Photo Credit: Bob Donnan

Health Professional Toolkit

ENVIRONMENTAL HEALTH PROJECT

DEFENDING PUBLIC HEALTH SINCE 2012

The last few decades have seen an oil and gas development boom across the U.S., with the addition of an estimated 1.3 million oil and gas facilities—active production wells, gas compressor stations, processing plants—not to mention a web of other infrastructure, such as pipelines, storage facilities, injection wells, waste sites, trucking services, and petrochemical plants.

Approximately 12.6 million people live within one-half mile of such a facility. Many, especially those in underserved and underrepresented communities, live near multiple sources of emissions. Nearly 3 million children attend school within a half-mile of these facilities. Against this backdrop of industry, the risk that people are being exposed to toxic chemicals is greatly intensified, a public health crisis that needs to be addressed.

Health Impacts of Shale Gas Development (SGD)

The primary driver of new oil and gas expansion is shale gas development (what some call "unconventional gas development" or "hydraulically fractured gas"). SGD introduces a number of health risks and impacts to people living in proximity to these facilities:

- Exposure to toxic chemicals through various exposure pathways, including air emissions and water contamination.
    - Air emissions from SGD contain levels of particulate matter high enough to create health hazards. Air pollution from SGD is a clear, well-defined pathway of exposure that is produced not only from activities in and around the well, but also from the transportation of water, sand, and chemicals to and from well pads and other ancillary processes. For more information on the impact of SGD on air, check out this page.
    - SGD has been linked to surface and groundwater contamination. Researchers found groundwater near drilling sites contained methane concentrations 17 times higher than wells where drilling was not taking place. For more information on the impact of SGD on water check out this page.
    - Toxic chemicals are used in SGD and are present in generated wastes and byproducts.
- Exposure to other social and biological stressors associated with related heavy industrial activities, such as noise and light pollution.
- Health symptoms reported by residents in gas producing areas have a psychological basis, given that increased levels of anxiety, tension, irritability, and depression have all been identified in these residents.

EHP's Health Professional Toolkit

The goal of the toolkit is to provide health professionals with up-to-date information and research on the impact of shale gas development on patients' and clients' health. In using the toolkit, health professionals will be able to:

- Understand the existing research that links shale gas development to health impacts.
- Recognize the potential impacts that shale gas development is having on patients' and clients' physical or mental health.
- Provide resources and recommendations for impacted patients and clients.

Course Outline

Click here to access the online version of the toolkit.

CME/CEU Course Checklist

Read through the following modules, checking off each one to keep track of your progress:

- ☐ Introduction
- ☐ Physical Health & Wellness
  - ☐ Endocrine Disruption
  - ☐ Maternal and Child Health
  - ☐ Oncology
  - ☐ Respiratory and Cardiovascular
- ☐ Mental Health & Wellness
- ☐ Potential Health Effects Due to Inhalation
- ☐ Survey for Potential Exposure

Visit the CME/CEU Credit page for detailed instructions on how to receive your credits or participation certificate.

More than two dozen peer-reviewed epidemiological studies, and hundreds of other investigations and firsthand accounts, have shown that shale gas development correlates with poor health outcomes in people living in proximity to such infrastructure. In addition, peer-reviewed studies indicate that health impacts increase the closer one is to shale gas facilities.

These studies show:

- Worsening asthma symptoms are linked to nearness of shale gas facilities.
- Symptoms that include headaches, fatigue, upper and lower respiratory complaints, and skin rashes have been reported near well pads.
- Babies born to mothers living less than a mile from wells were 25% more likely to be born with low birth weights, which may lead to serious future consequences in growth and development, including asthma, intellectual and developmental disabilities, obesity, and infant mortality.
- An increasing number of babies have been born with congenital heart defects and possibly neural tube defects, impacts dependent on both the number of wells in the vicinity and the distance from the wells to mothers' homes.
- Hospitalizations for heart failure are significantly higher in areas impacted by shale gas development.

A question frequently asked is whether individuals living or working near SGD should undergo blood and urine testing (biomonitoring) to determine if they have been exposed to harmful chemicals from SGD. Currently, no specific testing protocol exists for monitoring low levels of environmental exposures because of the various limitations. Limitations include:

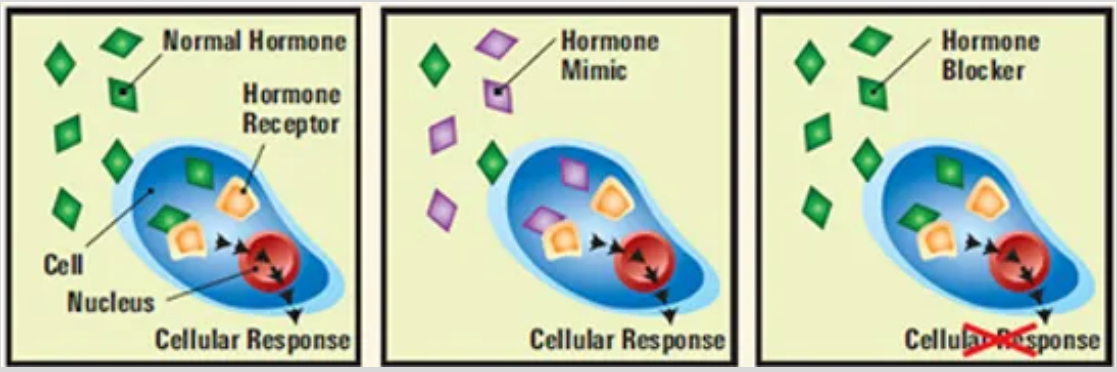
- Most of the chemicals associated with SGD activity are cleared rapidly from the body, so a test may not show the presence of a chemical or metabolite even if someone is exposed. This may result in a "false negative" result, which can be inappropriately reassuring.
- Some metabolites of potentially harmful chemicals are also metabolites of common foods or medications. The presence of these substances in blood or urine may present a "false positive" result, which can be inappropriately alarming.
- Many chemicals have multiple sources of exposure in the environment, so it can be difficult to determine if a positive result is from an SGD-related exposure or from some other exposure.
- Some toxic chemicals do not have an associated, measurable metabolite in the blood or urine that is specific to the chemical of concern. In this scenario, even if an exposure to environmental pollutants did occur, there may be no way to detect that exposure.
- Even if a chemical can be appropriately measured in blood or urine, for most chemicals or metabolites, there are no reference values to indicate whether the amount detected poses a health risk.

However, health professionals are encouraged to perform routine and periodic blood and urine tests to monitor kidney, liver, and thyroid function as well as hematologic status. When patients/clients are experiencing new symptoms, these should be evaluated, recognizing that environmental exposures may be contributing to the symptoms.

General Resources

- Case definition
- Health Impacts of Shale Gas Development: A Collection of Research
- MedlinePlus introductory video
- How Shale Gas Development (Fracking) Affects Public Health
- ATSDR Exposure History Form
- CDC/ATSDR Guidance on the Interpretation and Use of Blood Laboratory Analyses for Volatile Organic Compounds
- PSE's Repository for Oil and Gas Energy Research (ROGER) citation database
- U.S. National Library of Medicine (Medline Plus)
- OSHA/NIOSH Hazard Alert: Worker Exposure to Silica during Hydraulic Fracturing

Shale gas air emissions and solid and liquid wastes have been found to contain endocrine disrupting chemicals (EDCs). EDCs disrupt normal hormone signals in two main ways. First, they change the amount of a specific hormone available by altering production, metabolism, or secretion. Second, they mimic or block the action of hormones and their receptors at target tissues.



When absorbed in the body, an endocrine disruptor can decrease or increase normal hormone levels (left), mimic the body's natural hormones (middle), or alter the natural production of hormones (right).

Graphic courtesy of the National Institute of Environmental Health Sciences (2022)

EDCs may contaminate air, water, soil, and food sources and therefore expose residents through inhalation, ingestion, and skin absorption. Health effects from exposure to EDCs include but are not limited to: abnormal development of sex organs; reduced ability to have children; changes to secondary sex characteristics; cancers such as breast, ovarian, prostate, and testicular; impaired intellectual development; altered behavior or response to stress; and increased buildup of fat and changes in ability to respond to insulin and regulate blood sugar.

WHAT THE RESEARCH SAYS

Nagel, S. C., Kassotis, C. D., Vanderberg, L. N., et al. (2020). Developmental exposure to a mixture of unconventional oil and gas chemicals: A review of experimental effects on adult health, behavior, and disease.
Nagel and colleagues reviewed studies that evaluated the potential endocrine-mediated health impacts of exposure to a mixture of 23 unconventional oil and gas (UOG) chemicals, commonly found in wastewater, on laboratory animals and human tissue culture cells. They found:

- UOG chemicals and wastewater disrupted hormone receptors.
- Perinatal exposure to the UOG-mix altered adult health.
- UOG-mix altered sperm counts, folliculogenesis, and pituitary hormones in adulthood.
- UOG-mix altered mammary gland morphology and induced precancerous lesions.
- UOG-mix altered frog antiviral immunity and the immune system in three mouse models.

Balise, V. D., Cornelius-Green, J. N., Parmenter, B., et al. (2019). Developmental Exposure to a Mixture of Unconventional Oil and Gas Chemicals Increased Risk-Taking Behavior, Activity and Energy Expenditure in Aged Female Mice After a Metabolic Challenge.
Balise and colleagues found altered energy expenditure and activity in C57BL/6J mice that were preconceptionally, gestationally, and lactationally exposed to a UOG mixture. Mice were exposed via maternal drinking water to a laboratory-created mixture of 23 UOG chemicals from gestational day 1 to postnatal day 21 in 7-month-old female mice with no change in body composition. They found:

- Developmental exposure to the 23 UOG mixture was associated with increased activity and non-resting energy expenditure.
- There was increased exploratory behavior in the elevated plus maze test.
- The mice showed decreased sleep in 12-month female mice.
- Each of these effects was seen in the light cycle when mice are normally less active.

Bamberger, M., Nell, M., Ahmed, A. H., et al. (2019). Surface water and groundwater analysis using aryl hydrocarbon and endocrine receptor biological assays and liquid chromatography-high resolution mass spectrometry in Susquehanna County, PA.
Bamberger and colleagues analyzed surface water and groundwater samples collected throughout Susquehanna County, Pennsylvania. The researchers identified certain chemicals, including disclosed hydraulic fracturing fluid (HFF) additives, in samples that were either near impaired gas wells or that exhibited a biological effect. Potential endocrine activity was assessed using four endocrine receptors (androgen, estrogen, progesterone, and glucocorticoid). They found:

- 17 potential HFF additives or wastewater constituents that are associated with aryl hydrocarbon (Ah) receptor activity, estrogen (ER) activity, and proximity to impaired wells.
- In samples with significant activity, the magnitude of the effects seen for both agonism and antagonism are like those observed previously in areas of intensive drilling activity.
- Endocrine receptor agonism was present in 22 samples associated with estrogen.

Kassotis, C. D., Nagel, S. C., Stapleton, H. M. (2018). Unconventional oil and gas chemicals and wastewater-impacted water samples promote adipogenesis via PPARγ-dependent and independent mechanisms in 3T3-L1 cells.

Kassotis and colleagues assessed adipogenic activity (both triglyceride accumulation and pre-adipocyte proliferation) for a mixture of 23 commonly used unconventional oil and gas (UOG) chemicals and a small subset of UOG wastewater-impacted surface water extracts from Colorado and West Virginia. They found:

- Potent and efficacious adipogenic activity was induced by both a laboratory-created UOG chemical mixture and UOG-impacted water samples at concentrations below environmental levels.
- Activation of PPARγ at similar concentrations for some samples, suggesting a causative molecular pathway for the observed effects, but not for other adipogenic samples, implicating PPARγ-dependent and independent effects from UOG-associated chemicals.
- Taken together, these results suggest that UOG wastewater has the potential to impact metabolic health at environmentally relevant concentrations.

Kassotis, C. D., Vu, D. C., Vo, P. H., et al. (2018). Endocrine-Disrupting Activities and Organic Contaminants Associated with Oil and Gas Operations in Wyoming Groundwater.

Kassotis and colleagues characterized endocrine activities and measured select organic contaminants in groundwater from conventional oil and gas and UOG production regions of Wyoming. Groundwater samples were assessed for endocrine activities (estrogen, androgen, progesterone, glucocorticoid, and thyroid receptor agonism and antagonism). The researchers found:

- Groundwater extracts from Pavillion, WY, had the presence of putative UOG VOCs (2-ethylhexanol, naphthalene, and styrene) and increased endocrine bioactivities in this area relative to controls.
- Water samples from UOG and conventional oil areas exhibited greater estrogen antagonist activities than water samples from conventional gas areas.
- Samples from UOG areas tended to exhibit progesterone receptor antagonism more often, suggesting there may be a UOG-related impact on these endocrine activities.

Bolden, A. L., Schultz, K., Pelch, K. E., et al. (2018). **Exploring the endocrine activity of air pollutants associated with unconventional oil and gas extraction.**

Bolden and colleagues researched PubMed and Web of Science to identify studies that measured chemicals in air near sites of unconventional oil and gas (UOG) activity and their possible endocrine active chemicals. They evaluated 48 studies that sampled air sites and identified 106 chemicals. They found:

- 200 air chemicals were identified in association with UOG activity at sites in the US. They identified 26 as being on the TEDX list, which identifies chemicals with endocrine activity, and an additional eight of the most frequently detected air pollutants were identified as having potential endocrine activity.
- 21 chemicals have been shown to have endocrine activity including estrogenic and androgenic activity and ability to alter steroidogenesis.
- Literature also suggested pollutants affecting reproduction, development, and neurophysiological function, all endpoints which can be modulated by hormones.
- Water collected near UOG operations such as spill sites and surface water near wastewater injection sites were shown to have activity in estrogen, androgen, progesterone, glucocorticoid, and thyroid hormone in vitro receptor assays.

Webb, E., Moon, J., Dyrszka, L., et al. (2018). **Neurodevelopmental and neurological effects of chemicals associated with unconventional oil and natural gas operations and their potential effects on infants and children.**

Webb and colleagues reviewed scientific literature relevant to the potential neurodevelopmental health effects of UOG emissions on children and newborns. They reviewed human and animal studies and focused on five air and water pollutants (heavy metals, particulate matter, polycyclic aromatic hydrocarbons, BTEX, and endocrine disrupting compounds) that have been associated with potential permanent learning and neuropsychological disorders and neurological birth defects. They found:

- Neurodevelopmental effects such as prenatal exposure to EDCs may cause permanent changes in the brain and behavior.
- EDCs could cause neurocognitive effects such as compromised learning and memory.
- EDCs could also cause neuropsychological effects such as impaired social interaction, increased aggression and anxiety, increased susceptibility to sex- and/or hormonally differentiated behavioral disorders such as autism spectrum disorder, ADHD, and depression.
- Exposure to EDCs during the perinatal period has been shown to cause permanent changes in the brain and behavior.

LEARN MORE

EHP Resources

- HANDOUT
  - Endocrine Disrupting Chemicals (EDCs) and Shale Gas Development
- WEBINAR
  - Endocrine Disrupting Chemicals and Shale Gas Development
  - PFAS, Endocrine Disruption, and Shale Gas Development

Other Resources

- ARTICLE
  - Endocrine Society's Second Scientific Statement on Endocrine-Disrupting Chemicals, *Endocrine Reviews*
  - Plastics, EDCs & Health: A Guide for Public Interest Organizations and Policy-Makers on Endocrine Disrupting Chemicals & Plastics, *Endocrine Society and IPEN*

FULL CITATIONS

Bamberger, M., Nell, M., Ahmed, A. H., Santoro, R., Ingraffea, A. R., Kennedy, R. F., Nagel, S. C., Helbling, D. E., Oswald, R. E. (2019). Surface water and groundwater analysis using aryl hydrocarbon and endocrine receptor biological assays and liquid chromatography-high resolution mass spectrometry in Susquehanna County, PA. *Environmental Science: Processes & Impacts*, 21(6), 988-998. https://pubmed.ncbi.nlm.nih.gov/31093631

Balise, V. D., Cornelius-Green, J. N., Parmenter, B., Baxter, S., Kassotis, C. D., Rector, R. S., Thyfault, J. P., Paterlini, S., Palanza, P., Ruiz, D., Sargis, R., & Nagel, S. C. (2019). Developmental Exposure to a Mixture of Unconventional Oil and Gas Chemicals Increased Risk-Taking Behavior, Activity and Energy Expenditure in Aged Female Mice After a Metabolic Challenge. *Frontiers in Endocrinology*, 10. https://doi.org/10.3389/fendo.2019.00460

Bolden, A. L., Schultz, K., Pelch, K. E., Kwiatkowski, C. F. (2018). Exploring the endocrine activity of air pollutants associated with unconventional oil and gas extraction. *Environmental Health*, 17, 26. https://doi.org/10.1186/s12940-018-0368-z

Kassotis, C. D., Nagel, S. C., Stapleton, H. M. (2018). Unconventional oil and gas chemicals and wastewater-impacted water samples promote adipogenesis via PPARγ-dependent and independent mechanisms in 3T3-L1 cells. *Science of The Total Environment*, 640–641:1601-1610. https://www.sciencedirect.com/science/article/abs/pii/S0048969718316620

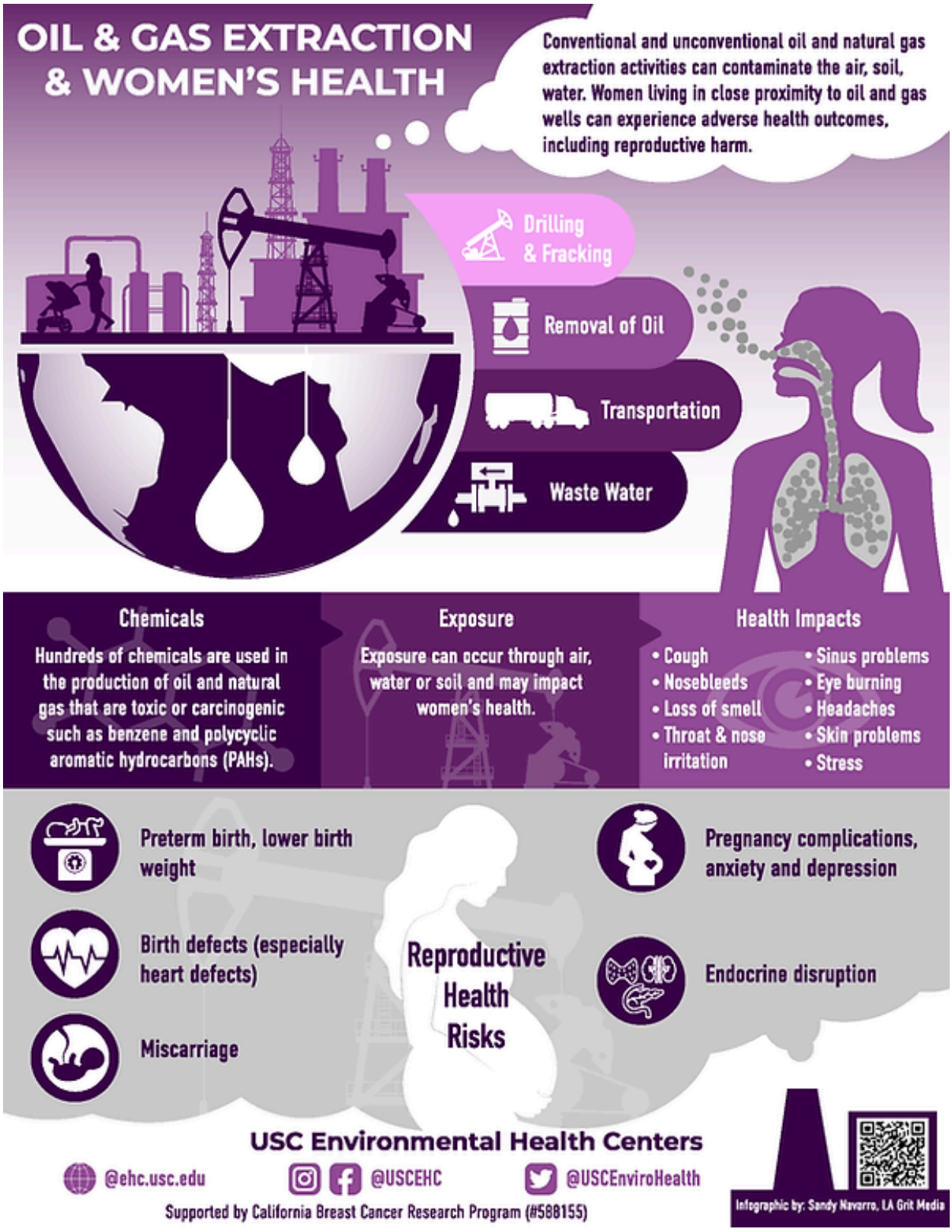
Kassotis, C. D, Vu, D. C., Vo, P. H., Lin, C. H., Cornelius-Green, J. N., Patton, S., Nagel, S. C. (2018). Endocrine-Disrupting Activities and Organic Contaminants Associated with Oil and Gas Operations in Wyoming Groundwater. *Archives of environmental contamination and toxicology*. 75, 247–258. https://link.springer.com/article/10.1007/s00244-018-0521-2

Nagel, S., Kassotis, C., Vandenberg, L., Lawrence, B., Robert, J., & Balise, V. (2020). Developmental exposure to a mixture of unconventional oil and gas chemicals: A review of experimental effects on adult health, behavior, and disease. *Molecular and Cellular Endocrinology*, 513, 110722. https://doi.org/10.1016/j.mce.2020.110722

Webb, E., Moon, J., Dyrszka, L., Rodriquez, B., Coz, C., Patisaul, H., Bushkin, S., London, E. (2018). Neurodevelopmental and neurological effects of chemicals associated with unconventional oil and natural gas operations and their potential effects on infants and children. *Reviews on Environmental Health*, 33(1), 3-29. https://pubmed.ncbi.nlm.nih.gov/29068792/

Pregnant individuals and newborns are vulnerable populations that can be adversely impacted from pollution, such as emissions from shale gas development (SGD). Research has shown complications such as low birth weight can be an indicator of impaired growth in the early years of a child's life. Research has also suggested that issues at birth (preterm birth, cognitive delays, etc.) can lead to increased mortality and morbidity as well as an increased risk for hypertension, coronary heart disease, and diabetes in adulthood. Newborns are in a critical stage of development when born, therefore being exposed to different environmental toxins can greatly impact the child's development.

In addition, research has indicated that exposure to ambient air pollution is associated with various birth outcomes, including congenital heart defects, neural tube defects, small for gestational age, low birth weight, preterm delivery, hypertension, and preeclampsia. This is evident from studies that looked specifically at impacts to pregnant individuals and children living in proximity to SGD.



Graphic courtesy of USC Environmental Health Centers (2021)

WHAT THE RESEARCH SAYS

Willis, M. D., Hill, E. L., Kile, M. L., et al. (2022). **Associations between residential proximity to oil and gas extraction and hypertensive conditions during pregnancy: a difference-in-difference analysis in Texas, 1996-2009.**
This study examined residential proximity to oil and gas extraction and hypertensive conditions during pregnancy, specifically gestational hypertension and eclampsia. The researchers found:

- Pregnant individuals living within 0.6 miles of an active oil and gas site had an estimated 5% increased odds of developing gestational hypertension.
- Pregnant individuals living within 0.6 miles from an active oil and gas site had an estimated 26% increased odds of developing eclampsia.

Willis, M. D., Hill, E. L., Boslett, A., et al. (2021). **Associations between Residential Proximity to Oil and Gas Drilling and Term Birth Weight and Small-for-Gestational-Age Infants in Texas: A Difference-in-Differences Analysis.**
These researchers examined the effect of living near oil and gas drilling sites on the birth weight of newborns in Texas. They found:

- Infants of mothers living within 1 km (0.6 miles) of a drilling site at the time of birth had birth weights an average of 30g lower in comparison to those not near a drilling site.
- Infants of mothers living 3-10 km (1.8-6.2 miles) from a drilling site at the time of birth had birth weights an average of 14g lower in comparison to those not near a drilling site.
- Overall, the difference between birth weight in relation to drilling activity was 16g.

Caron-Beadudoin, É., Valter, N., Chevrier, J., et al. (2018) **Gestational exposure to volatile organic compounds (VOCs) in Northeastern British Columbia, Canada: A pilot study.**
Researchers evaluated gestational exposure to benzene and toluene in the Peace River Valley of Northeastern British Columbia, Canada. They found:

- There are higher levels of t,t-MA (trans, trans-muconic acid) levels in women in the Peace River Valley region than in the general Canadian population.
- There was no significance found in the levels of S-BMA (toluene) or S-PMA (benzene), but the sample size was quite small and more extensive research needs to be done in this area.

Hill, E. L. (2018). **Shale Gas Development and Infant Health: Evidence from Pennsylvania.**
This researcher looked at singleton births to mothers who resided in proximity to shale gas wells from 2003-2010 in Pennsylvania.

- The introduction of drilling increased low birth weight and decreased term birth weight on average for pregnant individuals living within 2.5 km (1.5 miles) of a well.
- An additional well is associated with a 7% increase in low birth weight.
- An additional well is associated with a 5-gram reduction in term birth weight.
- An additional well is associated with a 3% increase in premature birth.

Currie, J., Greenstone, M., Meckel, K. (2017). Hydraulic fracturing and infant health: New evidence from Pennsylvania. This study looked at more than a million births in Pennsylvania from 2004 to 2013 and compared infants born to mothers at different distances from active shale gas development (SGD) sites. They found:

- SGD negatively affects the health of infants born to individuals living within 3 km (1.8 miles) of a shale gas well site during pregnancy.
- The closer the pregnant individuals live to the wells, the higher the probability of lower birth weight and significantly lower average birth weight.
- Most of the health deficiencies are within a 3 km radius of the wells, so it is safe to say that the health impacts are highly localized.

Busby, C., & Mangano, J. J. (2017). There's A World Going on Underground—Infant Mortality and Fracking in Pennsylvania.
In this study, researchers investigated associations between early infant mortality (0-28 days) by county in Pennsylvania for people living in proximity to shale gas development (SGD) activities. They found:

- There was an increase in the affected counties from 34 infant deaths to 60.
- SGD appears to be associated with early infant mortality in PA counties.
- There is some evidence that this mortality is related to private water well density or environmental law violations.
- Babies born in the 4 years after SGD began in the major SGD counties in PA were 28% more likely to die in the first month than babies born under the same conditions in the 4 years prior to SGD.

Whitworth, K. W., Marshall, A. K., Symanski, E. (2017). Maternal residential proximity to unconventional gas development and perinatal outcomes among a diverse urban population in Texas.
Researchers examined associations between unconventional natural gas development (UGD) and perinatal outcomes. They found:

- Increased odds of preterm birth associated within 10 miles of UGD activity.
- Increased odds of fetal death within 2 miles of UGD activity.
- No indication of an association with small for gestational age or term birthweight.

LEARN MORE

EHP Resources

- BLOG
  - Examining the Impacts of Air Pollution on Children
  - Pregnant Women and Fracking: A Case for Special Concern
- HANDOUT
  - Facts for School Nurses
  - How to Talk with Pediatric Health Professionals
  - Health Risks to Children from Shale Gas Development
- WEBINAR
  - PFAS, Pregnancy, & Public Health: Experts Weigh In
  - Reproductive Health and Shale Gas Development

Other Resources

- WEBINAR
  - How Fracking and Natural Gas Impact Maternal Health, *Center for Environmental Health*
- HANDOUT
  - How Oil and Gas Operations Impact your Baby's Health, *Moms Clean Air Force*
- STUDY
  - Hydraulic Fracturing and Infant Health: New Evidence from Pennsylvania, *University of Chicago*
- ARTICLE
  - Oil and Gas Development and Adverse Birth Outcomes: What More Do We Need to Know? *Environmental Health Perspectives*

FULL CITATIONS

Busby, C., & Mangano, J. J. (2017). There's a World Going on Underground—Infant Mortality and Fracking in Pennsylvania. *Journal of Environmental Protection*, 08(04), 381–393. https://doi.org/10.4236/jep.2017.84028

Caron-Beaudoin, L., Valter, N., Chevrier, J., Ayotte, P., Frohlich, K., & Verner, M. A. (2018). Gestational exposure to volatile organic compounds (VOCs) in Northeastern British Columbia, Canada: A pilot study. *Environment International*, 110, 131–138. https://doi.org/10.1016/j.envint.2017.10.022

Currie, J., Greenstone, M., & Meckel, K. (2017). Hydraulic fracturing and infant health: New evidence from Pennsylvania. *Science Advances*, 3(12). https://doi.org/10.1126/sciadv.1603021

Hill, E. L. (2018). Shale gas development and infant health: Evidence from Pennsylvania. *Journal of Health Economics*, 61, 134–150. https://doi.org/10.1016/j.jhealeco.2018.07.004

Whitworth, K. W., Marshall, A. K., & Symanski, E. (2017). Maternal residential proximity to unconventional gas development and perinatal outcomes among a diverse urban population in Texas. *PLOS ONE*, 12(7), e0180966. https://doi.org/10.1371/journal.pone.0180966

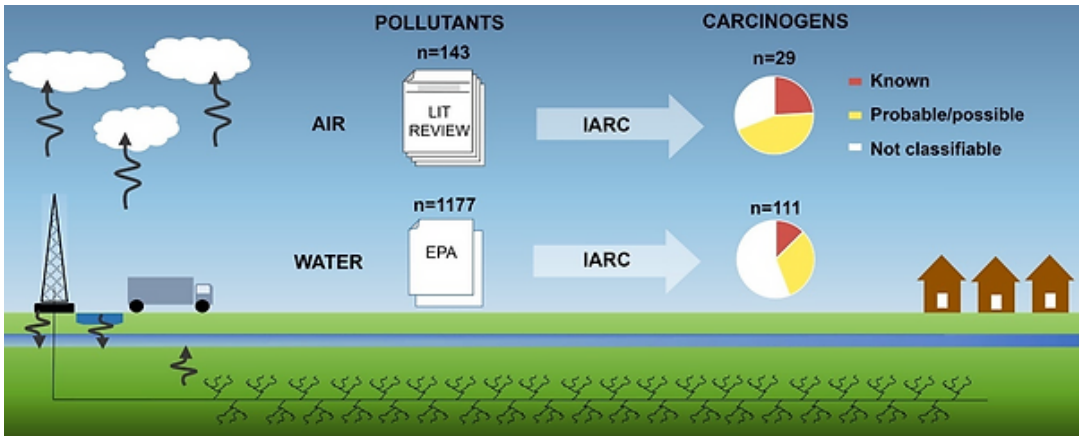
Willis, M. D., Hill, E. L., Boslett, A., Kile, M. L., Carozza, S. E., & Hystad, P. (2021). Associations between Residential Proximity to Oil and Gas Drilling and Term Birth Weight and Small-for-Gestational-Age Infants in Texas: A Difference-in-Differences Analysis. *Environmental Health Perspectives*, 129(7), 077002. https://doi.org/10.1289/ehp7678

Willis, M. D., Hill, E. L., Kile, M. L., Carozza, S., & Hystad, P. (2021). Associations between residential proximity to oil and gas extraction and hypertensive conditions during pregnancy: a difference-in differences analysis in Texas, 1996–2009. *International Journal of Epidemiology*, 51(2), 525–536. https://doi.org/10.1093/ije/dyab246

The scientific community continues to quantify and qualify the oncologic risks of living, working, and playing in proximity to shale gas development (SGD). As the latency periods for different types of cancers are variable and can be long, and since high-volume SGD began ramping up from 2005-2010, existing studies on cancer related to SGD are limited but expected to increase over time.

KNOWN CARCINOGENS BY EXPOSURE PATHWAY
(Elliott et al., 2017)

AIR EMISSIONS	FRACKING FLUID	WASTEWATER
1,3-Butadiene	1,3-Butadiene	Radium 226 & 228
Formaldehyde	Formaldehyde	Benzo(a)pyrene
Radon	Ethylene oxide	Beryllium
Diesel exhaust	Arsenic	Arsenic
Benzene	Benzene	Benzene



Graphic courtesy of Elliot, E.G. et al., (2017)

Research suggests at least 55 carcinogenic compounds—49 carried by water, 20 by air (some overlap)—are potentially released into the environment as a result of SGD. Note that the majority of the chemicals emitted in air and liquid waste in SGD, represented by the white part of the pie above, have not been tested for human carcinogenicity.

WHAT THE RESEARCH SAYS

Clark, C.J., Johnson, N.P., Soriano, Jr, M., et al. (2022). Shale gas development exposure in Pennsylvania and risk of childhood Acute Lymphoblastic Leukemia.
The authors of this study examined whether there was a correlation between exposure to SGD and cases of cancer, specifically ALL in Pennsylvania.

- Children living in proximity to SGD had up to 2-3 times the odds of developing ALL.
- There was an increased odds ratio for those upgradient of a shale gas well which suggests that water is a potential exposure pathway for substances leading to the development of ALL.
- Children had the greatest increased odds of developing ALL in proximity to SGD if exposed during the perinatal window (three months before conception up to birth).

Jost, E., Dingley, B., Jost, C., et al. (2021). Associations Between the Density of Oil and Gas Infrastructure and the Incidence, Stage and Outcomes of Solid Tumours: A Population-Based Geographic Analysis.
The authors studied populations in Alberta, Canada, to see if there was a correlation between development of solid tumors and living in proximity to oil and gas development. They found:

- A positive correlation between density of oil and gas development and solid tumor diagnoses.
- A positive correlation of specific tumor types associated with higher oil and gas density measured as > 30 total facilities/100 km2 (approximately 38.6 square miles). This includes breast, prostate, lung, colorectal, melanoma, renal, head and neck, gastric, and hepatobiliary malignancies.

Xu, Y., Sajja, M., Kumar, A. (2019). Impact of the Hydraulic Fracturing on Indoor Radon Concentrations in Ohio: A Multilevel Modeling Approach.
The authors analyzed radon data from 2007 to 2014 in Ohio to determine if there was an association between distance to SGD wells and household radon levels. They found:

- A strong correlation between indoor radon concentrations and SGD in Ohio.
- Data suggests that household radon levels increase as the distance to shale gas sites decreases.

McKenzie, L. M., Blair, B., Hughes, J., et al. (2018). Ambient Nonmethane Hydrocarbon Levels Along Colorado's Northern Front Range: Acute and Chronic Health Risks.
The authors measured air emissions at various distances from SGD facilities in Colorado to calculate lifetime risk of cancer. They found:

- Residents within 500 feet of SGD facilities had a lifetime cancer risk of 8.3 per 10,000 people, which exceeds the EPA's upper limit of risk (1 per 10,000 people).
- They attributed this risk to the levels of benzene.

McKenzie, L. M., Allshouse, W. B., Byers, T. E., et al. (2017). Childhood hematologic cancer and residential proximity to oil and gas development.

The authors compared incidence of acute lymphocytic leukemia (ALL) in young people (5-24 years) to all other childhood cancers in Colorado in relation to exposure to shale gas wells. They found:

- ALL cases were 4.3 times as likely to be found in young people with the highest level of exposure to shale gas wells when compared to young people with diagnosis of other types of cancer.
- ALL incidence decreased as exposure decreased.

Elliott, E. G., Trinh, P., Ma, X., et al. (2017). Unconventional oil and gas development and risk of childhood leukemia: Assessing the evidence.

The authors set out to determine what was known about the carcinogenicity of chemical compounds emitted into the air or present in the waste stream. They checked 1,177 water pollutants and 143 air pollutants potentially emitted by SGD with the International Agency for Research on Cancer's carcinogen monographs. They found:

- Over 80% of pollutants had not yet been assessed for carcinogenicity.
- 49 water and 20 air pollutants (55 unique compounds) were identified as known, probable, or possible carcinogens.
- 20 compounds had evidence of leukemia/lymphoma risk.

Finkel, M. (2016). Shale gas development and cancer incidence in southwest Pennsylvania.

The author investigated whether SGD was correlated with increased cancer incidence in southwest Pennsylvania. The author found:

- The observed number of urinary bladder cases 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 urinary bladder cases was essentially nonexistent.
- Thyroid cancer increased substantially among both sexes over time in all counties regardless of the number of wells drilled.

LEARN MORE

EHP Resources

- BLOG
  - Shale Gas Development and Childhood Cancer: Should I Worry About My Kids?
- HANDOUT
  - Protecting Your Health from Shale Gas Development (Fracking)
  - Shale Gas Development and Cancer
- WEBINAR
  - Shale Gas Development & Cancer | Part 1
  - Shale Gas Development & Cancer | Part 2
  - Shale Gas Development & Cancer | Part 3
- MEETING RECORDING
  - Community Meeting on Childhood Cancers in SWPA

Other Resources

- ARTICLE
  - America's Radioactive Secret, *Rolling Stone*
  - The Human Toll, *Pittsburgh Post-Gazette*
  - Human Toll Part 2, *Pittsburgh Post-Gazette*
- STUDY
  - Hydraulic fracturing for natural gas: impact on health and environment, *Reviews on Environmental Health*

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Jost, E., Dingley, B., Jost, C., Cheung, W. Y., Quan, M. L., Bouchard-Fortier, A., Kong, S., Xu, Y. (2021). Associations between the density of oil and gas infrastructure and the incidence, stage and outcomes of solid tumours: A population-based geographic analysis. *Frontiers in Oncology*, 11. https://doi.org/10.3389/fonc.2021.757875

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McKenzie, L. M., Blair, B., Hughes, J., Allshouse, W. B., Blake, N. J., Helmig, D., Milmoe, P., Halliday, H., Blake, D. R., Adgate, J. L. (2018). Ambient Nonmethane Hydrocarbon Levels Along Colorado's Northern Front Range: Acute and Chronic Health Risks. *Environmental Science & Technology*. 52(8):4514-4525. https://pubmed.ncbi.nlm.nih.gov/29584423/ Erratum in: (2018) Environmental Science & Technology. 52(24):14568-14569. https://pubs.acs.org/doi/10.1021/acs.est.8b06179

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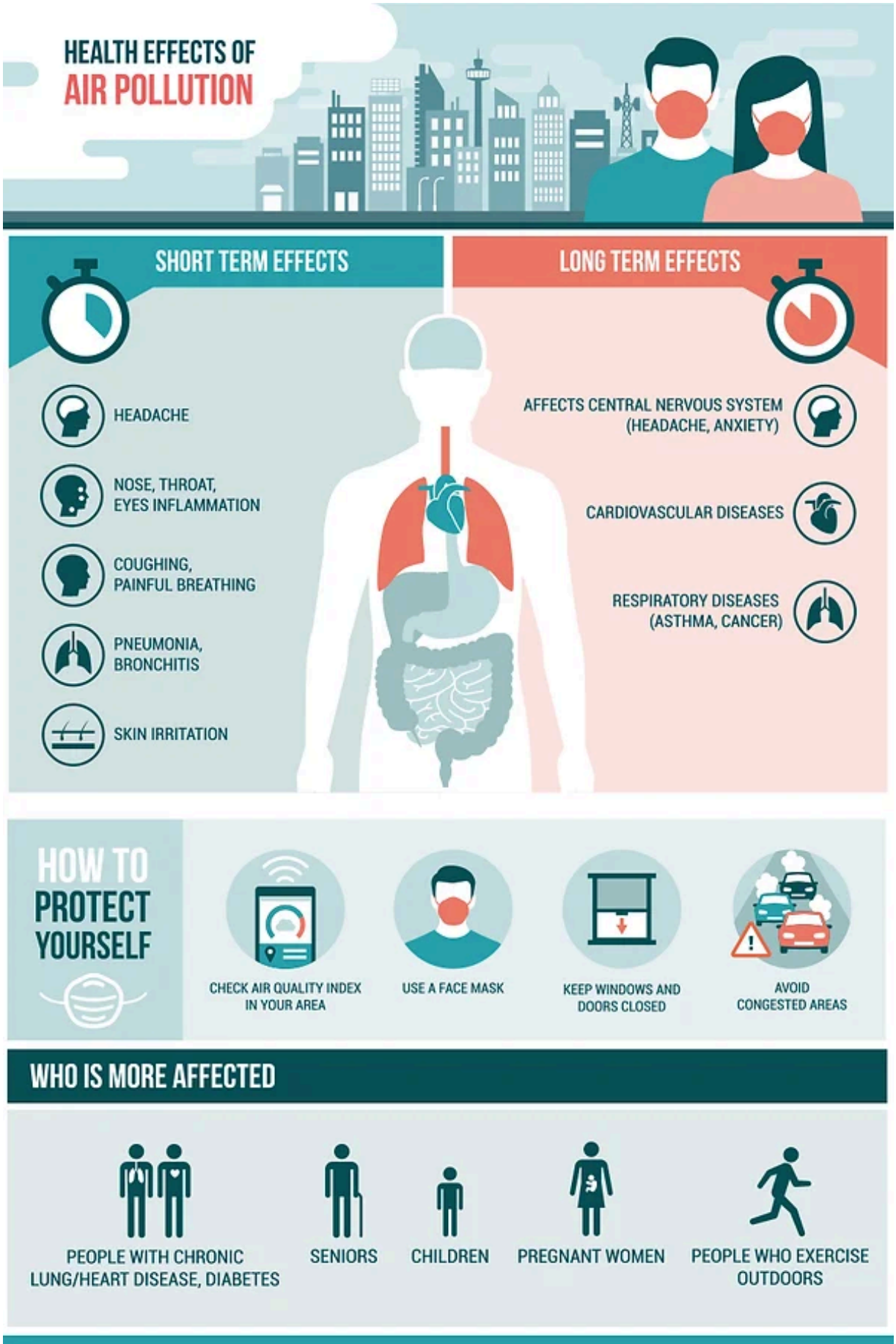
Finkel, M. (2016). Shale gas development and cancer incidence in southwest Pennsylvania. *Public Health*, 141:198-206. https://www.researchgate.net/publication/309455462_Shale_gas_development_and_cancer_incidence_in_southwest_Pennsylvania

In 2021, the State of the Air report, published annually by the American Lung Association, reported that 40% of Americans, or four in ten people, live in areas with unhealthy air pollution levels. This report considers the most widespread air pollutants, including fine particulate matter, ozone, and volatile organic compounds. All these air pollutants are emitted during the various stages of shale gas development (SGD).

These pollutants are known to trigger or worsen a variety of respiratory and cardiovascular diseases, including asthma, chronic obstructive pulmonary disease (COPD), cerebrovascular accidents (stroke), acute coronary syndrome, and many others. Heart disease is already the leading cause of death in the United States, and air pollution only contributes more to this problem. The American Heart Association advocates for measures that reduce exposure to air pollution and recommends that physicians and other health professionals talk to their patients about the cardiovascular and respiratory disease risks from exposure to polluted air.



Infographic courtesy of Dr. Lal PathLabs Limited (2018).

WHAT THE RESEARCH SAYS

Denham, A., Willis, M. D., Croft, D., et al. (2021): Acute Myocardial Infarction (Heart Attack) Associated With Unconventional Natural Gas Development: A Natural Experiment.
Researchers in this study examined hospital discharge and mortality data related to acute myocardial infarction (AMI) from 2005-2014 from people living in Pennsylvania (where shale gas activity is high) and New York (where shale gas drilling is banned). They found:

- Hospitalization rates for heart attacks increased in PA counties that hosted shale gas drilling when compared with NY communities that did not.
- The increase was seen in males between 45-54 years old and men and women 65 and older.
- Mortality from AMI was more than 5% higher in middle-aged males in PA when compared to NY communities.

McAlexander, T. P., Bandeen-Roche, K., Buckley, J. P., et al. (2020): Unconventional Natural Gas Development and Hospitalization for Heart Failure in Pennsylvania.
Researchers in this study examined associations between SGD and hospitalization rates with heart failure (HF) patients from 2008-2015 using electronic health records from Geisinger. They found:

- Over 9,000 HF patients with over 5,000 hospitalizations. The average age was 71, and 47% were females.
- SGD activity was examined in four phases: pad preparation, drilling, stimulation, and production. The adjusted odds ratios for HF with the four phases were 1.70, 0.97, 1.80, and 1.62 respectively.
- Older patients with HF were particularly vulnerable to adverse health outcomes from SGD.

Croft, D. P., Zhang, W., Lin, S., et al. (2019). The Association between Respiratory Infection and Air Pollution in the Setting of Air Quality Policy and Economic Change.
This study examined the rate of respiratory infections in adults in association with increases in fine particulate matter 2.5 (PM2.5) concentrations, specifically in the New York region. The researchers found:

- Over 400,000 adults in NY had a primary diagnosis of influenza, bacterial pneumonia, or culture-negative pneumonia from hospital or ER visits between 2005-2016.
- Researchers estimated the rate of healthcare encounters associated with increases in PM2.5 within the last 1-7 days and then looked at the differences between 2005-2007, 2008-2013, and 2014-2016.
- Increased rates of culture-negative pneumonia and influenza were associated with increases in PM2.5 during the week prior.
- This association continued despite changes in air quality policies or economic changes.

Willis, M. D., Jusko, T. A., Halterman, J. S., et al. (2018). Unconventional natural gas development and pediatric asthma hospitalizations in Pennsylvania.

This study set out to quantify the association between SGD and pediatric asthma hospitalizations. The researchers compared pediatric asthma hospitalizations by zip code with those exposed to SGD and those not exposed between 2003-2014. They found:

- Elevated odds of hospitalization were consistently observed in those in closer proximity to SGD.
- During the time when the well was drilled, there was a 25% increase in the odds of being hospitalized for asthma.

Rasmussen, S. G., Ogburn, E. L., McCormack, M., et al., (2016). Asthma Exacerbations and Unconventional Natural Gas Development in the Marcellus Shale.

This study evaluated the association between SGD and asthma exacerbations in Pennsylvania. Asthma patients with exacerbations between 2005-2012 were compared with those without exacerbations. The researchers found:

- SGD activity was statistically associated with increased odds of mild, moderate, and severe asthma exacerbations.

LEARN MORE

EHP Resources

- BLOG
  - Respiratory Hazards and Your Health
- HANDOUT
  - Aggregate/Combination Air Pollution and Shale Gas Development
  - Asthma and Shale Gas Development
  - Infectious Lung Disease and Air Pollution (Flu, COVID-19)
- WEBINAR
  - Virtual Expert Panel: Infectious Lung Disease and Air Pollution

Other Resources

- ARTICLE
  - Health and Environmental Effects of Particulate Matter (PM), *Environmental Protection Agency (EPA)*
- PRESENTATION
  - Fracking Fumes - Air Pollution Impacts on Health and Well-Being, *Rutgers Robert Wood Johnson Medical School, EOHSI, Center for Environmental Exposures and Disease*

FULL CITATIONS

Croft, D. P., Zhang, W., Lin, S., Thurston, S. W., Hopke, P. K., Masiol, M., Squizzato, S., van Wijngaarden, E., Utell, M. J., & Rich, D. Q. (2018). The Association between Respiratory Infection and Air Pollution in the Setting of Air Quality Policy and Economic Change. *Annals of the American Thoracic Society*. https://doi.org/10.1513/annalsats.201810-691oc

Denham, A., Willis, M. D., Croft, D. P., Liu, L., & Hill, E. L. (2021). Acute myocardial infarction associated with unconventional natural gas development: A natural experiment. *Environmental Research*, 195, 110872. https://doi.org/10.1016/j.envres.2021.110872

McAlexander, T. P., Bandeen-Roche, K., Buckley, J. P., Pollak, J., Michos, E. D., McEvoy, J. W., & Schwartz, B. S. (2020). Unconventional Natural Gas Development and Hospitalization for Heart Failure in Pennsylvania. *Journal of the American College of Cardiology*, 76(24), 2862–2874. https://doi.org/10.1016/j.jacc.2020.10.023

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Willis, M. D., Jusko, T. A., Halterman, J. S., & Hill, E. L. (2018). Unconventional natural gas development and pediatric asthma hospitalizations in Pennsylvania. *Environmental Research*, 166, 402–408. https://doi.org/10.1016/j.envres.2018.06.022

Stress, anxiety, depression, and other mental health symptoms increase the closer one is to shale gas development. Individuals living near SGD experience environmental stressors including:

- Noise, light, and vibration that accompanies drilling, often lasting days or weeks at a time
- Air or water quality changes
- Uncertainty regarding toxic exposures
- Increased emissions, noise, dust, and travel delays caused by truck traffic
- Uncertainty over their health and that of their families

Stress in these environments tends to fall into one or more categories: physical stressors, psychological stressors, or psychosocial stressors. Review the below resources for more information around the impact of SGD on mental health.

Additional Resources

- Mental Health and Shale Gas Development
- Chronic Stress and Environmental Contamination (training)
- Preliminary Findings from a Systematic Review of Chronic Environmental Contamination, Psychosocial Stress, and Community Resilience (webinar)
- Community Stress Resource Center

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Potential Health Effects Due to Inhalation of Air Pollutants

The table below is aimed at providing a summary of research about the most common air pollutants and should not be considered a comprehensive list of all toxic exposures. This chart may not include the health effects of high-level exposures. All the information is from Agency for Toxic Substances and Disease Registry (ATSDR) ToxProfiles. There is a rapidly expanding body of scientific evidence linking air pollution and health concerns.

Chemical	Short-term Exposures, Acute Health Symptoms	Long-term Exposures, Chronic Health Effects
Volatile Organic Chemicals (VOCs)	**Varies by chemical (see below)**	**Varies by chemical (see below)**
Benzene	Headache, dizziness, fatigue, rapid heart rate, tremors, confusion, unconsciousness	Anemia, leukemia, irregular menstrual periods, increased chance of infection, potential impacts to fertility
Toluene	Headache, fatigue, confusion, dizziness, weakness, memory loss, nausea, loss of appetite	Permanent neurological effects, hearing and color vision loss, during pregnancy can lead to developmental effects such as reduced mental abilities and stunted growth
Ethyl Benzene	Eye and throat irritation, dizziness	Cancer, irreversible damage to the inner ear and hearing
Xylene	Eye, nose, throat, and skin irritation; difficulty in breathing and problems with the lungs; memory difficulties; stomach discomfort; changes in liver and kidney; headaches; lack of muscle coordination; dizziness; confusion; changes in balance	Permanent neurological effects
Polycyclic Aromatic Hydrocarbons (PAHs)	Eye and skin irritation, asthma attacks, acute cardiac events, fertility issues, in pregnancy higher rates of birth defects and lower body weights	Contribute to the development or worsening of pulmonary or cardiac diseases; lung, skin, and bladder cancer
Formaldehyde	Nose and eye irritation, increased risk of asthma and allergies, decrease in weight, stomach ulcers, liver and kidney damage	Asthma, eczema, nasal and throat cancer
Methylene Chloride	Decreased attentiveness, difficult hand-eye coordination, dizziness, nausea, tingling of toes and fingers, burning and redness of skin	Chance of cancer was seen in animals exposed, unsure still whether it can cause cancer in humans

Chemical	Short-term Exposures, Acute Health Symptoms	Long-term Exposures, Chronic Health Effects
Hydrogen Sulfide	Eye, nose, and throat irritation; difficulty breathing for asthmatics; headaches; poor memory; fatigue; balance problems	Respiratory distress or arrest if exposed to very high levels, headaches, poor attention span, poor motor function
Diesel Exhaust (contains VOCs and $PM_{2.5}$)	Eye, nose, throat, and lung irritation; Headaches; dizziness; nausea	Worsening respiratory disease, lung cancer
Particulate Matter 2.5 ($PM_{2.5}$)	Asthma attacks, acute bronchitis, heart attacks in individuals with cardiac disease	Reduced lung function, chronic bronchitis, neurodegenerative diseases
Ozone	Chest pain; coughing; throat irritation; congestion; increased symptoms in bronchitis, emphysema, and asthma	Contributes to development of chronic lung disease and worsens pre-existing bronchitis, emphysema, and asthma
Radon	None	Lung cancer
Carbon Monoxide (CO)	Decreased exercise tolerance, decreased vigilance, increased risk for cardiac ischemia in individuals with heart disease	Decreased exercise tolerance, decreased vigilance, increased risk for cardiac ischemia in individuals with heart disease
Nitrogen Oxides (NO_x)	Respiratory symptoms, worsening asthma	Respiratory disease, worsening heart disease

Some sources of shale gas emissions for air pollutants can include well pads, compressor stations, processing facilities, power plants, impoundments, injection wells, storage wells, landfills, oil refineries, etc. More information on these types of facilities can be found at Illustrated Stages of Shale Gas Development. For more information on protecting your health, visit Protecting Your Health from Shale Gas Development.

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Survey for Potential Environmental Exposure

The following questions can help you to understand if the symptoms a patient/client is experiencing may be attributable to environmental exposures from shale gas development (SGD).

1. **Do you currently live near any SGD facilities, such as the ones listed below? (Check all that apply)**

Well Pad		Impoundment Pond	
Truck Traffic		Metering Station	
Processing/Cryogenic/Fractionation Plant		Compressor Station	
Pipeline		Pigging Station	
Landfill accepting shale gas waste		Wastewater Treatment Plant (WWTP) accepting shale gas waste	
Injection Well accepting shale gas waste		Petrochemical Plant	

2. **Have there been incidents such as spills, leaks, or explosions that have occurred near your home, school, or place of work?** ◯ No ◯ Yes ◯ Unsure

3. **Have you noticed a change in the taste, odor, or appearance in the water source at your home?**
◯ No ◯ Yes

4. **Have you noticed any unusual smells or changes in appearance in the air near your home?**
◯ No ◯ Yes

5. **Have you noticed any unusual dust, film, or residue on the outside of your home or car?**
◯ No ◯ Yes

6. **Have you experienced any of the following symptoms during or after activities near your home (that wouldn't necessarily be explained by an ongoing condition)? (Select all that apply)**

Sore or irritated throat		Sinus symptoms (runny nose/postnasal drip, etc.)	
Cough or wheezing		Itchy/burning eyes	
Itching of skin or rash		Nosebleeds	
Shortness of breath		Abdominal pain/discomfort	
Headache		Significant weight loss/gain	
Dizziness		Nausea	
Sleep disturbance		Anxiety	
Fatigue		Irritability/mood swings	
Other:		Other:	

7. **Have you discussed symptoms you are having with any other doctors or health professionals previously?** ◯ No ◯ Yes

8. **Have you ever been diagnosed with any medical conditions?** ◯ No ◯ Yes
   If yes, please state: _____

9. **Do you or anyone else in your household work onsite at a shale gas facility or in the transportation and processing of shale gas waste?** ◯ No ◯ Yes

Additional Concerns or Notes

Click here to access a fillable version of the survey online.

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