

The Science Behind the Need for Health Buffers from Oil and Gas

Summary of Key Articles and Reports

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There is abundant research that describes and provides evidence for the health risks and harms of oil and gas production and pollution (see, for example, the 9th edition of the [fracking compendium](#)). With the aim of informing policy to reduce public health hazards, this summary highlights research that addresses the question of *distances* at which increased health risks and harms from oil and gas activities are observed to occur.

Approximately 144,000 New Mexicans reside within a half-mile (2,640 feet) of oil and gas production. About half of these people are people of color.¹ Nearly 35,000 children go to school within a mile of oil and gas facilities.

There is ample scientific evidence to support a minimum setback distance of at least 1 mile (5,280 feet) to mitigate harms to public health, especially for vulnerable populations, including children and pregnant people.

For example, the following studies, summarized below, all find evidence of harm at distances of a mile (5,280 feet) or greater:

- Buchanich et al. (2025) found that there is an increased risk of asthma exacerbations during unconventional gas production at exposure zones of **1 mile, 2 miles, 5 miles, and 10 miles**.
- Cao (2025) found that individuals residing within **10 km** of unconventional oil and gas development during pregnancy were at higher risk of having a child of low birthweight and small gestational age, even among term births.
- Gaughan et al. (2023) found that individuals residing within **10 km** of unconventional oil and gas development during pregnancy were at higher risk of having a child with birth defects, including neural tube defects, limb reduction defects, and spina bifida.
- Weisner et al. (2023) found that children living within **2 miles** of multi-well unconventional oil and gas development had higher frequencies of respiratory and gastrointestinal distress symptoms than those living more than 2 miles away, as well a greater frequencies of nosebleeds, nausea, vomiting, and shortness of breath.
- Talbott et al. (2023) found that children who live within **1 mile (5,280 feet)** of an unconventional gas well are 5-7 times more likely to develop lymphoma than unexposed children. Children living within **2-5 miles** of unconventional gas wells are 2 times more likely to develop lymphoma than unexposed children.
- Gonzalez et al. (2022) found higher concentrations of ambient air pollutants within **4 km (13,123 feet)** of preproduction wells and within **2 km (6,561 feet)** of producing wells.

¹ Earthworks & FrackTracker, The Oil & Gas Threat Map (2023), <https://oilandgasthreatmap.com/threat-map/newmexico/>

- Cairncross et al. (2022) found that individuals who resided within **10 km (32,808 feet)** of one or more fracking wells during pregnancy were at higher risk for adverse birth outcomes.
- Apergis et al. (2019) found that there is an increased risk of adverse health outcomes for infants when individuals reside at distances of up to **20 km**, with greater harms within 1 km.
- Currie et al. (2018) found a 25% increased risk of low birthweight, a significant decline in average birthweight, and decreased overall health index for infants born to individuals living within 1 km of an active well site that was fracked, and elevated risks for infants born to mothers living at up to **3 km** from active well sites.

Additionally, Rabinowitz et al. (2015) found that persons living within **1 km** of natural gas wells were more likely to experience respiratory and skin problems than persons living 2 km or more from natural gas wells in Pennsylvania. Shamasunder et al. (2018) found that there is a significantly higher risk of asthma for people living within 1,500 feet of oil and gas. And Tran et al. (2021) found that proximity to hydraulic fracturing within **1 km (3,280 feet)** during pregnancy was associated with adverse birth outcomes.

In a comprehensive review of existing literature through July 2023, Shonkoff et al (2024) found that “existing epidemiologic studies were not designed to test and establish a specific “safe” buffer distance between OGD [oil and gas development] sites and sensitive receptors, such as homes and schools. Nevertheless, **studies consistently demonstrate evidence of harm at distances less than 1 km (3,281 ft), and some studies also show evidence of harm linked to upstream OGD activity at distances greater than 1 km (3,281 ft).**”² Shonkoff et al. (2024) present a hierarchy of protective strategies to reduce human health hazards from oil and gas pollution. The most health protective strategy is to stop drilling and developing new wells, phase out existing upstream OGD activities and associated infrastructure, and properly plug remediate legacy wells and ancillary infrastructure. The next most protective strategy is to introduce setbacks for new and existing wells combined with engineering emissions controls and monitoring.³

Study Summaries

COMPREHENSIVE LITERATURE REVIEW AND PANEL ANALYSIS

California Oil and Gas Public Health Rulemaking Scientific Advisory Panel (2024)

Shonkoff, Seth B.C., Rachel Morello-Frosch, Joan Casey, Nicole Deziel, Dominic DiGuilio, Stephen Foster, Jo Kay Ghosh, Gretchen Goldman, Robert Harrison, Jill Johnston, Kenneth Kloc, Lisa McKenzie, Thomes McKone, Mark Miller, and Andrea Polidori

https://www.conservation.ca.gov/calgem/Documents/Public%20Health%20Panel%20Final%20Report_20240621.pdf

² Shonkoff, Seth B.C. et al., California Oil and Gas Public Health Rulemaking Scientific Advisory Panel (2024), https://www.conservation.ca.gov/calgem/Documents/Public%20Health%20Panel%20Final%20Report_20240621.pdf at 3-95

³ *Id.* at 3-96

About: The California Oil and Gas Public Health Rulemaking Scientific Advisory Panel, a group of fifteen experts appointed by the California Department of Conservation, provided subject matter expertise to the California Geologic Energy Management Division (CalGEM) to inform the agency’s rulemaking process to establish a science-based setback for oil and gas operations. The Panel evaluated and synthesized the best available peer-reviewed science and publicly available data on the public-health dimensions of upstream oil and gas development.

The study identified 72 peer-reviewed epidemiological studies that evaluated upstream oil and gas development and adverse health outcomes in oil and gas regions in the United States and Canada that were published between January 1, 2009, and July 15, 2023. These studies were conducted in California, Colorado, North Dakota, New York, Ohio, Oklahoma, Pennsylvania, Texas, and West Virginia in the United States, and Alberta and British Columbia in Canada. The health outcomes included adverse birth outcomes (perinatal), cancer, respiratory and cardiovascular health, non-outcome specific hospitalizations, mental and behavioral health, additional self-reported health symptoms and health outcomes, and sexually transmitted infections.

Health Harms of Upstream Oil and Gas Development

Key findings:

- The likelihood of adverse health outcomes increases as the distance between human-occupied residences and upstream oil and gas development operations decreases, or the density of wells and production volume increases. Studies consistently show increased potential for exposure to air pollution and noise, as well as increased risk for several adverse health outcomes in populations living within and beyond 1 kilometer (km) (~0.62 miles or 3,281 feet) of oil and gas well sites. Certain groups face disproportionate exposures to oil and gas development sites.
- More than 72 peer-reviewed epidemiological studies conducted across the United States and Canada published through July 15, 2023, evaluated the associations between upstream oil and gas development and several adverse health outcomes.
 - This body of evidence consistently indicates that human populations residing *closer* to upstream oil and gas development experience a greater risk of decreased respiratory function and adverse perinatal outcomes compared to those living farther away.
 - Additionally, higher *density* of upstream oil and gas development in the vicinity of residences is associated with greater respiratory and perinatal health risks compared to lower density of oil and gas development.
 - Finally, higher *production volume of oil and gas* is associated with increased risk of adverse respiratory and perinatal health impacts. These trends have been observed in urban and rural settings.
 - For other health outcomes, including cancer, cardiovascular disease, sexually transmitted infections, and mental and behavioral health, there are limited studies and more research is needed to evaluate the consistency of relationships.

Conclusions:

- The Panel concludes with a high level of certainty that there is a causal relationship between close residential proximity to upstream oil and gas development and adverse perinatal and respiratory outcomes. The Panel derived this level of certainty from the consistency of results across multiple studies that were conducted using different methodologies, in different locations, with diverse populations, and during different time periods.
- The human health risks associated with chemical and physical stressors emitted by upstream oil and gas sites (air and water pollutants, noise, etc.) can be reduced by establishing greater setback distances between upstream oil and gas development and sensitive receptors, whether it be a human receptor or a receptor relevant to human exposure (e.g., an aquifer that is currently used or in the future could be used for drinking water).
- The human health risks associated with chemical and physical stressors emitted by upstream oil and gas development can be reduced by lowering the density of oil and gas sites around human receptors or receptors relevant to human exposure (e.g., an aquifer that is currently used or in the future could be used for drinking water).

Recommendations for setbacks:

- **Implement a health-protective minimum surface setback.** Implementing minimum surface setbacks between upstream oil and gas operations and human receptors is critical to protect public health. To mitigate health risks associated with upstream oil and gas development, the setback distance should be at least 1 km (3,281 ft). In communities with higher well density, high hydrocarbon production volumes, dense ancillary oil and gas development infrastructure, and the presence of other environmental hazards and socioeconomic stressors, a larger setback should be applied.
- Decision-making regarding the appropriate health-protective minimum surface setback distance should consider the following:
 - **Inclusion of an additional margin of safety to account for the vulnerabilities of particular population subgroups** (e.g., children, pregnant people, those with chronic illnesses, and the elderly) and given the potential for off-normal events (e.g., blowouts, loss of containment events, and accidental releases) that cannot be immediately controlled or consistently prevented.
 - **Decisions on a health-protective minimum surface setback distance should be made with particular attention to the locations of sensitive receptors**, including but not limited to schools (pre-K to 12th grade), childcare facilities, healthcare facilities, senior care facilities, correctional facilities, parks, and residential buildings.
 - **Multiple stressors associated with upstream oil and gas development** (e.g., noise, odor, vibration, air pollution, water pollution), rather than solely mitigating health and safety impacts of an individual stressor (e.g., only air pollution).
 - **Existing environmental and socioeconomic burdens experienced by communities that may enhance vulnerability to the adverse health effects of oil and gas development activities.** Upstream oil and gas siting decisions and setback requirements should be informed by and account for data-driven metrics used to assess the cumulative burden of communities to ensure that the additional burden associated with upstream oil and gas development is not placed on disadvantaged communities.

- “Existing epidemiologic studies were not designed to test and establish a specific “safe” buffer distance between OGD [oil and gas development] sites and sensitive receptors, such as homes and schools. Nevertheless, studies consistently demonstrate evidence of harm at distances less than 1 km (3,281 ft), and some studies also show evidence of harm linked to upstream OGD activity at distances greater than 1 km (3,281 ft).” (3-95)
- There is a hierarchy of protective strategies to reduce human health hazards from oil and gas pollution. The most health protective strategy is “to stop drilling and developing new wells, phase out existing upstream OGD activities and associated infrastructure, and properly plug remediate legacy wells and ancillary infrastructure.” The next most protective strategy is “the elimination of new and existing wells and ancillary infrastructure within scientifically informed setback distances, and the deployment of engineering emission controls and associated monitoring approaches that lead to rapid leak detection and repair for new and existing wells and ancillary infrastructure.” (3-96)

Types and Sources of Pollutants: Methane and non-methane VOCs (NMVOCs) are emitted during upstream oil and gas development. Many of the NMVOCs emitted are toxic air contaminants or ground-level ozone precursors, including n-hexane, benzene, ethylbenzene, toluene, and xylenes. Wells, valves, tanks and other equipment used to produce, store, process and transport petroleum products are associated with emissions of toxic air contaminants, hazardous air pollutants and other health-damaging NMVOCs. Diesel engines used to power on-site equipment and trucks and oil and gas development sites directly emit health damaging hazardous air pollutants, fine particulate matter, and nitrogen oxides and VOCs.

Summary of Studies Included in Literature Review

Perinatal Outcome Studies: Overall, 24 of 25 studies that examine perinatal effects found increased risk of at least one adverse birth outcome in those most exposed to upstream OGD (measured using metrics including, but not limited to proximity, well density, and production volume). Adverse perinatal outcomes include preterm births, low birth weight, small-for-gestational age births, and congenital malformations. These adverse perinatal outcomes increase the risk of mortality and long-term developmental problems in newborns (Liu et al., 2012; Vogel et al., 2018) as well as longer term morbidity through adulthood (Baer et al., 2016; Barker, 1995; Carmody & Charlton, 2013; Frey & Klebanoff, 2016).

Preterm birth

Eight of the 13 studies examining preterm birth (defined as less than 37 weeks of gestation) report a positive association between upstream OGD and preterm birth. Seven of these studies across three oil and gas regions (California, Pennsylvania and Texas) found statistically significant increases in preterm birth among infants born to mothers in the highest exposed groups living in proximity to upstream OGD (Cairncross et al., 2022; Casey et al., 2016; Cushing et al., 2020; Gonzalez et al., 2020; Hill, 2018; Walker Whitworth et al., 2018; Whitworth et al., 2017).

Two Texas studies found preterm birth rates significantly increased with exposure to upstream OGD within 2,640 ft (0.8 km) during the drilling phase, production phase, as well as all phases of OGD (Walker Whitworth et al., 2018; Whitworth et al., 2017). These findings were observed in the Barnett Shale region of Texas, with effects remaining significant up to 10 miles (16.1 km)

for those in the highest exposure tertile (Walker Whitworth et al., 2018; Whitworth et al., 2017). A study conducted in Alberta, Canada, found that, mothers living within 10 km (6.2 miles) of more than 100 hydraulically fractured wells during one year prior to conception through birth of their child had a significantly increased risk of preterm birth (Cairncross et al., 2022).

Low birth weight

Five of six studies found a statistically significantly higher risk of low birth weight (birth weight less than 5.51 lbs) in the highest activity category for oil and gas communities compared to those individuals located farther away (Apergis et al., 2019, Oklahoma; Currie et al., 2017, Pennsylvania; Hill, 2018, Pennsylvania; Tran et al., 2020, 2021, California).

Term birth weight

Nine of 13 studies report a statistically significant inverse association between exposure to upstream OGD and term birth weight (>37 week gestation) in California, Oklahoma, Pennsylvania, Texas, and British Columbia (Apergis et al., 2019; Caron-Beaudoin et al., 2020; Casey et al., 2016; Currie et al., 2017; Cushing et al., 2020; Stacy et al., 2015; Tran et al., 2020; 2021; Willis et al., 2021).

Small for gestational age birth

Four of 10 studies that examined small for gestational age birth (birthweight less than the country sex-specific 10th percentile of weight for each week of gestation) report a positive association between exposure to upstream OGD and small for gestational age births, including two studies in California (Tran et al., 2020, 2021), one in Alberta, Canada (Cairncross et al., 2022) and two studies in Pennsylvania (Hill, 2018; Stacy et al., 2015).

Congenital heart defects

All seven studies that evaluated associations between upstream OGD and congenital heart defects report increased risk of congenital heart defects increasing levels of and/or proximity to OGD within 1–16.1 km (0.6–10 mi) of the birth residence. Four retrospective cohort and two case-control studies observed increased odds of congenital heart defects with increased upstream OGD (Han et al. 2023, Gaughan et al. 2023, Tang et al. 2021, McKenzie et al. 2014, McKenzie et al. 2019, Janitz et al. 2019, Willis et al. 2023).

Neural tube defects

Five out of six studies that evaluated neural tube defects and upstream OGD found that the risk of neural tube defects increased with increasing level activity and/or proximity to upstream OGD within 1–16.1 km (0.6–10 mi) of the birth residence (Han et al. 2023, Gaughan et al. 2023, Janitz et al., 2019; McKenzie et al., 2014; Tang et al., 2021; Willis et al., 2023).

Infant health index

Three studies found statistically significant decrease in the infant health index (a composite value that combines birth weight, prematurity, any congenital anomalies, presence of abnormal conditions) with proximity to upstream OGD (Apergis et al., 2019; Currie et al., 2017; Hill, 2018).

Apergis et al. (2019) found statistically significant decreases in the infant health index up to 20 km (12 mi) from hydraulically fractured oil and gas wells in Oklahoma, with the largest

decreases seen at the closest distance examined of 1km (3,281 ft). The authors also found smaller decreases in the infant health index up to 20 km (12 mi) from oil and gas wells that were not hydraulically fractured.

Currie et al. (2017) found statistically significant decreases in the infant health index up to 3 km (1.9 mi) from hydraulically fractured oil and gas wells, with the largest decreases within 1 km (3,281 ft). Similarly, Hill (2018) found a statistically significant increase in the probability of an adverse health outcome at birth within 2.5 km (1.5 mi) of hydraulically fractured shale gas well activity post-drilling.

Fetal death

Two studies assessed fetal death and upstream OGD. Busby and Mangano (2017) assessed county-level infant deaths and unconventional OGD in Pennsylvania and found a significant increase in infant mortality in the 10 counties where hydraulic fracturing was present. Whitworth et al. (2017) conducted a retrospective cohort study in the Barnett Shale region of North Texas by assessing individual exposure to active oil and gas wells and fetal death, and found increased odds of infant mortality among those living within a half-mile (2,640 ft, 0.8 km) of oil and gas activity in the highest exposure category. These effects were also observed for women living within two miles (3.2 km) of oil and gas activity in the second tertile of exposure.

High-risk pregnancy

Casey et al. (2016) found that exposure to unconventional natural gas development in Pennsylvania was significantly associated with 30% increased odds of physician-reported high-risk pregnancy when comparing the highest level of activity to the lowest.

Gestational hypertension and eclampsia

Willis et al. (2022) found that pregnant women in Texas living within 1 km (3,281 ft) of an active oil and gas well had 5% increased odds of gestational hypertension and 26% increased odds of eclampsia when compared to pregnant women living far away from extraction activities (>10 km; >6.2 mi). Significantly increased odds were not found for pregnant women living within 1–2 km (3,281–6,561 ft) or 2–3 km (6,561–9,842 ft) of an active oil and gas well (Willis et al., 2022).

Respiratory Health Outcome Studies

Respiratory health outcomes

Of 11 peer-reviewed studies, two studies in California found an association between upstream OGD and self-reported and physician-diagnosed asthma, reduced lung function, and self-reported acute respiratory symptoms (e.g., recent wheeze) (Johnston et al., 2021; Shamasunder et al., 2018). Nine studies in other oil and gas regions (New York, Pennsylvania, and Texas) reported an association between upstream OGD and asthma exacerbations, asthma hospitalizations, and other respiratory symptoms or outcomes (Bushong et al., 2022; Koehler et al., 2018; Li et al., 2023; Peng et al., 2018; Rabinowitz et al., 2015; Rasmussen et al., 2016; Trickey et al., 2023; Willis et al., 2018, 2020). Many criteria air pollutants (e.g., PM_{2.5}, ozone, nitrogen oxides) and toxic air contaminants emitted from upstream OGD have a well-established body of scientific literature indicating that exposure to these pollutants causes an increased risk

of development and exacerbation of respiratory disease (Bolden et al., 2015; Ferrero et al., 2014).

Asthma

Eight studies that examined asthma exacerbations and hospitalizations all found upstream OGD was associated with increased asthma-related outcomes: five focused in Pennsylvania, one focused in Pennsylvania and New York (multiple states), and two focused in Texas (Bushong et al., 2022; Koehler et al., 2018; Li et al., 2023; Peng et al., 2018; Rabinowitz et al., 2015; Rasmussen et al., 2016; Willis et al., 2020, 2018).

Studies in Pennsylvania have found that upstream OGD is associated with increased pediatric hospitalizations for asthma, increased rates of mild asthma exacerbations, and increased rates of lower respiratory symptoms, including mild asthma exacerbations (Koehler et al., 2018; Peng et al., 2018; Rabinowitz et al., 2015; Rasmussen et al., 2016; Willis et al., 2018). Two studies found an association with increased rates of mild asthma exacerbations and oil and gas exposure within 1 km (3,281 ft) of a well compared to those living greater than 2 km (1.2 mi) away (Koehler et al., 2018; Rabinowitz et al., 2015). Bushong et al. (2022) found a significant positive association between asthma hospitalization rates and annual well density. Similarly, Willis et al. (2018) found a significant positive association between pediatric asthma hospitalization rates and annual well density. Rasmussen et al. (2016) found that those living next to the densest areas of oil and gas production in the Marcellus Shale region had significantly increased odds of mild asthma exacerbation compared to those living near lower-density activity. This result was found to be significant during all four phases of development (pad development, drilling, stimulation, and production). In addition to mild asthma exacerbations, Rasmussen et al. (2016) also found that those living in the highest quartile of residential unconventional natural gas development activity for all four phases (pad development, drilling, stimulation, production) had significantly higher odds of moderate and severe types of asthma exacerbations (emergency department visits, and hospitalizations, respectively) than those in the lowest quartile.

In Texas, Willis et al. (2020) observed an increased odds of pediatric asthma hospitalizations associated with natural gas development, for both conventional drilling and unconventional drilling activities, and increased well production volumes. Li et al. (2023) observed an increase in asthma rates in census block with higher counts of oil and natural gas wells in Texas.

Studies on Other Adverse Health Effects

Cancer

Four out of five studies that examined oil and gas development and cancer outcomes between 1990 and 2017 found statistically significant associations between upstream OGD and cancer: Pennsylvania (Clark et al. 2022; Finkel, 2016); Colorado (McKenzie et al., 2017), and Texas (Hoang et al. 2023).

Cardiovascular outcomes

Five studies evaluated associations between cardiovascular outcomes, including markers of cardiovascular disease, heart failure hospitalizations, acute myocardial infarction hospitalizations and mortality, and stroke mortality (Denham et al., 2021; Hu et al., 2022; McKenzie et al., 2019b; McAlexander et al., 2020; Trickey et al., 2023) and upstream OGD.

- McKenzie et al. (2019b) found that well intensity per square kilometer was associated with indicators of cardiovascular disease, including increased indications of systemic inflammation, arterial stiffness, and systolic blood pressure among those not taking prescription medications, in a study focused in northeastern Colorado's Denver-Julesburg Basin.
- McAlexander et al. (2020) examined heart failure among residents living near unconventional natural gas development in Pennsylvania, with exposure defined as residential proximity to wells, nearby well density, well depth, natural gas production, and phase of activity at the well pad 30 days prior to hospitalization. A statistically significant increase in heart failure hospitalization was observed among those in the highest exposure category compared to the lowest exposure category during pad preparation, stimulation and production.
- Denham et al. (2021) found significant associations between acute myocardial infarction hospitalization and mortality rates and county-level contemporaneous drilled wells, overall well count, and well density in Pennsylvania.
- Trickey et al. (2023) showed that OGD was associated with more cardiovascular disease-related hospitalizations among Medicare enrollees in three Northern Pennsylvania counties.

**PUBLISHED STUDIES THAT LOOKED AT HEALTH IMPACTS
AT DISTANCES OF 1 MILE (1.6 KILOMETERS) OR MORE (PARTIAL LIST)**

ADVERSE BIRTH OUTCOMES

Low Birthweights and Small for Gestation Age, 10 km (6.2 miles)

Cao, Alan, Assessing Impact of Maternal Proximity to Unconventional Oil and Gas Wells on Neonatal Birthweight in Ohio: A Retrospective Cohort Study (2010-2017), *Public Health Theses* 2477 (2025), <https://elischolar.library.yale.edu/ysphtdl/2477/>

About: A retrospective cohort study of 965,272 live singleton births in Ohio from 2010 to 2017. Maternal residential proximity to active UOGD wells was calculated with buffer zones of less than 2 km, 2-5 km, 5-10 km, and greater than 10 km. Exposure was assessed during the year prior to delivery and across trimesters.

Key Findings:

- Maternal residence within 5-10 km of active UOGD was consistently associated with increased odds of low birthweight. Small gestational age was also associated with 5-10 km exposure, even among term births.
- Continuous birthweight decreased with exposure to UOGD at 2-10 km.
- Bottom line: Maternal residential proximity to UOGD is associated with increased odds of adverse birth outcomes, particularly during the second trimester.

Birth Defects, 10 km (6.2 miles)

Gaughan, Casey. et al., Residential Proximity to Unconventional Oil and Gas Development and Birth Defects in Ohio, 229 *Environ Res* 115937 (2023), <https://pubmed.ncbi.nlm.nih.gov/37076028/>

About: A registry-based cohort study of nearly one million live births in Ohio between 2010-2017, where gas production increased significantly during that time period. Exposure to fracking was assigned based on maternal residential proximity to unconventional oil and gas wells (within 10 km) and based on whether residences were hydrologically connected to oil and gas wells.

Key findings:

- Bottom line: There is a higher level of birth defects for children born to mothers living within 10 km of unconventional oil and gas development as compared to unexposed mothers.
- Birth defects: neural tube defects, limb reduction defects, and spina bifida.

Low Birthweights and Small for Gestational Age, 10 miles (16 km)

Buchanich, Janine and Talbott, Evalyn, *Final Report for Pennsylvania Department of Health, Bureau of Epidemiology, Hydraulic Fracturing Epidemiology Research Studies: Birth Outcomes*, (July 31, 2023), https://www.health.pa.gov/topics/Documents/Environmental%20Health/Report_Birth_outcomes_2023.pdf

About: A retrospective cohort study of birth outcomes in Southwestern Pennsylvania where unconventional natural gas production has surged. Looked at live births between 2010-2020. Assessed four birth outcomes: 1) low 5-minute apgar score, small for gestational age, preterm birth, and term birthweight. Considered five buffer distances: 0.5 miles, 1 mile, 2 miles, 5 miles, and 10 miles of exposure to unconventional gas activity, also accounting for cumulative well count. Considered four phases of development: well pad preparation, drilling, hydraulic fracturing, and production.

Key findings:

- Small for gestational age: Moderate to strong data to suggest an increased risk for small to gestational age births at exposure within 2-, 5-, and 10-mile residential buffers.
- Term birthweight (birthweight in grams between 37-41 weeks gestation): statistically significant association between residential proximity to unconventional natural gas production and low birthweight within 5- and 10-mile buffers. Statistically significant reductions in birthweight with increasing intensity of exposure (p.58-59).
 - “There were moderate data to support that reductions in term birthweight were associated with proximity to both compressor stations and facilities accepting oil and gas waste” (61) – Indicating that additional studies should investigate non-well oil and gas production activities and infrastructures.
- Preterm births: Found moderate association between preterm births and exposure to PM2.5 (particulate matter) as has been shown previously in multiple studies in the United States and internationally.

Adverse Birth Outcomes, 10 km (6.2 miles)

Cairncross, ZF et al., Association Between Residential Proximity to Hydraulic Fracturing Sites and Adverse Birth Outcomes, 176 *JAMA Pediatr* 585 (2022), <https://pubmed.ncbi.nlm.nih.gov/35377398/>

About: A study of 26,193 people with 34,873 unique pregnancies in Alberta, Canada. Individuals were considered exposed if they lived within 10 km of 1 or more fracked (hydraulically fractured) well during year 1 of preconception or during pregnancy.

Key findings:

- Small for gestational age and major congenital anomalies were significantly higher for individuals who lived within 10 km of at least 1 fracked well.
- Risk of spontaneous preterm birth and small for gestational age were significantly increased in those with 100 or more wells within 10 km.
- Bottom line: Individuals who are exposed to fracking during pregnancy may be at higher risk of several adverse birth outcomes.

Pre-term birth, 10 km (6.2 miles)

Gonzalez, D. J. X. et al., Oil and gas production and spontaneous preterm birth in the San Joaquin Valley, CA: A case-control study, 4 *Environmental Epidemiology* e099 (2020), <https://doi.org/10.1097/EE9.0000000000000099>

About: Gonzalez et al. (2020) conducted a case-control study to evaluate the association between exposure to oil and gas wells and preterm birth risk in the San Joaquin Valley between 1998 and 2011.

Key Findings:

- The study found statistically significantly higher risk of early preterm birth (28–31 weeks) with high exposure to wells compared to unexposed births. The authors assessed exposure using an inverse-distance squared metric of wells in pre-production and active wells within 10 km (6.2 miles) of maternal residence.
- The risk was confined to and heightened among early preterm births to Hispanic and non-Hispanic Black mothers, and to mothers with 12 or fewer years of education attainment.
- In a secondary analysis, Gonzalez et al. (2020) found evidence of significantly higher PM2.5 and coarse particulate matter (PM10) concentrations at monitors close to drilling sites compared to “unexposed” monitors located farther away.
- In a follow-up study using a more robust study design, the same authors corroborated the findings of marginal increases in PM2.5 and PM10 concentrations downwind of drilling sites and active wells (Gonzalez et al., 2022).

Infant Mortality, 1-10 km (0.6-6.2 miles)

Apergis, Nicholas et al., Fracking and Infant Mortality: Fresh Evidence from Oklahoma, 26 *Environ Sci Pollut Res* 32360 (2019), <https://doi.org/10.1007/s11356-019-06478-z>

About: Analyzed relationship between birth health and proximity to fracking wells within buffer zones of 1 km, 5 km, 10 km, and 20 km from mother’s residence in Oklahoma.

Key Findings:

- Proximity to fracking wells during pregnancy causes negative health impacts for infants. The study found negative impacts to infant total health index at distances of up to 20 km, with the strongest impacts occurring within the 1 km distance.
- Risks of infant mortality were observed at 5 km – 10 km distance
- Risks of low birthweight are significant within 10 km, and strongest within 1 km.

Low Birth Weight, 3.5 km (2.2 miles)

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

About: This study examines singleton births to mothers residing close to a shale gas well from 2003 to 2010 in Pennsylvania.

Key Findings:

- Shale gas wells are associated with reduced average birth weight and reduced term birth weight among infants born to mothers living within a 2.5 km radius from a shale gas well.
- An additional well is associated with a 7 percent increase in low birthweight, a 5 g reduction in term birth weight and a 3 percent increase in premature birth.
- There are detectable effects of shale gas development on low birthweight and term birth weight more than 3.5 km from the well head (more than 2 miles or over 11,000 ft).

Adverse Infant Health Outcomes, 1-3 km (0.6-1.9 miles)

Currie, Janet, et al., Hydraulic Fracturing and Infant Health: New Evidence from Pennsylvania, 3 *Science Advances* (2017), <https://www.science.org/doi/10.1126/sciadv.1603021>

About: An analysis of more than 1.1 million births in Pennsylvania between 2004-2013, comparing infants born to mothers at different distances from active fracking sites and those born before and after fracking started. Considered births within 0-1 km of fracking, 1-2 km of fracking, and 2-3 km, and compared data within these zones to the unaffected group (mothers 3-15 km)

Key Findings:

- “Maternal residence within 1 km [3,280 feet] of an active well site that was hydraulically fractured before conception is associated with significantly worse infant health outcomes than are more distant locations.”
- Health harms to infants occur at up to 3 km (9.842 feet), with the greatest risk to infants born to mothers living within 1 km of an active oil and gas site during pregnancy. For those infants/mothers, a 25% increase in probability of low birthweight was observed, and a significant decline in average birthweight and in index of infant health.

ADVERSE RESPIRATORY HEALTH EFFECTS

Asthma Exacerbations, 0-10 miles (0-16 km)

Buchanich, Jeanine. et al., Severe asthma exacerbations associated with unconventional natural gas development activity in area of concentrated development, 62 *Journal of Asthma* 1418 (2025), <https://doi.org/10.1080/02770903.2025.2483000>

About: A retrospective study cohort study of asthma (46,676 patients) to deepen understanding of relation between asthma and exposure to unconventional natural gas development (UNGD) in Southwestern Pennsylvania, where UNGD has proliferated. Considered exposure zones of 10 miles, and buffer distances of 1 mile, 2 miles, 5 miles, and 10 miles. Considered four phases of UNGD (well pad prep, drilling, hydraulic fracturing, and production). Considered three types of asthma events: severe, ED severe, and hospitalization severe.

Key findings:

- Strong evidence to suggest an increased risk in the production phase of unconventional natural gas development for all buffer zones (1, 2, 5, and 10 miles) for all types of asthma events (severe, ED severe, and hospitalization).
- Bottom line: Proximity to UNGD increases risk to asthma exacerbations.

Respiratory, Gastrointestinal and Acute Response Symptoms, 0-2 miles (0-3.2 km)

Weisner, M.L. et al., Health Symptoms and Proximity to Active Multi-Well Unconventional Oil and Gas Development Sites in the City and County of Broomfield, Colorado, 20 *Int. J. Environ. Res. Public Health* 2634 (2023), <https://doi.org/10.3390/ijerph20032634>

About: This study surveyed 3,993 randomly selected households in the City and County of Broomfield, PA, with respondents living either within 1 mile, 1-2 miles, or beyond 2 miles of multi-well unconventional oil and gas development (UOGD) sites. The respondents were asked to report on the frequency of symptoms related to upper respiratory, lower respiratory, neurological, gastrointestinal, and mental health distress.

Key findings:

- Parents living within 2 miles of a Broomfield UOGD site reported more symptoms and higher frequencies of all symptoms, except neurological symptoms, in their children than those living more than 2 miles from the sites.
- Survey respondents living within 1 mile of a multi-well UOGD site reported greater frequencies of upper respiratory and acute response symptoms in the past 14 days than those living more than 2 miles from the sites.
- Study was the first to report greater frequencies of self-report nosebleeds, nausea, vomiting and shortness of breath symptoms near UOGD sites in Pennsylvania's Marcellus Shale region.

CANCER

Acute Lymphoblastic Leukemia, 13 km (8 miles)

McKenzie, Lisa M. et al., Exposures from Oil and Gas Development and Childhood Leukemia Risk in Colorado: A Population-Based Case-Control Study, 34 *Cancer Epidemiol Biomarkers Prev* 658 (2025), <https://doi.org/10.1158/1055-9965.EPI-24-1583>

About: A case-controlled study of children born in Colorado between 1992 and 2019. Considered the increased acute lymphoblastic leukemia (ALL) risk due to proximity to intense upstream oil and gas development.

Key Findings:

- Colorado's children living within 13 km of oil and gas well sites are at increased risk of acute lymphoblastic leukemia, with children within 5 km bearing the greatest risk.
- Children aged 2 to 9 years diagnosed with ALL between 2002 and 2018 were 1.40 to 2.64 times more likely to live within 13 km of an oil and gas well site than children without a cancer diagnosis.
- Bottom line: Young people and children diagnosed with certain cancers are more likely to live near oil and gas development.

Childhood Lymphoma, 0-5 miles (0-8 km)

Talbott, Evalyn et al., *Final Report for Pennsylvania Department of Health, Bureau of Epidemiology, Hydraulic Fracturing Epidemiology Research Studies: Childhood Cancer Case-Control Study*, (August 3, 2023), https://www.health.pa.gov/topics/Documents/Environmental%20Health/Report_Cancer_outcomes_2023.pdf

About: A case-control study of childhood cancers initiated by the Pennsylvania Governor Wolf's administration due to concerns about the Ewing sarcoma cluster and significant rise of hydraulic fracturing and unconventional gas development (UNGD) in western Pennsylvania since 2005. Considered four phases of UNGD (well pad prep, drilling, hydraulic fracturing, and production). Considered exposure distances by buffer zones of 0-0.5 miles, 0.5-1 mile, 1-2 miles, and 2-5 miles.

Key findings:

- Lymphoma: This study provided moderate evidence suggesting an association between unconventional gas development (UNGD) and childhood lymphoma.
 - Children who live within 1 mile of a well are 5-7 times more likely to develop lymphoma than unexposed children (who live 5 miles or farther away from oil and gas).
 - Children who live between 1-2 miles from a well are 2.45 times more likely to develop lymphoma than unexposed children.
 - Children who live between 2-5 miles from UNGD are 2 times more likely to develop lymphoma than unexposed children.
- Bottom line: The closer a child lives to a UNGD site, the higher the risk of lymphoma.

Acute Lymphocytic Leukemia, 16.1 km (10 miles)

McKenzie, Lisa M. et al., Childhood hematologic cancer and residential proximity to oil and gas development, 12 *PLoS ONE* e170423 (2017), <https://journals.plos.org/plosone/article?id=10.1371/journal.pone.0170423>

About: A case-controlled study of hematologic cancers and proximity to oil and gas based on concerns of carcinogenic pollution, including benzene, from oil and gas development in residential areas. Considered associations between 137 hematological cancer diagnoses between 2001-2013 and distance from oil and gas development.

Key Findings:

- Acute lymphocytic leukemia cases were more likely to live near oil and gas development.
- For ages 5-24, acute lymphocytic leukemia cases were 4.3 times as likely to live in the area with the highest number of wells.

AMBIENT AIR POLLUTION FROM OIL AND GAS

Residential Proximity to Oil and Gas Wells and Exposure to Indoor Air VOCs

Daley, Coreen et al., Residential proximity to conventional and unconventional wells and exposure to indoor air volatile organic compounds in the Exposures in the Peace River Valley (EXPERIVA) study, 263 *Int. J. Hyg. Environ. Health* 114462 (2025), <https://doi.org/10.1016/j.ijheh.2024.114462>

About: This study reported on the correlation between proximity to conventional and unconventional oil and gas wells and measured indoor air VOC concentrations. Eighty-four pregnant individuals participated in the study, with buffers of 0, 5, and 10 km around residences considered.

Key Findings:

- Over the VOC measurement period, indoor air acetone was positively associated with the density of all wells within 10 km, while both acetone and decanal were positively associated with the density of conventional wells within 10 km and 5 km.
- Indoor air chloroform was positively associated with density of all wells within 10 km as well as just unconventional wells within 10 km.
- Unconventional oil and gas well drilling activities were positively associated with indoor air chloroform.
- Bottom line: The concentration of VOCs in residences is positively associated with the density of nearby oil and gas wells.

PM_{2.5} Pollution from Oil and Gas Activity in the Permian Basin

Goodkind, Andrew L. et al., *PM_{2.5} Pollution from Oil and Gas Activity in the Permian Basin: An Economic Analysis of its Human Health Impacts and Damages*, Department of Economics, University of New Mexico (July 17, 2023), https://econ.unm.edu/common/documents/2023nm-research_goodkind-et-al.pdf

About: This study characterized oil and gas PM2.5 sources in the Permian Basin and spatial and temporal trends in total ambient PM2.5 pollution concentrations to provide context for how the oil and gas sector has affected pollution levels and health outcomes in the area.

Key Findings:

- Emissions from oil and gas activity contributed 27.5% of PM2.5 concentrations in the Permian Basin from 2011 to 2017. VOC emissions from oil and gas activity were the largest source of PM2.5 precursor emissions, primarily from oil well tanks.
- In 2017, nationwide, 638 premature deaths were associated with PM2.5 from the Permian Basin oil and gas sector. Out of the total, 33% occurred in the Permian Basin while 67% occurred outside of the Basin, in other parts of Texas and New Mexico but also in neighboring states and beyond, indicating that oil and gas activity is impacting human health both locally and distantly.

Upstream Oil and Gas Production and Ambient Air Pollution in California

Gonzalez, David al., Upstream Oil and Gas Production and Ambient Air Pollution in California, 806 *Science of The Total Environment* 150298 (2022),
<https://www.sciencedirect.com/science/article/pii/S0048969721053754>

About: This study investigated whether drilling new wells (pre-production) or increasing production at existing wells increased concentrations of particulate matter, carbon monoxide, nitrogen oxide, ozone, and VOCs. The study is in California.

Key Findings:

- Preproduction/Drilling: Observed higher concentrations of PM2.5 (particulate matter) and CO (carbon monoxide) at preproduction wells. Observed higher concentrations of NO2 (nitrogen oxide) at monitors at 1-2km from wells and O3 (ozone) from 2-4km from the wells.
- Increased production: Monitors near wells that were increasing their production observed higher concentrations of PM2.5, NO2, and VOCs within 1km, and higher O3 concentrations at 1-2km.
- Bottom line: Observed higher concentrations of ambient air pollutants within 4km (13,123 feet) of preproduction wells (drilling) and within 2km (6,561 feet) of producing wells.

**PUBLISHED STUDIES THAT LOOKED AT HEATH IMPACTS
AT DISTANCES OF 1 MILE (1.6 KILOMETERS) OR LESS (PARTIAL LIST)**

Childhood Cancer, 0.5 miles (0.8 km)

Talbott, Evelyn O. et al., Cumulative Exposure to Unconventional Natural Gas Development and Risk of Childhood Cancer: A Registry-Based Case-Control Study, 22 *Int. J. Environ. Res. Public Health* 68 (2025), <https://doi.org/10.3390/ijerph22010068>

About: A case-control study with 498 children diagnosed with leukemia, lymphoma, central nervous system neoplasms, and malignant bone tumors during 2010-2019, identified through the Pennsylvania Cancer Registry.

Key Findings:

- Individuals living within 0.5 miles of an unconventional natural gas development (UNGD) site were 3.94 times more likely to develop a malignancy compared to non-exposed children.
- Overall UNGD cumulative activity as well as proximity to UNGD wells were associated with an increased risk of childhood lymphoma specifically and overall childhood cancers combined.

Adverse Birth Outcomes, 1 km (0.62 miles)

Tran, Kathy V. et al., Residential Proximity to Hydraulically Fractured Oil and Gas Wells and Adverse Birth Outcomes in Urban and Rural Communities in California (2006-2015), 5 *Environmental Epidemiology* e172 (2021), <https://pubmed.ncbi.nlm.nih.gov/34909552/>

About: A retrospective cohort study of nearly one million births in eight California counties with hydraulic fracturing between 2006-2015 with at least 1 well hydraulically fractured within 1 km of their home during pregnancy. Examined association between fracking and low birth weight, preterm birth, small for gestational age birth, and term birth weight.

Key findings:

- Among rural mothers living within 1 km of fracking during pregnancy, exposure to fracking was associated with increased odds of low birth weight, small for gestational age birth, preterm birth, and lower term birth weight. Among urban mothers living within 1 km of fracking during pregnancy, exposure to fracking was positively associated with small for gestational age birth.
- Bottom line: Proximity to fracking during pregnancy was associated with adverse birth outcomes, particularly in rural areas.

Higher Rates of Asthma, 1,500 feet (0.46 km)

Shamasunder, Bhavna. et al, Community-Based Health and Exposure Study around Urban Oil Developments in South Los Angeles, 15 *Int J Environ Res Public Health* 138 (2018), [https://doi:10.3390/ijerph15010138](https://doi.org/10.3390/ijerph15010138)

About: Community-based health and exposure survey in South Los Angeles. Researchers tested the capacity of low-cost sensors to measure localized exposures, and surveyed residents within two 1,500 buffer areas (from oil and gas) and compared overall test rates to the California Interview Survey for Services Planning Area 6 (SPA6) and Los Angeles County.

Key Findings:

- The age-adjusted rate of diagnosed asthma was significantly higher in both surveyed neighborhoods than in the SPA6.
- Residents in these buffer areas experienced asthma symptoms of coughing and wheezing on a weekly or daily basis

Skin and Respiratory Symptoms, 1 km (0.62 miles)

Rabinowitz, Peter M. et al., *Proximity to Natural Gas Wells and Reported Health Status: Results of a Household Survey in Washington County, Pennsylvania*, 123 Environmental Health Perspectives 21 (2015), <https://ehp.niehs.nih.gov/doi/pdf/10.1289/ehp.1307732>

About: This study investigated the relationship between household proximity to natural gas wells and reported health symptoms. The authors conducted community environmental health assessment of 492 persons (180 households) in Washington County, Pennsylvania, where there is active gas drilling within 1 km.

Key findings:

- The number of health symptoms per person was higher among residents living within 1 km or less from the nearest gas well compared to residents living 2 km or more from the nearest gas well.
- Skin conditions and upper respiratory problems were more frequently reported in people living in homes within 1km or less to the nearest gas well, compared to people living within 2 km or more from the nearest gas well.
- Three possible causes for the prevalence of skin and other problems among residents living within 1 km or less from gas wells: contamination of well water from gas production (all people surveyed had ground-fed water supply), air pollution from gas pollution, and anxiety due to knowledge of environmental risks from gas production.