and surveyed self-reported health symptoms of more than 100 residents living near drilling and UNGD operations. The team detected a total of 19 volatile organic compounds in ambient air sampled outside of homes. The reported health symptoms closely matched the established effects of chemicals detected through air and water testing at those nearby sites. Moreover, those symptoms occurred at significantly higher rates in households closer to the gas facilities than those farther away. The top eight categories of symptoms reported were: Sinus/respiratory, behavioral/mood/energy, neurological, muscles/joints, ear/nose/mouth, digestive/stomach, skin reactions, vision/eyes.

**Bamberger M, Oswald RE. 2012. Impacts of gas drilling on human and animal health. *New Solut* 22(1):51-77, doi: [10.2190/NS.22.1.e](https://doi.org/10.2190/NS.22.1.e).** Bamberger and Oswald conducted interviews with animal owners in six states (including Pennsylvania) who believe they were affected by unconventional natural gas drilling (UNGD). When possible, the researchers also interviewed the animal owners' veterinarians. The researchers found several pathways through which people and animals are affected by water exposures from UNGD activities. Water exposures resulted from accidents or negligence and also from normal operations of the gas extraction processes. Bamberger and Oswald report 24 cases of human health impacts from shale gas activities. These impacts include: upper respiratory symptoms, burning of eyes, headache, gastrointestinal, dermatological, neurological, immunological, vascular, and sensory symptoms.



**For more information, contact Beth Weinberger at the Environmental Health Project [bweinberger@environmentalhealthproject.org](mailto:bweinberger@environmentalhealthproject.org) or 203.530.3436.**