Public Health Effects of Fracking: An Update

September 2026

by Carmi Orenstein, MPH, Ted Schettler, MD, MPH, and Sandra Steingraber, PhD

Additions reviewed by Barbara Gottlieb, former national Director of Environment & Health, retired, Physicians for Social Responsibility

With assistance from Larysa Dyrszka, MD

Total Energies' Cornerstone Drill Site in Arlington, Texas, gas wells are 324 feet from a daycare building. Photo Credit: Liveable Arlington, December 2018.

A section update of the "Compendium of Scientific, Medical, and Media Findings Demonstrating Risks and Harms of Fracking and Associated Gas and Oil Infrastructure," Ninth Edition, October 2023
https://concernedhealthny.org/compendium/ and
https://psr.org/resources/fracking-compendium-9/

About Concerned Health Professionals of New York and the Science and Environmental Health Network

Concerned Health Professionals of New York (CHPNY) is an initiative by health professionals, scientists, and medical organizations for raising science-based concerns about the impacts of fracking on public health and safety. CHPNY provides educational resources and works to ensure that careful consideration of science and health impacts are at the forefront of the fracking debate. In June 2021, the Ceres Trust granted funding for CHPNY to become a program of the Science and Environmental Health Network (SEHN). Since 1998, SEHN has been the leading proponent in the United States of the Precautionary Principle as a basis for environmental and public health policy. In service to communities and future generations, the Science and Environmental Health Network is a research institution that forges law, ethics, and science into tools for action.

About Physicians for Social Responsibility

For more than 65 years, Physicians for Social Responsibility (PSR) has confronted the gravest threats to health and survival, mobilizing health professionals and concerned allies to advocate for environmental justice, solutions to climate change, and a world free of nuclear weapons. Guided by the values and expertise of medicine and public health, PSR works to care for and defend those who are most impacted by these threats, including radioactive pollution, toxic chemicals, and the health consequences of fossil fuels. PSR has thousands of individual members, a network of state and local chapters around the country, and global partners around the world.

For purposes of the Compendium project, we use the word "fracking" to refer to a collective suite of unconventional oil and gas production methods that depend on hydraulic fracturing to extract dispersed oil or natural gas trapped inside rock layers that would otherwise not flow to the surface. Note that the authors of some of the studies described in our Compendium code fracking sites as unconventional oil and natural gas (UOG) operations, in which case we follow the language in the original study in our summaries. **For more background on the Compendium project, please see the introductory sections of the full report at:** https://concernedhealthny.org/compendium/ or https://psr.org/resources/fracking-compendium-9/

Introduction

In the ninth edition fracking science Compendium (October 2023) we identified the following trend in our review of the body of research: **Public health problems associated with fracking include prenatal harm, respiratory impacts, cancer, heart disease, mental health problems, and premature death**. Subsequent original studies, reviews, and analyses have added evidence to previous findings in the majority of these areas, especially with regard to adverse birth impacts and childhood cancer. Fracking processes and emissions include known carcinogens and endocrine disruptors, indicating plausible biological mechanisms for these impacts. With at least 17.6 million Americans living within one mile of an active oil or gas well, and inactive wells also releasing pollutants, the research points to a vast public health crisis.

The newer findings summarized in the present Update include results from studies published from May 2023 through February 18, 2026 (since the ninth edition and through this project's cutoff date), plus several studies that were previously missed. They reflect increasingly sophisticated epidemiological study designs that incorporate increasingly refined measures. Many studies are firsts that focus on a particular impact in a specific geographic area, with others building on well-studied locations, such as Pennsylvania, Colorado, and California's San Joaquin Valley. Several of the new studies utilize complex analyses of factors including exposure to the various phases of drilling and fracking for oil and gas and analysis of those exposures at varying distances. Six new reviews, with varying areas of focus and with various designs, incorporate and analyze data from hundreds of studies.

The new studies and analyses described in this Update show serious health impacts of urgent concern. Many document dose-response relationships: the closer people reside to oil and gas sites, the greater the exposures and the greater the harm they experience. Reinforcing these findings, a recent interdisciplinary analysis including animal and laboratory research found moderate evidence that fracking plays a role in disrupting reproductive health. Further, a review of toxicological studies addressing exposure to fracking chemicals and water samples linked to fracking found deleterious effects—including endocrine disruption, carcinogenicity, behavioral changes, impaired metabolism, immune dysregulation, and impacts on mammary gland development—that align with the epidemiological literature.

The evidence also overwhelmingly points to the benefits of increased setbacks. That is, from a public health point of view, the distance between fracking sites and communities where people live and work should be as great as possible, as many researchers recommend. Authors of studies that document early-life exposures linked to harmful outcomes, including birth defects and childhood cancers, note the possible effects on a child's entire life course and even survival. A three-university research team said that the consistent findings on childhood cancer are "directly actionable and can inform siting decisions, setback distances, and land-use policies," and called for strengthening children's health protections. This and other policy-relevant statements are included in the summaries below.

Our most recent full edition of the Compendium, which contains sixteen additional sections—including topics such as air pollution, water contamination, and occupational health and safety hazards—concludes: **Our examination uncovered no evidence that fracking can be practiced in a manner that does not threaten human health directly or without imperiling climate**

stability upon which human health depends. As shown by this section Update, the second in a series, the research continues to affirm our conclusion.

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The research summaries below include: all those in the ninth edition fracking science Compendium, either in the section entitled "Public health effects, measured directly" (pages 263-301) or covered as late-breaking studies in that report's introduction; new studies appearing after May 8, 2023 and through February 18, 2026; and several studies that were missed in the ninth edition. The italicized research summary is updated from the ninth edition.

Public Health Effects: A Ninth Edition Compendium Section Update

Scientific evidence for a broad range of public health impacts linked to fracking continues to emerge across the United States and Canada.

Notably, in multiple states and nationally, studies of pregnant women in regions of intensive oil and gas extraction point to reproductive and developmental risks, including low birth weight, preterm births, and birth defects. A study that surveyed U.S. birth certificate data from 1990 to 2020 showed that exposure to oil and gas drilling activity significantly reduces birthweight by an average of 10 grams. A review of 24 studies showed maternal exposure to oil and gas extraction was significantly linked to preterm birth, miscarriage, small for gestational age, and reduced birth weight, and a scoping review including 52 epidemiological studies concluded that injurious effects on birth outcomes linked to proximity to fracking included reduced fetal growth, an increase in preterm birth, and various birth defects. In a recent study, there were elevated risks of birth defects in four core fracking counties of the Barnett Shale region compared to overall statewide risk of these conditions in Texas. Studies conducted in previous years in states including Oklahoma, Texas, Colorado, and Ohio, found birth defects elevated among infants whose mothers lived near drilling and fracking sites while pregnant. In California's San Joaquin Valley, women who lived with the highest exposure to oil and gas wells during early pregnancies were eight to 14 percent more likely to experience preterm births. Two related studies in British Columbia found that pregnant indigenous women living near fracking sites had elevated levels of developmental toxicants, including barium and strontium, in their hair and urine.

Residential proximity to oil and gas development is strongly linked to childhood cancer, most consistently for leukemia, according to a 2025 systematic review. Fracking has been linked to various cancers in several states. Researchers identified a higher risk of acute lymphoblastic leukemia in Colorado children within 13 kilometers (8 miles) of an active oil and/or gas well site; they also noted the presence in this environment of "leukemogens," specific carcinogens known to increase the risk of leukemia. Children living within a half mile of a fracking site in southwestern Pennsylvania were almost four times more likely to develop one of four cancers studied compared to children who lived farther away, and the risk of lymphoma specifically was elevated even at greater distances. Previous studies in these two states had also found elevated childhood cancer rates among those living near oil and natural gas development operations.

As shown by multiple studies in Pennsylvania, as the number of gas wells increases in a community, so do rates of hospitalization. Replicating previous study results, medical records of over 46,000 asthma patients in Southwestern Pennsylvania showed strong evidence for an increased risk of exacerbation of asthma symptoms, emergency room visits, and hospitalizations for those living within 1 to 10 miles of fracking sites. Hospitalizations for pneumonia among the elderly were likewise found to be elevated in areas of fracking activity. Pennsylvanians living in proximity to gas wells also experience sleep disturbance, headache, throat irritation, stress/anxiety, cough, shortness of breath, sinus problems, fatigue, wheezing, and nausea.

Researchers are documenting increased rates of other serious health impacts associated with proximity oil and gas wells. An emerging body of evidence from multiple states links fracking to increased risk of death and increased rates of heart attack, ischemic heart disease, and heart failure among older residents living nearby. Drilling and fracking operations in multiple states are

variously correlated with increased rates of asthma; increased hospitalizations for pneumonia and kidney, bladder, and skin problems; high blood pressure; elevated motor vehicle fatalities; symptoms of depression and anxiety; ambulance runs and emergency room visits; and incidence of sexually transmitted diseases. In Colorado, acute health risks remained despite "best management practices" to reduce air emissions from fracking operations, according to a new cumulative human health risk assessment. Increased risk of Coccidioidomycosis (Valley Fever) was identified in those Kern County, California residents living within 5 kilometers of new oil and gas wells. A recent analysis of ten years of Medicaid claims and U.S. county-level oil and gas production data showed a small increase in inpatient psychiatric hospitalization rates during bust periods. A new study found an increase in premature deaths among adults aged 25–64 years old in oil and gas boom-and-bust U.S. counties, especially during bust periods, and with "extreme production busts" reaching up to over 19 additional deaths per county. (See the full Compendium for data on fatality rates for oil and gas workers specifically.)

Chemical exposures associated with oil and gas operations pose specific risks. Benzene levels in ambient air surrounding drilling and fracking are sufficient to elevate risks for future cancers in both workers and nearby residents, according to studies. Animal studies show numerous threats to fertility and reproductive success from exposure to various concentrations of oil and gas chemicals at levels representative of those found in drinking water near some oil and gas operations. At least 43 chemicals used in drilling and fracking operations are classified as known or presumed human reproductive toxicants, while 31 others are suspected human reproductive toxicants. Two dozen chemicals commonly used in fracking operations are known endocrine disruptors that can variously disrupt organ systems, lower sperm counts, and cause reproductive harm. Endocrine-disrupting chemicals have also been identified in fracking wastewater. Tissue culture and animal studies show endocrine-disrupting effects in response to exposures to mixtures of fracking chemicals that reflect concentrations found in fracking wastewater. The most recent reviews analyzing the pool of non-human studies corroborate these earlier findings.

- February 18, 2026 – According to an analysis using U.S. birth certificate data from 1990 to 2020, in utero exposure to oil and gas drilling activity significantly reduces birth weight by an average of 10 grams and increases the incidence of low birth weight, preterm birth, and small for gestational age by 2-3 percent. The researchers exploited the "staggered timing and geographic rollout of fracking operations" across different shale plays in 19 states to develop this novel study of fracking's impacts on infant health. Their use of a comprehensive dataset describing fracking activity across various geographic, regulatory, and geological contexts, merged with the birth certificate data, is unique in the literature. This difference-in-differences study design, sometimes called a "controlled before-and-after" study, uses multiple cohorts within the decade before and after the sharp increases in oil and gas production in the 2000s and 2010s. In addition, using national air pollution "Daily Summary Data," the researchers showed that drilling increases air pollutants known to adversely affect fetal development, including ozone, PM2.5, PM10, and SO2. They also noted that fracking-associated economic gains tend to improve infant health, so the adverse effects they documented may represent a lower bound on fracking's negative health effects. As economists and policy experts, these

researchers aimed to introduce an innovative type of analysis to understand the human costs of fracking.[1]

- January 15, 2026 – Because exposure to "unconventional hydraulically fractured [fracked] oil and gas wells" during pregnancy has been linked with a higher risk of structural birth defects, researchers posed the question of whether these findings could be extended to exposure to conventional oil and gas wells. They also investigated exposure to inactive wells (a broad category that includes idle and plugged wells), which are known to emit teratogens including benzene. Their study found that living near active wells in the San Joaquin Valley, California, where most drilling is conventional, was associated with risk of some structural birth defects, but researchers declared that these findings were notably imprecise and, given the low number of statistical tests they conducted, may be spurious. They found that living near inactive wells was significantly linked with an increased risk of cleft lip and cleft palate. This case-control study made use of data about birth outcomes between 1997 and 2011 from the California Center of the National Birth Defects Prevention Study. Increased risk of cleft lip and cleft palate has previously been documented near oil and gas activity, and exposure to benzene has been linked to this birth defect. Because vast numbers of people live near inactive wells—9 million within one kilometer in California alone—researchers recommend further examination of the risk of adverse birth outcomes for this population.[2]

- January 14, 2026 – In a case-control study in California, Hispanic children with birth addresses within 10 kilometers of plugged/abandoned oil and gas wells were 1.33 times more likely than non-Hispanic children to be diagnosed with Ewing sarcoma, a rare, aggressive bone and soft tissue cancer particularly affecting children and teens. This study did not find such links for children with prenatal exposures to active wells. Pediatric cancer risk and proximity to oil and gas development have been linked, but those studies focused on hematologic cancers such as leukemia. There has been only preliminary investigation into suspected clusters of Ewing sarcoma near oil and gas sites and other industrial activities that release carcinogens. Due to this concern, in addition to data gaps about the huge numbers of people living near abandoned wells emitting under monitored contaminants, researchers accessed data on the 558 known children born in California from 1982–2015 who were diagnosed with Ewing sarcoma at 0–19 years from 1988–2015, as well as a control set of children. Because "there is very little literature in this area with which to compare [their] results," and the plausibility of a link due to the emitted carcinogens, researchers state that study "replication in different populations and regions with diverse patterns of [oil and gas] activity is necessary to draw concrete conclusions."[3]

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[1] Hamid Noghanibehambari et al., "The Relationship between Oil Production and Infant Health Outcomes: Evidence from Fracking Boom," *Economics & Human Biology* 61 (May 2026): 101583, https://doi.org/10.1016/j.ehb.2026.101583.
[2] Juliana Stone et al., "Structural Birth Defects and Exposure to Oil and Gas Wells during Pregnancy," *Pediatric Research*, ahead of print, January 15, 2026, https://doi.org/10.1038/s41390-025-04719-1.
[3] Cassandra J. Clark et al., "Residential Proximity to Active and Abandoned Oil and Gas Development and Risk of Childhood Ewing Sarcoma in California," *Environmental Health* 25, no. 1 (2026): 12, https://doi.org/10.1186/s12940-025-01259-3.

- November 24, 2025 – Across 24 studies published up to June 16, 2024 that met researchers' criteria, maternal exposure to oil and gas extraction was significantly linked to preterm birth, miscarriage, small for gestational age (SGA), and reduced birth weight. Specifically, the increased likelihood of preterm birth was 7 percent, the risk of miscarriage was doubled, the increased likelihood of SGA was 23 percent, and the average reduction in weight was over 30 grams. This analysis did not find significant links to stillbirth, birth defects, or low birthweight. The study was the first to use the tool of systematic review and meta-analysis for evaluating the association between maternal exposure to oil and gas processes—exploration, extraction and processing—and birth outcomes. This approach can provide comprehensive synthesis and assessment of risks; however, it was hampered in this instance by differences across studies, including study design, population characteristics, and outcome measures, leading these researchers to call for more standardized, large-scale studies. They also note the lack of detailed information on the timing of the exposures during pregnancies, an important aspect of the many plausible biological mechanisms for the impacts of pollution on pregnancy outcomes. The researchers call for policy makers to consider pregnant women when regulating and siting activities, and for strengthened monitoring and surveillance, buffer zones, and continued action for the protection of maternal and infant health.[4]

- November 20, 2025 – A study of working-age deaths (premature deaths among adults aged 25–64 years old) in oil and gas boom-and-bust counties found increases in all-cause working-age mortality in both booms and busts, with stronger evidence that busts, rather than booms, were associated with the increases. Researchers found 0.38 additional deaths per county during the bust cycles, with "extreme production busts" reaching up to 19.51 additional deaths per county. In examining cause-specific mortality, the study found that consistent patterns there were difficult to discern. Data was drawn from 1,164 U.S. oil- and gas-producing counties across 32 states from 2000 to 2011, "a relatively early time in the modern era of [oil and gas development]." Researchers wrote that their "results highlight the complex relation between boom-and-bust cycles in oil and gas production and working-age mortality in the U.S."[5]

- September 21, 2025 – Cases of Coccidioidomycosis, a lung infection from a fungus known as Valley Fever that grows in soil, were 11 percent higher in Kern County, California residents that lived within 5 kilometers of new oil and gas wells. Kern County is one of the highest oil-producing counties in the United States and has the highest level of coccidioidomycosis incidence. This fungus is released to the air during wind or digging episodes, and the construction of new wells is known to disturb soils. Linking infection risk with the preproduction stage (the period between preparing for "spudding" or active drilling and the completion date) of oil and gas development "identifies a novel

[4] Ali Mohammad Latifi et al., "Association between Maternal Exposure to Oil and Gas Extraction Process with Adverse Birth Outcomes: A Systematic Review and Meta-Analysis," *BMC Pregnancy and Childbirth* 25, no. 1 (2025): 1261, https://doi.org/10.1186/s12884-025-08022-z.
[5] Ryan P. Thombs and Mary D. Willis, "Impact of Oil and Gas Boom and Busts on Working-Age Mortality in the U.S.," *Environmental Epidemiology* 9, no. 6 (2025): e438, https://doi.org/10.1097/EE9.0000000000000438.

pathway of exposure risk for an emerging fungal disease." This study is the first to recognize this adverse impact of oil and gas development.[6]

- September 19, 2025 – There is a positive, statistically significant link between residential proximity to oil and gas development (OGD) and childhood cancer, most consistently for leukemia, according to the majority of studies which met inclusion criteria for a systematic review. Researchers screened over 3,00 articles and included 10: four case-control studies and six ecological studies, examining both conventional and unconventional OGD. Specifically, all of the studies with the more rigorous case-control design looking at childhood leukemia risk found increasing risk with decreasing distance to wells, and two of the studies set in different states, Colorado and Pennsylvania, found highly similar risk for those living closest to wells (2.07 times the risk at 3 kilometers or less and 1.98 times the risk at 2 kilometers or less, respectively). Focusing on studies reflecting real-world community exposure to OGD, with its documented air and water contaminant emissions that include multiple carcinogens, the researchers discussed the relevance of their findings to policy. "These metrics are directly actionable and can inform siting decisions, setback distances, and land-use policies." They note that setback policies, where they do exist, typically do not apply retroactively to non-active wells, which continue emitting pollutants, and may not apply to all places where children spend time, like schools. Researchers conclude that "given the consistency of positive findings of cancer risk in relation to OGD proximity from four case-control studies, this review provides support for strengthening OGD protections for children's health."[7]

- September 17, 2025 – Researchers found a small increase in annual county-level inpatient psychiatric hospitalization rates in U.S. oil- and gas-producing counties in their bust periods. The study hypothesis was that "harmful first-order economic and social effects of booms and busts have adverse second-order effects on mental health." The study used Medicaid claims from 2001–2011 and county-level oil and gas production data. Medicaid beneficiaries are lower-income and/or disabled and geographically and demographically diverse. Their finding of increased psychiatric hospitalizations during bust periods was strongest among older people, people who identify as White, and people living in rural counties. No such findings were made during boom periods. The study contributes to the literature on psychiatric impacts of economic booms and busts in the following ways: by focusing on low-income populations who are most vulnerable to mental health symptoms due to poverty; in recognizing that this population is "likely to be most vulnerable to extractive industries" (e.g. by often not owning land or mineral rights), and by being national in scope and analyzing both booms and busts.[8]

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[6] Lisa I. Couper et al., "Oil and Gas Well Development and Coccidioidomycosis Risk in California: A Case-Crossover Study," preprint, Epidemiology, September 21, 2025, https://doi.org/10.1101/2025.09.19.25336198.
[7] Eric C. Stewart et al., "A Systematic Review of Residential Proximity to Upstream Oil and Gas Development and Childhood, Adolescent and Young Adult Cancer Risk," *Current Problems in Pediatric and Adolescent Health Care* 55, no. 9 (2025): 101838, https://doi.org/10.1016/j.cppeds.2025.101838.
[8] Mary D. Willis et al., "Impact of Boom-and-Bust Economies from Oil and Gas Development on Psychiatric Hospitalizations among Medicaid Beneficiaries," *Environmental Research: Health* 3, no. 3 (2025): 035008, https://doi.org/10.1088/2752-5309/ae01ce.

- May 28, 2025 – Acute health risks exist for communities near unconventional oil and gas (UOG) sites along Colorado's Front Range even though the local industry uses what are considered best management practices (BMP) to reduce emissions, according to a cumulative human health risk assessment (CHHRA). Seeking a more accurate picture of real-world exposure to air pollutants, the study was the first to assess cumulative exposure to both the "nonattainment" ozone levels which persist in the region and the concurrent presence of oil- and gas-related volatile organic compounds (VOCs). The study used precise measurements enabled by an extensive air quality monitoring system already in place. Researchers analyzed the short- and long-term risks of exposure to this array of chemicals on multiple health risks including cancer, as well as taking into account the various phases of UOG (e.g. drilling, well completions, production). This highly complex study contained numerous other variables and analyses, generating many separate results for immunological, respiratory, reproductive, developmental, neurological, and cancer risks. It utilized hazard indices (HIs), a semi-quantitative method of estimating risk of adverse outcomes within categories of diseases. HIs are useful when co-exposures to multiple chemicals are involved and where the specific most sensitive endpoint attributable to a single chemical differs among chemicals in the mixture. Elevated HIs indicate an increased risk of one or more specific outcomes within each category due to the cumulative exposures. (For example, cough and asthma are both classified as respiratory outcomes and may be triggered by different chemicals at different exposure levels. Preterm birth, low birth weight, and prolonged time to pregnancy are reproductive outcomes, influenced by different chemicals at different thresholds.) Among the highlights of their results, researchers included the following: "At near-pad sites, acute HIs exceeded thresholds for immunological, respiratory, reproductive, developmental, and neurological end points during well completions. In addition, immunological and neurological HIs were above thresholds during drilling." The team discussed policy implications, both for Colorado's Front Range in particular and for oil and gas development elsewhere: "The results from this cumulative human health risk assessment further substantiate the findings from an epidemiological investigation in the same community and studies such as this should be used to inform policymakers when making permitting decisions in populated areas." They also noted that "Greater protection to public health could be afforded by establishing policies that require drilling and well completions to be conducted outside the summer ozone season."[9]

- May 2, 2025 – Colorado children diagnosed with acute lymphoblastic leukemia (ALL) between 2002 and 2019 were 1.4 to 2.64 times more likely to live within 13 kilometers (8 miles) of an active oil and/or gas well site than those who did not receive this diagnosis, concluded a study of 451 children with this cancer and 2,706 controls without ALL. Children who lived 5 kilometers (about 3 miles) or closer to these sites had even higher risk overall, and within those distances (the 13 kilometer and 5 kilometer groups), those in areas of greater intensity of activity and emissions had higher risk than those near lower-intensity areas. The authors emphasize at several points in their publication that

[9] Meagan L. Weisner et al., "Cumulative Human Health Risk Assessment of Regional Ozone and Volatile Organic Compounds from Unconventional Oil and Gas Sites in Colorado's Front Range," *Environmental Health Perspectives* 133, no. 5 (2025), https://pmc.ncbi.nlm.nih.gov/articles/PMC12120841/.

their data, as well as previous findings, show that setback distances between oil and gas well sites and residences—including Colorado's own 2,000-foot setback—"may not be sufficient to protect children from an increased burden of ALL risk." They also cite evidence of the presence in this environment of "leukemogens," specific carcinogens known to increase the risk of leukemia. Leukemogens include benzene, 1,3-butadiene, formaldehyde, and polycyclic aromatic hydrocarbons (PAHs), all known to be emitted from oil and gas sites. The authors explain that childhood leukemia "may be an early health outcome" from exposure to these sites because of leukemia's "relatively short latency and the particular vulnerability of children," with a "peak incidence occurring at 2 to 5 years of age."[10]

- January 7, 2025 – Children living within a half mile of an unconventional natural gas development (UNGD) site in southwestern Pennsylvania were almost four times more likely to develop one of four cancers studied compared to children who did not, and the risk of lymphoma specifically was elevated at distances up to five miles from such sites, with a dose-response relationship, concluded a case-control study of 498 children who had been diagnosed with leukemia, lymphoma, central nervous system neoplasms, or malignant bone tumors. The risk of lymphoma within one-half mile was over seven times greater and within one-half to one mile was five times that of children not in proximity to UNGD. Diagnoses had been made from 2010 to 2019 as per the Pennsylvania Cancer Registry; UNGD accelerated in this region beginning in 2005. According to the authors, this was first population-based study on UNGD activities and childhood cancer risk which used a control group of randomly sampled age-, race-, and sex-matched individuals drawn from birth records. This study used a new metric called "overall UNGD exposure" which, in addition to distance from the site at the time of birth, "simultaneously accounted for the duration of UNGD activity (including all four phases, well pad preparation, drilling, fracturing, and production)." Authors found consistent links between the various UNGD activities and cancer outcomes, "further strengthening a probable link between UNGD activities in general and the risk of childhood cancer." The strong lymphoma findings in particular led this team to call for the "development of a public health policy that would safeguard residents from living too close to a UNGD installation."[11]

- December 27, 2024 – Healthcare inpatient claims "for conditions plausibly related to groundwater water contamination" were 8.6 percent higher in areas where fracking began compared to those areas where it did not, on the Eagle Ford Shale in southern Texas, according to a pre-print analysis. Counties that have fracking within one kilometer of a public groundwater source showed a 9.1 percent increase in healthcare utilization for these conditions; the impacts were smaller and not statistically significant for counties whose public water sources lay within three or five kilometers. The researcher developed

[10] Lisa M. McKenzie et al., "Exposures from Oil and Gas Development and Childhood Leukemia Risk in Colorado: A Population-Based Case–Control Study," *Cancer Epidemiology, Biomarkers & Prevention* 34, no. 5 (2025): 658–68, https://doi.org/10.1158/1055-9965.EPI-24-1583.

[11] Evelyn O. Talbott et al., "Cumulative Exposure to Unconventional Natural Gas Development and the Risk of Childhood Cancer: A Registry-Based Case–Control Study," *International Journal of Environmental Research and Public Health* 22, no. 1 (2025): 68, https://doi.org/10.3390/ijerph22010068.

a strategy to account for the influx of new workers. The analysis identifies a relationship between increases in healthcare utilization and drilling near a public water source which the researcher wrote, "cannot be explained by compositional changes or air pollution, suggesting that groundwater contamination may serve as a primary pathway for pollution exposure." This study observed increases in perinatal healthcare utilization, pregnancy complications, and congenital abnormalities, consistent with several previous studies. It also documented significant increases in utilization for mental health conditions, cancer, neurological conditions, gastrointestinal conditions, urological conditions, dermatological conditions, and blood diseases. Recommendations include protections for those living near shale development, including drinking water testing, restricting drilling to less populated areas, and health monitoring.[12]

- September 5, 2024 – There is "moderate evidence" for the role of unconventional oil and natural gas (UOG) operations that use fracking in the disruption of the reproductive health of human and animals, according to an extensive, interdisciplinary analysis by a U.S and Canadian research team. The researchers reviewed published research for evidence of reproductive health effects in animals near UOG sites, evidence for reproductive health effects in humans near UOG sites, and mechanistic evidence for potential reproductive toxicity of fracking chemicals. Reviewing impacts on animals studied in the laboratory, in farm animals, in fish, and in invertebrate and microbial communities, they conclude that there is "increasing evidence suggesting that exposure to UOG chemicals can affect reproduction and development of diverse fauna surrounding UOG operations." Looking at the epidemiological assessments of UOG on low birth weight, small for gestational age, preterm birth, congenital abnormalities, and infant mortality in humans, they found that more than half of the studies in each category found detrimental impacts. The inherent challenges in epidemiology, the authors said, lead to inconsistences in the research, but nevertheless, "growing evidence agrees that nearby exposure to UOG development is associated with adverse birth outcomes in humans." Finally, the researchers review the evidence from controlled laboratory testing showing endocrine system disruption by the complex chemical mixtures used in fracking, finding those chemicals "clearly can impact endocrine signaling, revealing potential mechanisms through which UOG activity could adversely affect reproductive health." They note, however, that existing research has only been able to address a small subset of the over 1500 chemicals known to be used in fracking and other phases of UOG development. Their paper identifies many other data gaps and makes recommendations for priorities for future research.[13]

- July 11, 2024 – All 17 toxicological laboratory studies included in a scoping review found "significant deleterious effects" linked with exposure to fracking chemicals or to water samples linked to fracking, i.e. water samples impacted by UOG, including wastewater, drinking water, surface water, and groundwater, or lab-made mixtures of

[12] Cara Haughey, "The Effect of Unconventional Oil and Gas Drilling on Healthcare Utilization: Evidence from Texas," preprint, SSRN, 2024, https://doi.org/10.2139/ssrn.5066194.
[13] Kyle R. Siegel et al., "IMPACT OF REAL-LIFE ENVIRONMENTAL EXPOSURES ON REPRODUCTION: Evidence for Reproductive Health Effects Following Exposure to Hydraulic Fracturing Chemical Mixtures," *Reproduction* 168, no. 4 (2024): e240134, https://doi.org/10.1530/REP-24-0134.

UOG chemicals. These studies, which used either *in vivo* (animal testing using rodents) or *in vitro* (lab studies using human or animal cells) methods or both, showed outcomes including endocrine disruption, carcinogenicity, behavioral changes, impaired metabolism, immune dysregulation, and impacts on mammary gland development. The authors state that the main deleterious effects identified align with the current epidemiological literature on the links between exposure to fracking sites and human health outcomes, such as those described in their companion review to this one (see footnote 17). As previous researchers have noted, there are ongoing challenges to studying the over 1,000 chemicals commonly used in fracking, including "the withholding of information on proprietary or trade secret grounds." Nevertheless, many of these chemicals are known toxicants, including as endocrine disruptors and human carcinogens, and the studies in this review all documented harmful impacts with plausible mechanisms. The authors identify types of studies that would fill existing data gaps, including increased measurement of exposure to fracking chemicals in humans, and additional toxicological research using environmentally-relevant concentrations of these chemicals.[14]

- June 25, 2024 – In a study involving 29,730 Texas residents under 19 years old diagnosed with any primary cancer between 1995 to 2017, those with acute myeloid leukemia (AML) living within 1000 meters of oil or gas wells at the time of their diagnosis had a 36 percent increased risk of death, and those with hepatoblastoma had almost double the risk. Authors noted a dose-response relationship with closer proximity to oil and gas wells. The dataset for this study distinguished between "oil and gas wells" and "horizontal wells," according to the categories used by the state's oil and gas regulating agency, the Railroad Commission of Texas, and the results did not show associations with proximity to horizontal wells. Horizontal wells, elsewhere referred to as unconventional oil and gas development or fracking, involve high volumes of pressurized water and fracking fluid injected underground. However, authors said that they did not have data on use of fracking fluids: "Although we did not find an association between living within 1000 m of a horizontal well and mortality in children with cancer, we did not have information on when and where fracturing fluid might contaminate groundwater to evaluate their potential impact on survival because the Railroad Commission of Texas does not collect fracking information." Though the study also did not directly address exposure to air pollutants, the authors note that oil and gas drilling and gas flaring emit toxic air pollutants, and that their consistent observation of lower survival in children with AML or hepatoblastoma with closer proximity to a well or higher number of wells "suggests that toxic air pollutants from oil or gas wells may affect treatment response." Key strengths of this study—the first to address the association between living near oil and gas developments at the time of pediatric cancer diagnosis and the risk of death—are its large number of cases and the large numbers of wells, and its setting in the top oil- and gas-producing state. The study used conservative statistical methods to address 21 different types of pediatric cancers with different survival rates, different treatment plans, and different vulnerabilities to pollutants. "Because we observed

[14] Élyse Caron-Beaudoin et al., "The Human Health Effects of Unconventional Oil and Gas (UOG) Chemical Exposures: A Scoping Review of the Toxicological Literature," *Reviews on Environmental Health* 40, no. 2 (2025): 259–76, https://doi.org/10.1515/reveh-2024-0076.

differences by histological subgroup, our findings highlight the importance of conducting analyses by histology," the authors wrote."[15]

- May 17, 2024 – Living within two kilometers of active oil and gas development (OGD) was linked with three measures of psychosocial stress and depressive symptoms compared to living 20 to 50 kilometers away, in a study of 5,725 U.S. and Canadian women attempting to become pregnant. Specifically, those living closer to OGD were more likely to experience moderate to high perceived stress and moderate to severe depressive symptoms, as well as to use psychotropic medication. This analysis used cross-sectional data from a North American preconception cohort study of couples trying to conceive without the use of fertility treatments, a population that the researchers said, "may be highly susceptible to the health risks associated with the industry." They wrote that their "results provide support for the hypothesis that resource-extractive industries, such as OGD, pose a hazard for the mental health of local communities." They also note that their findings of adverse mental health outcomes occur beyond typical regulatory setback distances from OGD, even the most stringent. The study suggests that "[g]iven the strong link between maternal mental health and birth outcomes," these results "may explain some of the associations seen in the literature on OGD and adverse birth outcomes.[16]

- March 8, 2024 – Adverse impacts, particularly birth outcomes and asthma, are shown in a growing body of research on the effects of exposure to fracking on human health, according to a scoping review that included 52 epidemiological studies. Injurious effects on birth outcomes included reduced fetal growth, an increase in preterm birth, and various birth defects. Asthma risks included exacerbations, with dose-response relationships found. The Canadian research team, citing the country's status as a major methane gas producer, was interested in the extent to which the question of health impacts had been studied in Canadian populations, and found only two such studies of the 52. The remainder of the studies addressed were set in diverse U.S. states and regions. Calling for more Canadian studies, they expressed concern about the lack of health impacts data on "remote and rural communities where Indigenous people are more likely to reside" and where Canadian fracking typically occurs. This review provided a substantive update, as over half the studies included had not been part of previous reviews. The researchers identified knowledge gaps but concluded that there was evidence of detrimental health effects related to living in proximity to fracking.[17]

- December 19, 2023 – Proximity to oil and gas wells before birth increases adverse birth outcomes and pregnancy-related complications, according to a study of all births in Colorado from 2000 to 2011. Specifically, the incidence of low birth weight and

[15] Thanh T. Hoang et al., "Residential Proximity to Oil and Gas Developments and Childhood Cancer Survival," *Cancer* 130, no. 21 (2024): 3724–33, https://doi.org/10.1002/cncr.35449.
[16] Mary D. Willis et al., "Residential Proximity to Oil and Gas Development and Mental Health in a North American Preconception Cohort Study: 2013–2023," *American Journal of Public Health* 114, no. 9 (2024): 923–34, https://doi.org/10.2105/AJPH.2024.307730.
[17] Amira M. Aker et al., "The Human Health Effects of Unconventional Oil and Gas Development (UOGD): A Scoping Review of Epidemiologic Studies," *Canadian Journal of Public Health* 115, no. 3 (2024): 446–67, https://doi.org/10.17269/s41997-024-00860-2.

premature birth of the babies of mothers living within 1 kilometer of a well were increased by 31 percent and 33 percent, respectively. The author states that, "[w]hile these impacts are remarkably large, they are biologically plausible given the correlations between air pollution (or maternal stress) and birth outcomes found in previous studies." The author explains that this study's results show that proximity to oil and gas extraction also lead to an increase in "very low birth weight and very premature birth," which may lead to increased infant mortality and certainly lead to higher health-care costs. Findings also included an increase in gestational diabetes and hypertension for mothers. The author included several policy-related conclusions and comments, such as,

> It is clear from these results that policies intended to mitigate the risks of OGD can have significant health benefits. I find detectable effects of OGD up to 1.5 km from a well. Current required setback distances (distance between well and nearby residences, hospitals, and schools) range from 300 ft to 800 ft across the 34 states where OGD is taking place. With detectable infant health effects up to 1 mile away, these setback distances may be deemed insufficient to protect human health.

She also calls for regulators to further address air emissions from fracking, as well as for industry to do so voluntarily. She states that the paper "highlights the importance of protecting reproductive health for women living near OGD activities."[18]

- September 4, 2023 – An Australian comprehensive review found evidence of a broad array of harms associated with oil and gas developments, with effects across the entire human lifespan. The University of Sydney team synthesized over 300 peer-reviewed scientific papers addressing risk in areas including biodiversity, water and food security, climate, air and water, and to human health near oil and gas fields. The report was undertaken in response to the request of a group of Australian pediatricians concerned about proposed shale gas development. A chapter addressing "Effects on health and wellbeing: Physical, social, emotional, cultural and spiritual," details individual study outcomes including on: symptoms and markers of disease; hospitalization increases; asthma exacerbations; increases in deaths and reduced life expectancies; more frequent traffic and pedestrian injuries and fatalities; mental health conditions; increased rates of sexually transmitted disease; and adverse pregnancy outcomes. Authors concluded, "As a body of research, this evidence provides a compelling case for direct harms of the oil and gas industry across the lifespan on individuals – from foetal development, to infancy and childhood, to young and pregnant women to adulthood and elderhood," impacts that "can have whole of life consequences." They warn against "an American-style industry" in Australia, a place with "a substantially smaller pool of public health researchers and resources."[19]

- August 3, 2023 – Children in Southwestern Pennsylvania who lived within one mile of a fracking well had approximately 5 to 7 times the chance of developing lymphoma

[18] Elaine L. Hill, "The Impact of Oil and Gas Extraction on Infant Health," *American Journal of Health Economics* 10, no. 1 (2024): 68–96, https://doi.org/10.1086/724218.
[19] Melissa Haswell et al., *The Risks of Oil and Gas Development for Human Health and Wellbeing: A Synthesis of Evidence and Implications for Australia* (Office of the Deputy Vice Chancellor (Indigenous Strategy and Services), University of Sydney., 2023), https://apo.org.au/node/324169.

compared to children who did not live within five miles of fracking, according to University of Pittsburgh School of Public Health researchers. Their case-control study involved children in an eight-county area, with the case children having been diagnosed with one of four categories of cancer between 2010 and 2019. No or limited data suggested relationships with fracking activity and leukemia, central nervous system cancer, or malignant bone tumors/Ewings sarcoma, but there was limited to moderate evidence showing a link between overall exposure and any of the four malignancies included in the study. The lymphoma results showed that children who lived closer, especially near the most intensive fracking activities, had the highest risk, with a strong dose-response relationship.[20]

- July 31, 2023 – There is strong evidence for an increased risk of exacerbation of asthma symptoms, specifically during the wells' production phases, for those whose residences are within 1 to 10 miles of fracking sites, according to University of Pittsburgh School of Public Health researchers. The production phase is defined as "the process of collecting natural gas or oil that, following hydraulic fracturing, travels through the wellbore to the surface." They found risk to be consistently increased for severe exacerbations, emergency department visits, and hospitalizations. The research, prepared for Pennsylvania's Department of Health, was based on the electronic medical records in the University of Pittsburgh Medical Center system of 46,676 asthma patients living in Southwestern Pennsylvania, aged 5−90, from 2011 to 2020. These findings replicated and expanded on previous research in Southeastern Pennsylvania. (See footnote 122).[21]

- July 31, 2023 – Babies born to mothers who lived near active gas wells, compressor stations, or fracking waste facilities in eight counties in Southwestern Pennsylvania were significantly smaller at birth, found a study of 257,447 births from 2010-2020, conducted by the University of Pittsburgh School of Public Health. The study analyzed three birth outcomes—small for gestational age (SGA), preterm birth (22-36 weeks' gestation), and term (37-41 weeks' gestation) birthweight—with regard to distances from various phases of fracking activity and fracking-related sites, with mixed results. Findings of increased risk included: moderate to strong data linking the production phase of fracking with SGA up to ten miles away; limited data linking the drilling phase with preterm birth; and, for reductions in term birthweight,

  > limited data to suggest an increased risk with the drilling phase, moderate data to suggest an increased risk with cumulative well count, and strong data to suggest an increased risk with the production phase, with statistically significant reductions in birthweight with increasing intensity of exposure.

  This study, one of the first to look at these birth outcomes with regard to fracking infrastructure, also found moderate data showing reductions in term birthweight with

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[20] University of Pittsburgh School of Public Health, *Hydraulic Fracturing Epidemiology Research Studies: Childhood Cancer Case-Control Study*, no. 4400018535 (Pennsylvania Department of Health, Bureau of Epidemiology, 2023), https://paenv.pitt.edu/assets/Report_Cancer_outcomes_2023_August.pdf.

[21] University of Pittsburgh School of Public Health, *Final Report for Pennsylvania Department of Health, Bureau of Epidemiology Hydraulic Fracturing Epidemiology Research Studies: Asthma Outcomes*, Contract number: 4400018535 (2023), https://www.pa.gov/content/dam/copapwp-pagov/en/health/documents/topics/documents/environmental-health/Report_Asthma_outcomes_2023.pdf.

proximity to compressor stations and oil and gas waste facilities. Authors said, "Our results provide important new information about the associations between UNGD activity and birth outcomes."[22]

- May 8, 2023 – Using air quality data from six government monitors, a study in northeastern British Columbia examined the relationship between particulate air pollution levels (PM10 and PM2.5) at or near the homes of 92 pregnant women and proximity to conventional oil and gas wells and wells that were fracked. The results showed that higher density and activity of nearby oil and gas wells increased gestational exposure to particulate matter among participants. Higher conventional well metrics (proximity, density, and activity) were more strongly correlated with higher PM10 estimations whereas the metrics for fracked wells were correlated with higher levels of inhalable PM2.5 but not with PM10.[23]

- May 8, 2023 – An analysis of health impacts from air pollution due to oil and gas production in the United States in 2016: 1) used information from a US EPA emissions database; 2) simulated the resulting PM2.5, NO2, and ozone air pollution as it dispersed; and 3) estimated asthma and premature mortality and related economic impacts of exposure to those pollutants at the census tract level. The research team found that air pollution from the oil and gas sector in the United States resulted in 410,000 asthma exacerbations, 2,200 new cases of childhood asthma, and 7,500 excess deaths, with a mid-point estimate of $77 billion in total health impacts. Nitrogen dioxide was the highest contributor to health impacts (37 percent) followed by ozone (35 percent) and fine particulate matter (28 percent). The impacts were highest in, but not limited to, areas with concentrated oil and gas production as they also extended to areas downwind, even into states that do not have oil and gas activity themselves.[24]

- April 24, 2023 – Compared to other dog breeds, boxers and golden retrievers are at elevated risk for developing multicentric lymphoma, a malignancy similar to non-Hodgkin's lymphoma in humans. A recent study sought to determine whether residential radon and proximity to fracking operations are, in addition to breed, risk factors for the development of pet dog lymphoma. Fifty-six boxers and 54 golden retrievers with multicentric lymphoma were used in a case-control study. Controls without lymphoma were matched for age, breed, and sex. Counties of residence were matched to radon zones and percentage of home radon tests that exceeded the actionable radiation level of 4 pCi/L from 2008-2017. Locations of horizontal oil and gas wells were obtained from the Enverus Database. Distances from dog homes to the closest well and well density by county were calculated for each case and control. The analysis found no significant

[22] University of Pittsburgh School of Public Health, *Hydraulic Fracturing Epidemiology Research Studies: Birth Outcomes*, no. 4400018535 (Pennsylvania Department of Health, Bureau of Epidemiology, 2023), https://paenv.pitt.edu/assets/Report_Birth_outcomes_Revised_2023_July.pdf.
[23] Élyse Caron-Beaudoin et al., "Estimation of Exposure to Particulate Matter in Pregnant Individuals Living in an Area of Unconventional Oil and Gas Operations: Findings from the EXPERIVA Study," *Journal of Toxicology and Environmental Health, Part A* 86, no. 12 (2023): 383–96, https://doi.org/10.1080/15287394.2023.2208594.
[24] Buonocore et al., "Air Pollution and Health Impacts of Oil & Gas Production in the United States."

differences in radon zones, county level radon measurements, or residential proximity to active fracking wells between dogs with and without lymphoma in either breed of dog.[25]

- April 17, 2023 – There was an increase in several structural birth defects in babies born to mothers within 10 kilometers of unconventional oil and gas development (UOGD) in Ohio, according to the first study of these relationships based in that state. Specifically, neural tube defects, limb reduction defects, and spina bifida had increased odds of 1.57, 1.99, and 1.93 respectively. There were also 1.13 times greater odds of any structural defect in this group, part of a cohort of 965,236 live births in the state from 2010 to 2017. Ohio experienced a thirty-fold increase in the production of natural gas between 2010 and 2020. The research team used proximity metrics and other approaches employed in previous studies examining links between UOGD and structural birth defects, with the goals to facilitate "cross-cohort comparisons, triangulate evidence, and enhance generalizability of findings," from a state where conditions may differ. For example, "Ohio has among the shortest allowable setback distances… ranging from 50 to 200 feet." The team also used a newly developed metric for addressing the drinking water exposure pathway, which revealed the links with limb reduction defects and spina bifida. There was an inverse link with the common birth defect hypospadias, which the authors discuss: "The unexpected inverse association with hypospadias could be due to chance, or could be indicative of the possibility that endocrine disruptors can produce effect estimates in different directions… For example, hypospadias is linked to exposure to hormone disruptors, and both androgenic and anti-androgenic chemicals have been detected in hydraulic fracturing fluid and wastewater." They conclude that their results and those elsewhere in the body of research "underscore the need to consider impacts to children's health specifically when developing or improving public health protections around UOGD."[26]

- April 5, 2023 – Texas A&M University researchers found elevated risks of birth defects in four core fracking counties of the Barnett Shale region of Texas compared to overall risk of these conditions across the state. The study analyzed all live births between 1999 and 2014 (n = 627,580) in Denton, Johnson, Tarrant, and Wise Counties, addressing whether the risks of birth defects were higher in those counties and whether the rates of birth defects were linked with the level of gas production over the time. The researchers found that atrial septal defect (ASD), patent ductus arteriosus (PDA), and total birth defects were all strongly linked with annual gas production over the entire study period in all four counties. Specifically, researchers found an increased risk of ASD in all four of the counties during most of the sub-time periods examined. Higher risks of PDA and ventricular septal defect (VSD) were found only in Tarrant County, which had by far the highest level of gas production in the period studied. ASD, PDA, and VSD are cardiac and circulatory system defects. The study also identified an increased risk of abnormalities in the central nervous system in infants in these counties, particularly

[25] Ashleigh Tindle and Lauren Trepanier, "Radon and Fracking Exposures and Lymphoma Risk in a Canine Model of Non-Hodgkin Lymphoma," *Journal of Clinical and Translational Science* 7, no. s1 (April 2023): 142–142, https://doi.org/10.1017/cts.2023.502.
[26] Casey Gaughan et al., "Residential Proximity to Unconventional Oil and Gas Development and Birth Defects in Ohio," *Environmental Research* 229 (July 2023): 115937, https://doi.org/10.1016/j.envres.2023.115937.

Tarrant County. There, the risk of severe microcephaly (MIC) was associated with higher annual outputs of gas production from fracking; there is, however, the possibility that the presence of a large children's hospital in Tarrant County recorded birth defects that smaller hospitals missed. The authors found their results to be consistent with other studies addressing the relationship between the proximity of maternal residence to fracking sites and birth defects in offspring. As the authors note, because this was an ecological study, it could not take into account other individual and neighborhood factors. The strengths of this study identified by the researchers include the reliability of the gas production data, the examination of the specific birth defects, and the sophistication of the statistical methods.[27]

- March 6, 2023 – A study in the Marcellus Shale region of northern Pennsylvania and southern New York examined trends in hospitalizations for illnesses plausibly related to air pollution from drilling and fracking operations among older people as fracking activity rapidly increased in Pennsylvania after 2009. Using 2002-2015 Medicare claims, the authors took advantage of the stark difference in fracking activity between Pennsylvania, where the practice became widespread beginning in 2008, and New York, where the practice was and remains banned. The team selected three northern Pennsylvania counties to serve as the exposed areas and two unexposed neighboring regions in New York as controls. For each region, from 2002 to 2015, they identified the numbers and trends for hospitalization with acute myocardial infarction (heart attack), chronic obstructive pulmonary disease, bronchiectasis, heart failure, ischemic heart disease, and stroke among adults aged ≥65 years. The authors examined the differences in hospitalization rates for these conditions among the three regions before fracking began in Pennsylvania and then followed the numbers and trends in the following years with increasing exposure to fracking activities. They found that from 2002-2008 the rates of hospitalizations for these illnesses and their trends were similar in the Pennsylvania and New York regions. But soon after 2009, the trends began to diverge. In New York, the trends for heart attack and heart failure continued downward, while they began to increase in Pennsylvania where fracking intensity increased. For heart attacks, the association between hospitalization rates and fracking grew consistently larger between 2012 and 2015 in Pennsylvania. In 2015 alone, Pennsylvania counties had an additional 11.8, 21.6, and 20.4 hospitalizations for acute myocardial infarction, heart failure, and ischemic heart disease, respectively, per 1000 Medicare beneficiaries than would have been expected without fracking. The team did not find an association between fracking and chronic obstructive pulmonary disease or stroke.[28]

- February 1, 2023 – Researchers in Broomfield, Colorado studied health symptoms in residents where oil and gas fracking operations had rapidly developed close to residential neighborhoods. A survey of 3,993 randomly selected households investigated any association between living near wells and frequency of a variety of health-related

[27] JeongWon Han et al., "Associations between Occurrence of Birth Defects and Hydraulic Fracturing Activities in Barnett Shale Region, Texas," *Heliyon* 9, no. 4 (2023): e15213, https://doi.org/10.1016/j.heliyon.2023.e15213.
[28] Kevin S Trickey, Zihan Chen, and Prachi Sanghavi, "Hospitalisations for Cardiovascular and Respiratory Disease among Older Adults Living near Unconventional Natural Gas Development: A Difference-in-Differences Analysis," *The Lancet Planetary Health* 7, no. 3 (March 2023): e187–96, https://doi.org/10.1016/S2542-5196(23)00009-8.

symptoms. Homes were within 1 mile of well pads, within 1–2 miles, or more than 2 miles away. Response rates to the survey for the three distance bands were similar. During the survey, 30 wells were in the production phase, 21 in the pre-production phase, and 33 had no activity. The research team found no differences in unadjusted analysis of self-reported health symptoms by setback distance. However, after adjusting for a number of individual and family-related variables, symptoms trended higher as the distance to the wells decreased. This association was particularly apparent for upper respiratory, lower respiratory, and gastrointestinal symptoms. There were no differences in reports of mental health or neurological symptoms.[29]

- December 23, 2022 – Pregnant women living in the Peace River Valley in British Columbia, Canada, an area of intensive unconventional oil and gas (UOG) activity, may have increased exposure to certain trace elements, according to a study of 85 pregnant women. These women had median urinary levels that were twice as high for barium and strontium and three times as high for cobalt, compared to data on a reference population drawn from two large North American health databases. They also found higher urinary manganese concentrations in self-identified Indigenous participants than in non-Indigenous participants, as well as higher levels of other elements, but those did not reach statistical significance. Authors state, "These elements, commonly found in hydraulic fracturing wastewaters, are likely to contaminate surrounding aquifers and reach drinking water." The UOG activity in this region, which exploits one of the largest reserves in the world, dramatically expanded between 2005 and 2019, during which time fracking methods replaced conventional oil and gas drilling. This study expands on the same team's pilot study of gestational exposure to contaminants related to UOG activity which spurred a larger biomonitoring initiative in the region (see footnotes 83, 113). The present study used samples from seven consecutive days and concluded in their analysis that repeated measurements such as theirs are necessary to "better detect peak exposures," and because single samples are "insufficient to adequately reflect average exposure to certain trace elements." [30]

- December 2, 2022 – A Texas statewide population-based cohort study of birth defects, identified through two different birth defect registries, examined associations between multiple exposure measures of oil and gas extraction and odds of congenital anomalies. Birth outcomes of mothers who lived within 5 kilometers (3.1 miles) of an oil or gas well, combined with intensity of activity at the well(s), were compared to birth outcomes in an otherwise similar group. The study found a 25 percent increased risk of having a child with any birth defect, when using proximity to well site, well site count, gas production, and produced water as exposure measures. For cardiac and circulatory anomalies, the association was particularly robust and consistent for all measures of exposure. Associations were smaller and less consistent for oil production. The authors

[29] Meagan L. Weisner et al., "Health Symptoms and Proximity to Active Multi-Well Unconventional Oil and Gas Development Sites in the City and County of Broomfield, Colorado," *International Journal of Environmental Research and Public Health* 20, no. 3 (February 1, 2023): 2634, https://doi.org/10.3390/ijerph20032634.
[30] Lucie Claustre et al., "Assessing Gestational Exposure to Trace Elements in an Area of Unconventional Oil and Gas Activity: Comparison with Reference Populations and Evaluation of Variability," *Journal of Exposure Science & Environmental Epidemiology* 33, no. 1 (2023): 94–101, https://doi.org/10.1038/s41370-022-00508-8.

hypothesized that the agents responsible for this association may include hazardous fluids associated with various steps in the production process; pollutants from diesel truck traffic; flaring; and naturally occurring radioactive material that is pumped from the ground.[31]

- October 17, 2022 – A population-based, case control study in Germany examined the relationship between residential proximity to an oil or gas well and the likelihood of being diagnosed with a hematologic malignancy in adulthood. The study included 3,978 cases and 15,912 similar controls without malignancy. Residential proximity to oil or gas wells at the time of diagnosis was used as the exposure measure. Proximity to main roadways and agricultural land were considered potential confounders. Cases were not contacted so individual smoking history, occupation, and nutrition were unknown. The study found no association between residential proximity to oil or gas wells for all hematologic malignancies. When stratified by subtype, the odds of acute myelogenous leukemia was 34 percent higher, although this difference was not statistically significant. When stratifying by gender, the odds of malignancy was 50 percent higher in women living near wells than in controls. When the analysis was limited to gas production sites only, the odds of hematologic malignancy were 50 percent higher in people living within one kilometer (.62 miles) of a well.[32]

- October 3, 2022 – Most of the evidence of negative impacts of natural gas development on infant health comes from high-producing states in the United States. To expand the generalizability of the findings, a cross-sectional study examined associations between proximity to natural gas development and county-level birth outcomes, overall and by race/ethnicity, in all states where gas drilling takes place. The study included 33,849,409 births from the 28 states with any natural gas extraction—conventional and/or unconventional—from 2005 to 2018. The analysis examined birth outcomes associated with the distance between the population-weighted center in each county and the nearest well, combined with its production levels. Overall, prenatal proximity to natural gas extraction activity was associated with increased adverse birth outcomes. A 10 percent increase in gas production in a county was associated with a small decrease in mean birth weight (1.48 grams). The association was larger in women of color—a 10 percent increase in gas production decreased birth weight for infants born to Black women by 10.19 grams and Asian women by 2.76 grams. Increases in gas production were associated with slightly increased gestational age, particularly for infants born to Black women, a finding inconsistent with prior literature showing gas production associated with an increased risk of preterm birth. This study used county-level data for both birth outcomes and distance from each well and is, therefore, not as granular as others that are

[31] Mary D. Willis, Susan E. Carozza, and Perry Hystad, "Congenital Anomalies Associated with Oil and Gas Development and Resource Extraction: A Population-Based Retrospective Cohort Study in Texas," *Journal of Exposure Science & Environmental Epidemiology* 33, no. 1 (January 2023): 84–93, https://doi.org/10.1038/s41370-022-00505-x.

[32] Felix Forster et al., "Residential Proximity to Oil and Gas Production Sites and Hematologic Malignancies: A Case-control Study," *American Journal of Industrial Medicine* 65, no. 12 (December 2022): 985–93, https://doi.org/10.1002/ajim.23434.

able to examine the association between individual birth outcomes and residential distance from the nearest well.[33]

- August 17, 2022 – A well-designed study in Pennsylvania found that children whose birth residence was within 2 kilometers (1.2 miles) of a fracking site were 2-3 times more likely to be diagnosed with acute lymphoblastic leukemia between ages 2-7 years than otherwise similar children who were not living near fracking sites. While those living within two kilometers faced the highest risk, leukemia levels among children were elevated as much as 10 kilometers (6.2 miles) from a well, raising questions about safe setback distances. The study included 405 children with leukemia identified through the state cancer registry and considered prenatal, perinatal, and postnatal time periods as potential windows of susceptibility to fracking-related exposures. Similarly, increased odds of acute lymphoblastic leukemia were also seen when fracking wells were located upstream and groundwater flow toward the residence was considered as a potential pathway of exposure. These findings suggest that contaminated drinking water could be an important risk factor.[34]

- April 4, 2022 – A 2022 Canadian study in rural Alberta found that babies born to mothers living within 6.2 miles (10 kilometers) of one or more fracking wells had increased incidence of low birth weight, premature birth, and major congenital abnormalities. This study included nearly 35,000 pregnancies over a six-year period, 2013-2018.[35]

- January 30, 2022 – A research team working in Pennsylvania found "consistent and robust evidence that drilling shale gas wells negatively impacts both drinking water and quality of infant health." Using exact geographic locations of mothers' residences, gas wells, and public drinking water sources—as well as dates of infant births, timing of drilling and fracking activities, and water measurements—the team showed that shale gas operations near mothers' homes raised levels of contaminants in drinking water and raised the risk for preterm birth and low birthweight.[36]

- January 22, 2022 – Using data gathered from more than 15 million Medicare recipients and records from more than 2.5 million gas and oil wells, a Harvard University research team found that older citizens (65 years old and up) living near wells were at higher risk for dying earlier than those who lived in areas without fracking. Furthermore, those living

[33] Hailee Schuele et al., "Associations between Proximity to Gas Production Activity in Counties and Birth Outcomes across the US," *Preventive Medicine Reports*, October 2022, 102007, https://doi.org/10.1016/j.pmedr.2022.102007.
[34] Cassandra J. Clark et al., "Unconventional Oil and Gas Development Exposure and Risk of Childhood Acute Lymphoblastic Leukemia: A Case–Control Study in Pennsylvania, 2009–2017," *Environmental Health Perspectives* 130, no. 8 (August 2022): 087001, https://doi.org/10.1289/EHP11092.
[35] Zoe F. Cairncross et al., "Association Between Residential Proximity to Hydraulic Fracturing Sites and Adverse Birth Outcomes," *JAMA Pediatrics*, April 4, 2022, https://doi.org/10.1001/jamapediatrics.2022.0306.
[36] Elaine L. Hill and Lala Ma, "Drinking Water, Fracking, and Infant Health," *Journal of Health Economics*, 2022, 102595, https://doi.org/10.1016/j.jhealeco.2022.102595.

downwind from fracking wells were more likely to suffer premature death than those upwind.[37]

- January 20, 2022 – A research team that included First Nations investigators found that the air inside the homes of 85 pregnant women living close to fracking operations in British Columbia had higher levels of volatile organic compounds, including chloroform and acetone, compared with the general population. Further, greater well density was linked to increased exposure. Proximity to fracking operations was inconsistently linked to preterm birth and smaller birthweights.[38]

- January 6, 2022 – A retrospective cohort study in north central West Virginia documented a rise in cases of a rare autoimmune disease (ANCA-associated vasculitis) in areas of fracking activity and during a period of time in which gas extraction through fracking was increasing. Previous research demonstrates that environmental exposure is implicated in the pathophysiology of this disease.[39]

- December 13, 2021 – A study led by Oregon State University researchers of more than 3 million pregnant women in Texas showed that living near an active oil or gas well increased the risks for both gestation hypertension (high blood pressure) and eclampsia (onset of seizures or coma during pregnancy or childbirth). "Among pregnant women who reside within 1 km of at least one oil or gas drilling site, we find 5% increased odds of gestational hypertension and 26% increased odds of eclampsia."[40]

- July 21, 2021 – Living closer versus further (0-1 kilometer versus 3-10 kilometers) from all phases of oil and gas drilling was associated with a reduction in birth weight by an average of 7.3 grams, according to a study using 2,598,025 Texas birth records from between 1996 and 2009. There were also findings that suggested environmental injustices, including the strongest evidence of adverse impacts for the babies born to Hispanic women, as well as to those with the lowest educational attainment. This study also analyzed small-for-gestational age outcomes, and there was less evidence for that relationship. A strength of this study was the size of the retrospective birth cohort researchers assembled, as Texas has the largest population with potential exposure to oil and gas development in the United States.[41]

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[37] Longxiang Li et al., "Exposure to Unconventional Oil and Gas Development and All-Cause Mortality in Medicare Beneficiaries," *Nature Energy*, 2022, https://doi.org/10.1038/s41560-021-00970-y.
[38] Élyse Caron-Beaudoin et al., "Volatile Organic Compounds (VOCs) in Indoor Air and Tap Water Samples in Residences of Pregnant Women Living in an Area of Unconventional Natural Gas Operations: Findings from the EXPERIVA Study," *Science of The Total Environment* 805 (2022): 150242, https://doi.org/10.1016/j.scitotenv.2021.150242.
[39] Devan Makati et al., "Prevalence of ANCA-Associated Vasculitis amid Natural Gas Drilling Sites in West Virginia," *Journal of Nephrology*, 2022, https://doi.org/10.1007/s40620-021-01243-3.
[40] Mary D Willis et al., "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*, 2021, dyab246, https://doi.org/10.1093/ije/dyab246.
[41] Mary D. Willis et al., "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, no. 7 (2021), https://doi.org/10.1289/EHP7678.

- April 17, 2021 – A Stanford, Berkeley, and Columbia medical and public health science team identified a link between fracking-related air pollution and migraine headache as part of a study of long-term exposure to nitrogen dioxide (NO_2) and methane from industrial "super-emitters." One of two categories of methane super-emitters in the study included power plants, refineries, oil and gas production sites, wastewater treatment facilities, and oil and gas distribution infrastructure, such as compressors stations and distribution lines. The study also found that living within ten kilometers of any active oil and gas well was associated with increased frequency of outpatient neurologist visits, frequency of migraine-specific urgent care visits, and odds of at least one migraine-specific emergency room visit per person-year of follow-up. (This measurement takes into account the number of people in the study and the amount of time each person is in the study.) This study, the first to uncover a potential link between exposure to methane super-emitters and migraine, used a Northern California electronic health record data set of nearly 90,000 migraine cases between 2014 and 2018 and compared them to matched controls. It also documented a link between annual average NO_2 and fine particulate matter exposure and migraine headache severity. In addition to emitted air pollutants as risk factors, authors also noted that super-emitters such as oil and gas wells produce noise pollution, and both noise and odors are consistently linked with migraine headache.[42]

- March 31, 2021 – Fracking operations shorten lifespans and otherwise represent significant risks to the public health in Oklahoma, according to a unique study using a comprehensive health profile of the population across 76 counties, over twenty years (1998–2017). This research demonstrated that an increase in the number of fracking wells in a county has a detrimental effect on life expectancy. On average, a one percent increase in the number of fracking wells in a county leads to a 4.2 percent reduction in life expectancy. Researchers found analogous trends with other health outcomes. A one percent increase in the number of fracking wells led to a 7.9 percent increase in cancer incidence, a 7.3 percent increase in cardiac diseases, and a 5.9 percent increase in respiratory diseases. Researchers recommended that policymakers "dismiss fracking as a viable option and promote energy technologies that can have less harmful effects on health," and that "the public health risks results presented in this study can be beyond any effective regulation in which case prevention becomes a major policy option."[43]

- March 29, 2021 – Living near urban oil drilling sites in South Los Angeles was linked with reduced lung function among residents in a community-driven epidemiological study led by a University of Southern California and Occidental College team. The researchers obtained 747 valid spirometry tests of residents living less than 1000 meters from two oil well sites (one active, one idle) in the Las Cienagas oil field, measuring FEV1 (forced expiratory volume in the first second of exhalation) and FVC (forced vital

[42] Holly Elser et al., "Air Pollution, Methane Super-Emitters, and Oil and Gas Wells in Northern California: The Relationship with Migraine Headache Prevalence and Exacerbation," *Environmental Health* 20, no. 45 (2021), https://doi.org/10.1186/s12940-021-00727-w.
[43] Nicholas Apergis, Ghulam Mustafa, and Sayantan Ghosh Dastidar, "An Analysis of the Impact of Unconventional Oil and Gas Activities on Public Health: New Evidence Across Oklahoma Counties," *Energy Economics* 97 (2021), https://doi.org/10.1016/j.eneco.2021.105223.

capacity). These are measures of lung capacity and lung strength, and they are both predictors of serious health problems, as well as of early death. The study found that living fewer than 200 meters from oil operations was associated with on average −112 mL lower FEV1 and −128 mL lower FVC compared to those living more than 200 meters from the sites. Further, residents living downwind and less than 200 meters from oil operations had on average −414 mL lower FEV1 and −400 mL lower FVC, compared to residents living upwind and more than 200 meters away from the wells. Researchers adjusted for factors including but not limited to proximity to freeway, smoking status, and asthma status. Researchers wrote that the impacts on lung function they found among non-asthmatic participants indicated that the drilling "may have adverse effects on otherwise healthy people." A second part of the study, which included the collection of self-reported acute health symptoms, indicates that residents living near the active drilling site had a greater prevalence of symptoms, including wheezing, sore throat, chest tightness, dizziness, and eye or nose irritation compared to residents near the idle well site. Authors said that their urban findings are similar to those found in studies of rural residents near gas fracking sites. The area where this study was situated "is among the top 10% most disproportionately-environmentally burdened in the state."[44] In media coverage addressing a failed state legislative effort to enact 2,500-foot buffer between drilling sites and schools, home and playgrounds, lead study author Jill Johnston of USC said that the link between worse lung function and the drilling sites found in the communities where her research took place "shows this is a real public health hazard."[45]

- March 1, 2021 – High levels of fracking-related chemicals were found in the bodies of residents living in five southwestern Pennsylvania households located near fracking operations. None of the households included smokers and each included at least one child.[46] An investigative journalist and her colleagues with *Environmental Health News*, in consultation with scientific advisors, collected 59 urine samples, 39 air samples, and 13 water samples, which were subsequently analyzed in a University of Missouri lab. (Raw data by family and compound is available in the referenced link.)[47] This pilot study was the first to document the body burden of fracking-related chemicals in Pennsylvanians and represents one of very few biomonitoring studies of these chemicals. Findings included very high levels of chemicals known to be released from fracking sites in the bodies of a family living within 1.5 miles of six wells. This family had benzene, toluene, naphthalene, and 15 other chemicals in their urine samples. These chemicals are all known to have negative health impacts, including reproductive harm and cancer risk. A biomarker for toluene in a 9-year-old child in the family was 91 times as high as that of the average American. Each of the family's sample levels exceeded the U.S. 95th

[44] Jill E. Johnston et al., "Respiratory Health, Pulmonary Function and Local Engagement in Urban Communities Near Oil Development," *Environmental Research* 197 (2021), https://doi.org/10.1016/j.envres.2021.111088.
[45] Janet Wilson, "California Bill to Ban Fracking Dies, But Other Oil Regulation Measures Win Votes," *Desert Sun*, April 13, 2021, https://www.desertsun.com/story/news/environment/2021/04/13/california-bill-ban-fracking-dies-senate-committee-buffer-zones/7212190002/.
[46] Kristina Marusic and EHN Staff, "Fractured: The Body Burden of Living Near Fracking," *Environmental Health News*, March 1, 2021, https://www.ehn.org/fractured-series-on-fracking-pollution-2650624600/fractured-fracking.
[47] Charles Minshew, "EHN- A Family's Chemical Exposure," January 4, 2021, https://public.tableau.com/app/profile/charles.minshew2414/viz/EHN-AFamilysChemicalExposure/FamilyDashboard.

percentile for mandelic acid, a biomarker of ethylbenzene and styrene, and more than half of the family's samples exceeded the U.S. 95th percentile for phenylglyoxylic acid, another biomarker for ethylbenzene and styrene, as well as for trans, transmuconic acid, a biomarker for benzene. These U.S. percentiles for comparison were drawn from the Centers for Disease Control and Prevention's National Health and Nutrition Examination Survey. Overall, families in the investigation that lived closer to fracking operations had higher levels of several chemicals than those living further away. Highlighting this investigation, 35 members of the Pennsylvania House and Senate responded by publicly requesting that the Pennsylvania governor "direct adequate funding to thoroughly study the full and complete health impacts of fracking."[48]

- February 11, 2021 – An investigation of fracking and heart attack risk found that long-term exposure to fracking operations was associated with increased acute myocardial infarction (AMI) hospitalization rates and increased AMI death rates in a study that compared Pennsylvania and New York counties atop the Marcellus Shale, from 2005–2014. This study design was made possible by the natural experiment created by New York's statewide ban on fracking and the opposing decision by Pennsylvania to pursue shale gas extraction enthusiastically. Specifically, one hundred cumulative fracking wells drilled in a county was linked with 1.4–2.8 percent increases in AMI hospitalizations, depending on age and sex, and with a 5.4 percent increase in AMI deaths among men age 45 to 54. Of these findings, the authors wrote, "To put this into perspective, three Pennsylvania counties – Bradford, Washington, and Susquehanna… – each had over a thousand unconventional wells by the end of 2014, with hundreds more drilled since then. Not coincidentally, these three counties are the ones with the most individual cardiovascular health complaints submitted to the Pennsylvania Department of Health between 2011 and February 2018." Noting that their findings are consistent with a few previous studies on fracking and cardiovascular hospitalizations, the authors concluded that these results "suggest that bans on hydraulic fracturing can be protective for public health."[49]

- December 15, 2020 – A major study published in the *Journal of the American College of Cardiology* documented a link between fracking and heart failure. Using a case-control analysis and data on more than 12,000 patients from health records in an integrated health system across the state of Pennsylvania, researchers from Johns Hopkins University found that heart failure patients living near fracking sites were significantly more likely to become hospitalized. The results showed strong associations between fracking activity and two types of heart failure, with older heart-failure patients particularly vulnerable to adverse health impacts from fracking activity. Heart failure patients exposed to the highest intensity of fracking activity were more likely to be hospitalized for heart failure

[48] Sara Innamorato, "Pennsylvania House and Senate Elected Officials Strongly Urge Governor Wolf to Investigate Serious Health Impacts Associated with Fracking" (PA House of Reps., March 18, 2021), https://www.pahouse.com/Innamorato/InTheNews/NewsRelease/?id=118917.
[49] Alina Denham et al., "Acute Myocardial Infarction Associated with Unconventional Natural Gas Development: A Natural Experiment," *Environmental Research* 195 (2021), https://doi.org/10.1016/j.envres.2021.110872.

compared with those who were in the lowest intensity of exposure.[50] "These associations can be attributed to the environmental impacts of fracking, including air pollution, water contamination, and noise, traffic, and community impacts" with possible underlying mechanisms including systemic inflammation, autonomic dysfunction, prothrombotic pathways, and epigenomic changes, all of which are known to contribute to heart failure.[51]

- November 24, 2020 – Pregnant women living near fracking sites in Texas had increased risk for serious birth defects in their infants, including neurological defects, heart defects, and gastroschisis, according to a case-control study that compared nearly 53,000 cases with birth defects to 642,399 controls, from 1999 to 2011. Gastroschisis is an abnormality of the abdominal wall that allows the baby's intestines (and sometimes other organs) to protrude outside of the body. Specifically, researchers found links between maternal addresses within one kilometer (0.6 miles) of the highest fracking site density and the following birth defects: anencephaly, spina bifida, gastroschisis (for births from older mothers), aortic valve stenosis, hypoplastic left heart syndrome, and pulmonary valve atresia or stenosis. Based on these geographic patterns, the research team suggests that neural tube defects may be linked to "acute, frequent, and concentrated airborne exposures from high-intensity" fracking activities. Almost always fatal, anencephaly is a neural tube defect in which a large part of the skull is absent along with parts of the brain; spina bifida is a neural tube condition that affects the spine and spinal cord and can create paralysis. In addition, researchers found significant increased risk of congenital heart defects at all three maternal address distances to fracking that the study analyzed, radii of of 1, 3, and 7.5 kilometers. Because this type of risk was consistent across the three different distances, the researchers suggest that exposures linked with congenital heart defects might be due to groundwater contamination of a public supply serving an extended geographic area. An additional component of the study showed an increased risk for ventricular septal defects and atrial septal defects over time, possibly reflecting the increasing fracked well numbers around the state. Researchers wrote that their study supports previous research investigating fracking and birth defects, and that their analyses suggest that vulnerable populations near fracking sites, particularly minority and lower socioeconomic status (terms used by the authors) mothers, may be at greater risk for birth defects.[52]

- November 20, 2020 – A study appearing in the journal *Public Health Nursing* found a correlation between oil development and gonorrhea rates in North Dakota between the fracking boom years of 2002 to 2016. Previous research has documented the link between sexually transmitted infections (STIs) and fracking in Ohio and Pennsylvania, but,

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[50] Tara P. McAlexander et al., "Unconventional Natural Gas Development and Hospitalization for Heart Failure in Pennsylvania," *Journal of the American College of Cardiology* 76, no. 24 (2020): 2862–74, https://doi.org/10.1016/j.jacc.2020.10.023.

[51] Barrak Alahmad and Haitham Khraishah, "Unconventional Natural Gas Development and Heart Failure: Accumulating Epidemiological Evidence," *Journal of the American College of Cardiology* 76, no. 24 (2020): 2875–77, https://doi.org/10.1016/j.jacc.2020.10.040.

[52] Ian W. Tang, Peter H. Langlois, and Verónica M. Vieira, "Birth Defects and Unconventional Natural Gas Developments in Texas, 1999–2011," *Environmental Research* 194 (2021): 110511, https://doi.org/10.1016/j.envres.2020.110511.

heretofore, North Dakota has been far less studied. A second part of the study evaluated the state's public health infrastructure and ability to respond to the STI-related needs of North Dakota's growing transient population during that same period. Researchers found wide-ranging deficits, including lack of primary care services, limited STI testing, limited funding, large service areas, and lack of confidentiality. The authors recommended expanding the role of public health nurses in North Dakota to implement STI screening, which would allow for comprehensive reporting and treatment. This study documented increased STI rates across the state during the fracking boom without evidence of greater infection rates in oil-producing counties than in others. Authors posit this is due to factors unique to North Dakota such as the public health infrastructure deficits mentioned above, as well as factors such as workers traveling to oil-producing counties for work and returning home to more urban areas, where STI rates are documented to be higher.[53]

- September 30, 2020 – In a study that corroborates earlier findings from Pennsylvania on an association between asthma and fracking activities, researchers reported links between childhood asthma hospitalizations and both unconventional and conventional gas development in Texas. The team used a database of inpatient hospitalizations between 2000 and 2010, and zip code-level information including gas drilling type, production volumes, and gas-flaring volumes. They found increasing production volumes tracked with increased childhood asthma hospitalizations, following an exposure-response pattern. This study found inconsistent associations with gas flaring, but the authors noted that the available data on flaring was only "reasonable for inferring if flaring occurred, but the relative magnitude of flaring is more difficult to determine," and that flaring activity peaked in 2018 (beyond the years covered in the study). Hence, this study may have underestimated the impact of exposure to flaring. This study also has important environmental justice dimensions. Researchers found communities with lower income and more non-White population had higher odds of childhood asthma hospitalizations. Authors noted, "the U.S. Department of Energy is specifically instructed to monitor the impact of the energy sector on these communities, and the current study provides evidence that drilling exposures seem to be inequitably distributed in Texas."[54]

- August 18, 2020 – A modeling study that used a retrospective analysis and a novel method to quantify exposures from fracking wells in southwest Pennsylvania found that respiratory, neurological, and muscular symptoms tracked with cumulative well density around residential areas. The results suggest that living in proximity to wells may be associated with health symptoms. These findings also indicate that an estimation of exposure that relies on proximity to fracking wells alone may be simplistic, particularly in communities with increasing density of wells. The authors suggest that future research

[53] Andrea L. Huseth-Zosel et al., "Associations Between Oil Development and Sexually Transmitted Infections: Public Health Nurse Perspectives," *Public Health Nursing* 38, no. 1 (2021): 4–12, https://doi.org/10.1111/phn.12836.
[54] Mary Willis et al., "Natural Gas Development, Flaring Practices and Paediatric Asthma Hospitalizations in Texas," *International Journal of Epidemiology* 49, no. 6 (2020): 1883–96, https://doi.org/10.1093/ije/dyaa115.

should examine how the aggregation of exposures from fracking wells and potency of exposures at the residence levels affects health.[55]

- July 15, 2020 – Maternal proximity to flaring, the open combustion of natural gas, was linked to a fifty percent increased chance of preterm birth in a study of 23,487 birth records from 2012 to 2015 in the Eagle Ford Shale of south Texas.[56] The USC and UCLA researchers used satellite data on flaring activity to determine how much flaring took place during the pregnancies, within five kilometers of the maternal residence. They defined a "high" amount as ten or more nightly flare events within three miles of the residence. The researchers statistically adjusted for other known pregnancy risks, also including numbers of oil and gas wells in their analyses, "suggesting the effects of flaring on the length of gestation are independent of other potential exposures related to oil and gas wells." In addition to the flaring exposure effects, the study also found that living within five kilometers of oil and gas wells was independently linked to a higher chance of preterm birth, reduced gestational age, and reduced birth weight. In this first study to address the human health effects of flaring, offspring of Hispanic women were especially impacted. The researchers stated that this finding suggests theirs was "the first study to document greater health impacts associated with [oil and gas development] among women of color." Researchers expressed environmental justice concerns, given that approximately 50 percent of residents living within five kilometers of an oil or gas well are people of color. In an interview with *Environmental Health News,* a lead author said, "Historically, much of the waste disposal in the U.S. is concentrated in communities of color… One theory is that we're seeing the same pattern with flaring, which is essentially another type of waste disposal."[57] Authors called for measures to protect the health of infants, including reducing reliance on fossil fuels.

- July 10, 2020 – Researchers found inconsistent links between density/proximity to fracking wells during pregnancy and lower birthweight, and limited evidence of a link with increased risk of preterm birth, in the first epidemiological study of its kind in Northeastern British Columbia. They analyzed over 6,000 births at one hospital between December 30, 2006 and December 29, 2016, and the density and proximity of fracking wells in areas of 2.5, 5, and 10 kilometers (1.5, 3.1, and 6.2 miles) around the pregnant women's postal codes. Precise maternal addresses were not available to the researchers. The study found increased risk of preterm birth among women in the second quartile of well density/proximity of the 2.5-kilometer category. The researchers noted that a key limitation was their relatively small sample size compared to other epidemiological

[55] Hannah N. Blinn et al., "Exposure Assessment of Adults Living near Unconventional Oil and Natural Gas Development and Reported Health Symptoms in Southwest Pennsylvania, USA," *PLoS One* 15, no. 8 (2020): e0237325, https://doi.org/10.1371/journal.pone.0237325.
[56] Lara J. Cushing et al., "Flaring from Unconventional Oil and Gas Development and Birth Outcomes in the Eagle Ford Shale in South Texas," *Environmental Health Perspectives* 128, no. 7 (July 2020): 077003, https://doi.org/10.1289/EHP6394.
[57] Kristina Marusic, "Babies Born Near Gas Flaring Are 50 Percent More Likely To Be Premature," *The Daily Climate*, July 15, 2020, https://www.dailyclimate.org/fracking-preterm-births--2646412309/particle-4.

studies of fracking and birth outcomes, "which can decrease precision in our effect estimates."[58]

- June 5, 2020 – San Joaquin Valley, California women who lived with the highest exposure to oil and gas wells in the first and second trimesters of their pregnancies were eight to 14 percent more likely to experience a spontaneous preterm birth at 20 to 31 weeks' gestation, according to Stanford University research.[59] The women studied did not have maternal comorbidities for preterm birth, such as gestational or pregestational diabetes, gestational hypertension, and preeclampsia/eclampsia. The researchers analyzed data on 27,913 preterm births and 197,461 comparison term births between 1998 and 2011, with data for 83,559 wells in preproduction or production during the same period, establishing four "exposure quantiles" (no exposure up to the highest exposure). Most of these California wells were drilled using conventional methods. The harmful birth impacts of living near oil and gas wells were strongest among the women who were Hispanic, Black, or had fewer than 12 years of education. In a secondary analysis, the researchers determined that exposure to wells in preproduction was associated with higher concentrations of particulate matter. Though they found a link between preterm birth and exposure to both new and active wells, researchers were not able to determine whether exposure to wells in either stage presents more risk.

- June 3, 2020 – Living near active oil and gas wells during pregnancy was found to increase the risk of low-birthweight babies, specifically in rural areas, according to the largest study of its kind and the first in California.[60] The UC Berkeley-led study found that pregnant people who lived within 0.62 miles (one kilometer) of the highest producing oil and gas wells (more than 100 barrels of oil or the natural gas equivalent) were 40 percent more likely to have low birth weight babies. Further, among full-term births from mothers with the same proximity to highest producing wells, 20 percent were more likely to have babies who were small for their gestational age. The researchers used nearly 3 million birth certificates of babies born to mothers living within ten kilometers of at least one active or inactive well from 2006 to 2015, in the Sacramento Valley, San Joaquin Valley, South Central Coast and Los Angeles Basin. Mothers in the study group exposed to high production volume had an average of 160 inactive wells and 32 active wells within one kilometer. For urban areas, the group within one kilometer of high production volume, compared to no exposure, showed increased odds of small for gestational age babies. They also found modest impacts on birth outcomes linked to proximity to inactive wells, and suggested a possible role of emissions from inactive wells such as methane and residual off-gassing of BTEX contaminants. Certain factors that the researchers could not take into account, such as maternal occupation, housing

[58] Élyse Caron-Beaudoin et al., "Density and Proximity to Hydraulic Fracturing Wells and Birth Outcomes in Northeastern British Columbia, Canada," *Journal of Exposure Science & Environmental Epidemiology* 31, no. 1 (2021): 53–61, https://doi.org/10.1038/s41370-020-0245-z.
[59] David J. X. Gonzalez et al., "Oil and Gas Production and Spontaneous Preterm Birth in the San Joaquin Valley, CA: A Case–Control Study," *Environmental Epidemiology* 4, no. 4 (August 2020): e099, https://doi.org/10.1097/EE9.0000000000000099.
[60] Kathy V. Tran et al., "Residential Proximity to Oil and Gas Development and Birth Outcomes in California: A Retrospective Cohort Study of 2006–2015 Births," *Environmental Health Perspectives* 128, no. 6 (June 2020): 067001, https://doi.org/10.1289/EHP5842.

quality, and indoor air quality, may have contributed to differences between findings in rural and urban populations. Though the study could not account for maternal changes of residence during pregnancy, researchers suggested that because they saw similar effects across trimesters, "any bias resulting from maternal residential and occupational mobility is likely non- differential across trimesters." Authors concluded that prenatal exposure to active oil and gas production using the range of conventional and unconventional techniques employed in California was associated with adverse birth outcomes. Co-author Kathy Tran said to the *Guardian*, "Because researchers don't have direct access to the actual oil and gas sites, it's hard to get a good estimate of what people actually experience… The more in-depth exposure assessment we can get, the more we can really understand why we are seeing the [birth outcome] effects that we see."[61]

- May 27, 2020 – A fracking chemical called Genapol-X100 can interfere with normal activity of the male hormones, according to research performed by University of California toxicologists.[62] The scientists ranked 60 fracking chemicals used in California, based on their potential to interfere with androgens' ability to bind with living human cells. Their assessment found five fracking chemicals with the highest potential to interfere with this process, subsequently identifying Genapol-X100 as a significant androgen disruptor. In their discussion they said that exposure to these chemicals "can affect the normal physiology of androgen pathways such as male reproduction health," and have other related adverse outcomes. Previous research in 2016 reported that Genapol-X100 was used as a chemical constituent in well stimulation treatments more than 500 times, but authors stated that the levels of this chemical in humans and wildlife is not well documented. They wrote that their findings demonstrate this chemical "may pose significant environmental and health risks as it noncompetitively inhibits [human androgen receptor] and alters the expression of androgenic genes at relatively low concentrations."

- May 8, 2020 – A water disinfection byproduct (DBP), monohalogenated iodoacetic acid (IAA), disrupted each major level of the female reproductive axis in an animal model experiment by University of Illinois scientists.[63] DPBs arise when chemicals used to for water decontamination combine with organic material and they have been linked to reproductive disfunction. IAA forms when iodide reacts with a disinfectant. The researchers noted, "not only is iodide widely present in the water supply, especially in coastal communities and those near fracking sites, but IAA has been found to be one of the most cyto- and genotoxic DBPs." Their study linked exposure to IAA to disruptive expressions of key endocrine genes related to reproductive function.

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[61] Nina Lakhani, "Living near Oil and Gas Wells Linked to Low Birthweight in Babies," *The Guardian*, June 3, 2020, sec. Environment, http://www.theguardian.com/environment/2020/jun/03/living-near-oil-and-gas-wells-linked-to-low-birthweight-in-babies.

[62] Phum Tachachartvanich et al., "Structure-Based Discovery of the Endocrine Disrupting Effects of Hydraulic Fracturing Chemicals as Novel Androgen Receptor Antagonists," *Chemosphere* 257 (October 2020): 127178, https://doi.org/10.1016/j.chemosphere.2020.127178.

[63] Rachel Gonzalez et al., "Adult Exposure to Iodoacetic Acid Leads to Abnormal Expression of Key Genes Related to Hypothalamic and Pituitary Control of Reproductive Function," *Journal of the Endocrine Society* 4, no. Supplement_1 (May 8, 2020): SUN-241, https://doi.org/10.1210/jendso/bvaa046.1083.

- March 4, 2020 – Exposures to a mixture of fracking chemicals commonly found in wastewater caused effects on diverse physiological systems though hormone disruption, according to a set of coordinated studies carried out collaboratively by an interdisciplinary team.[64] (See also July 25, 2019 and May 22, 2019 entries below.) These studies, conducted in laboratory animals and human tissue culture cells, used four different doses of a 23-chemical mixture which reflected realistic concentrations ranging from those found in surface and ground water in fracking-dense regions, to concentrations found in fracking wastewater. In human tissue culture cells, exposures to the chemical mixture showed "potent antagonist activity" for the estrogen, androgen, glucocorticoid, progesterone, and thyroid hormone receptors. In animal models, developmental exposures "profoundly impacted" pituitary hormones, reduced sperm counts, and altered maturation of the ovarian follicle. These exposures also altered the mammary gland ductal density and produced precancerous lesions. Finally, exposure additionally had effects on energy expenditure, behavior, and the immune system. The team concluded, "Taken together, these data suggest a strong need to examine the impacts of residential and occupational UOG exposure in humans and other wildlife in drilling areas."

- March 2, 2020 – University of Illinois environmental economists documented a causal link between fracking-related trucking and fatal traffic crashes in the Bakken Formation in North Dakota from 2006-2014.[65] The researchers found that each additional post-fracking well within six miles of a road segments led to eight percent more fatal crashes and over seven percent higher per-capita costs in accidents. In their study, post-fracking wells were those horizontal wells completed in the previous month from which post-fracking wastewater flowback is a hauled to disposal sites. They extrapolated from their data "that an additional 17 fatal crashes occurred every year due to the fracking operations near the sampled 225 road segments… representing a 49% increase relative to the 2006 baseline crash counts of the eighteen drilling counties in North Dakota." They noted that an increase in alcohol-involved crash drivers was most likely "due to their vulnerability to heavier fracking- induced traffic rather than more alcohol-involved truck drivers near the fracking sites."

- January 27, 2020 – Pressured by families affected with rare childhood cancers in southwestern Pennsylvania, Governor Tom Wolf announced that his administration will spend $3 million to fund two studies to investigate the possible link between fracking and childhood cancers. Although an initial analysis had determined no "cancer cluster" existed in Washington County, it had had considered only three cases of the six cases known within a single school district. Nine preschoolers and students in the Canon-McMillan school district were diagnosed with rare cancers in the 2018-2019 school year. The state's chief epidemiologist, Sharon Watkins, said the results of the earlier analysis could change after more recent data is included. The first study will review existing

[64] S.C. Nagel et al., "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 (August 2020): 110722, https://doi.org/10.1016/j.mce.2020.110722.
[65] Minhong Xu and Yilan Xu, "Fraccidents: The Impact of Fracking on Road Traffic Deaths," *Journal of Environmental Economics and Management* 101 (May 2020): 102303, https://doi.org/10.1016/j.jeem.2020.102303.

literature on general health harms of fracking. The second will investigate whether young cancer patients had higher exposures to fracking than the general population.[66] From 2006-2017, 31 people in four counties in southwestern Pennsylvania had been diagnosed with Ewing's sarcoma, a rare bone cancer. This represents a 40 percent jump from 1995-2005, a period prior to the arrival of drilling and fracking activities in the area.[67] (See entry for May 14, 2019 below.)

- January 23, 2020 – Oil and gas development does not improve the "rural mortality penalty" according to an analysis of a large sample U.S. mortality rates from 2000-2016 and county-level counts of active wells.[68] The rural mortality penalty is the phenomenon in which those living in rural locations have higher mortality rates than those in suburban and urban places. This began to be the case approximately a half century ago, increasing over time, with a further 75 percent increase between 2004 and 2016. Though fracking may increase job growth and earnings in some places, the author concluded, "Importantly, [unconventional oil and gas development] does not seem to improve mortality rates, suggesting that UOGE cannot address this unique problem. This raises several questions of justice and fairness, as host communities do not seem to retain all the potential benefits of UOGE."

- January 9, 2020 – Rates of two sexually transmitted infections, gonorrhea and chlamydia, were respectively fifteen and ten percent higher in Texas counties with high levels of fracking compared to those without, in a Yale School of Public Health study.[69] The researchers considered the reported cases of these diseases, plus syphilis, from 2000-2016 in Texas, Colorado, and North Dakota. They sought to add to previous research on the link between increases in migrating and/or non-local workers and increased rates of sexually transmitted infections in host communities. Previous research took place in the Marcellus Shale formation states. Authors wrote, "Associations between shale drilling and chlamydia and gonorrhea in Texas are consistent with the previously observed associations in the Marcellus Shale, and may reflect increased risk in areas with greater drilling activity and increased proximity to major metropolitan areas." They expressed concern in the rise of both of these diseases; with gonorrhea due to the rise antibiotic-resistant infections, and chlamydia because asymptomatic people may not be treated.

- October 17, 2019 – Exposure to chemicals used in oil and gas development, such as benzene, may cause short-term negative health impacts including headaches, dizziness, respiratory effects, and skin and eye irritation at distances from 300 to 2000 feet from a

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[66] Chaffin, "Pennsylvania Governor Funds Research Examining Potential Fracking Health Impacts."
[67] Kris Maher, "After String of Rare Cancer Cases, Pennsylvania Investigates Potential Link to Fracking," *The Wall Street Journal*, December 20, 2019, sec. US, https://www.wsj.com/articles/after-string-of-rare-cancer-cases-pennsylvania-investigates-potential-link-to-fracking-11576837802.
[68] Adam P. Mayer, "Can Unconventional Oil and Gas Reduce the Rural Mortality Penalty? A Study of U.S. Counties," *Journal of Rural and Community Development* 14, no. 4 (2019), https://journals.brandonu.ca/jrcd/article/view/1712.
[69] Nicholaus P. Johnson et al., "A Multiregion Analysis of Shale Drilling Activity and Rates of Sexually Transmitted Infections in the United States," *Sexually Transmitted Diseases* 47, no. 4 (April 2020): 254–60, https://doi.org/10.1097/OLQ.0000000000001127.

well pad, concluded Colorado's state-funded human health risk assessment.[70, 71] The study used actual emissions data from oil and gas operations in the state, to model exposures and risks of health impacts. The study did not use actual health impacts. This contracted assessment followed the state's 2017 small health impacts study, which called for further research into the possible health effects and exposures for people living close to wells. A peer-reviewed summary of this 2019 assessment was published in the *Journal of the Air & Waste Management Association*.[72] *The Denver Post* reported, "While benzene has been linked to cancer, state officials said the study, based on measuring of emissions and computer modeling, did not find a basis for predicting long-term health harm."[73] The regulating agency, Colorado Oil and Gas Conservation Commission, said that though they were not previously involved in testing air around residents' homes, they will "immediately begin reviewing more strictly all industry applications to drill new wells within 2,000 feet of homes and start measuring air emissions around industry sites." The study only addressed the scenario of a single well pad, not the risks for those living near large, multi-well pads.

- October 11, 2019 – The first analysis of infant health at birth and proximity to fracking in Oklahoma counties found a clear, detrimental relationship, by several measures.[74] The analysis used 590,780 birth records across all 76 Oklahoma counties, from 2006–2017. Oklahoma's fracking boom began in 2006. Researchers determined distance between maternal residence and fracking wells, and their measures of infant health were total weight, low weight, and a composite health index of overall infant health. Researchers determined that 121,862 births took place within one kilometer of fracking wells, 148,783 births within five kilometers, 157,664 within ten, and 128,485 within 20 kilometers. The harmful effects of fracking wells on infant health were found for total birth weight and for the composite health index. For total birth weight, the results were significant within five kilometers and strongest within one kilometer. For the composite health index, the findings were significant across all distances, with the strongest impact taking place for maternal residence within one kilometer of fracking wells. These researchers also ran comparison analyses for conventional drilling, which constituted about 29 percent of Oklahoma drilling in the study period. They found more minor impacts, and at distances up to one kilometer only, concluding, "These findings provide

[70] Ed Carr et al., "Final Report: Human Health Risk Assessment for Oil & Gas Operations in Colorado" (ICF International for the Colorado Department of Public Health & Environment, 2019), https://www.fcgov.com/oilandgas/files/20191017-cdphe-healthimpactsstudy.pdf.
[71] Jessica Bralish, "State Health Department Publishes Oil and Gas Health Risk Study | Department of Public Health & Environment," Press Release (Colorado Department of Public Health & Environment, October 17, 2019), https://cdphe.colorado.gov/press-release/state-health-department-publishes-oil-and-gas-health-risk-study.
[72] Chris Holder et al., "Evaluating Potential Human Health Risks from Modeled Inhalation Exposures to Volatile Organic Compounds Emitted from Oil and Gas Operations," *Journal of the Air & Waste Management Association* 69, no. 12 (December 2, 2019): 1503–24, https://doi.org/10.1080/10962247.2019.1680459.
[73] Bruce Finley, "Colorado to Tighten Oversight of Oil and Gas Sites near Homes in Wake of Study Finding Possible Short-Term Health Effects," *The Denver Post*, October 17, 2019, https://www.denverpost.com/2019/10/17/colorado-oil-gas-health-risks-study/.
[74] Nicholas Apergis, Tasawar Hayat, and Tareq Saeed, "Fracking and Infant Mortality: Fresh Evidence from Oklahoma," *Environmental Science and Pollution Research* 26, no. 31 (November 2019): 32360–67, https://doi.org/10.1007/s11356-019-06478-z.

supportive evidence to the substantial (negative) role of fracking drilling activities for infants' health status."

- August 15, 2019 – Building on their previous work that considered health-related symptoms of those living near fracking wells, researchers developed a study that added processing plants and compressor stations, while also creating the first such study to incorporate weather and atmospheric conditions in their exposure estimates. They analyzed respiratory health outcomes in a sample of 87 people living near fracking sites who participated in a Southwest Pennsylvania Environmental Health Project data collection project between February 1, 2012 and December 31, 2017. Seventy-two percent of the people studied reported at least one respiratory symptom "that began or worsened after the onset of drilling activity and could not be plausibly attributed to pre-existing or current medical conditions, or practices such as smoking."[75] Forty percent reported sore throat, 36 percent reported both cough and shortness of breath, 26 percent reported sinus problems, and 16 percent report wheezing. Seventy-seven percent of those studied lived within two kilometers of at least one source, 29 percent within one to nine sources, one quarter within 10 to 19 sources, and 23 percent of those studied lived within two kilometers of 20 or more fracking-related exposure sources. Results showed some of the sources studied linked specifically to cough, shortness of breath, and "any respiratory symptom."

- July 25, 2019 – In this set of experimental studies in human tissue culture cells and laboratory animals, exposure to a mixture of fracking chemicals was linked to potent hormone disrupting activity.[76] This paper presented results that were part of a set of coordinated studies carried out collaboratively by an interdisciplinary team using four different doses of a 23-chemical mixture, reflecting realistic concentrations ranging from those found in surface and ground water in fracking-dense regions, to concentrations found in fracking wastewater (see March 4, 2020 entry above and May 22, 2019 below). In the human tissue culture cells, exposure to the mixture was linked to "potent antagonist activity for the estrogen, androgen, glucocorticoid, progesterone, and thyroid receptors." In a laboratory mouse model, the fracking chemical mixture given in pregnancy led to profound impacts on health and behavior in the developing and adult offspring. Offspring had reduced sperm counts, altered ovarian follicle development, and precancerous lesions. The mixture impacted energy expenditure, exploratory and risk-taking behavior, and the immune system. The research also found immune system effects in a frog model. Using these different model systems and demonstrating various physiological impacts, the researchers concluded that fracking "may be an important source of human [endocrine disrupting chemical] exposure and altered health parameters."

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[75] David R. Brown et al., "Assessing Exposure to Unconventional Natural Gas Development: Using an Air Pollution Dispersal Screening Model to Predict New-Onset Respiratory Symptoms," *Journal of Environmental Science and Health, Part A* 54, no. 14 (December 6, 2019): 1357–63, https://doi.org/10.1080/10934529.2019.1657763.
[76] Victoria D. Balise et al., "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 (July 25, 2019): 460, https://doi.org/10.3389/fendo.2019.00460.

- July 23, 2019 – Researchers found 4.3 additional cases of prenatal anxiety or depression per 100 women, among mothers who lived amid the most fracking activity during their pregnancies, compared to those who lived around less.[77] The study included 7,715 mothers without anxiety or depression at the time of conception, who delivered their babies at Geisinger Health System in central and northeast Pennsylvania, between January 2009 and January 2013. It included women who gave birth to single babies, without serious birth defects, and of viable weight and gestational age. In the highest quartile of the fracking activity metric developed for this study there were an average of 130 wells within 20 kilometers of the mothers' home, compared to 10 wells for mothers in the other three quartiles. The prevalence of anxiety or depression during pregnancy was 15 percent in the highest quartile, and 11 percent in the lower three quartiles. Researchers determined that the risk was greatest among low income women, among whom there were 5.6 additional cases of anxiety or depression per 100. In this study, researchers did not find a relationship between anxiety or depression during pregnancy and preterm birth and reduced term birth weight, though the same team found a link between proximity to fracking and these adverse birth outcomes.

- July 18, 2019 – Colorado mothers living in areas with the most intense levels of oil and gas activity were 40 to 70 percent more likely to have children with congenital heart defects (CHDs) in a study 3,324 of infants born in the state from 2005-2011.[78] University of Colorado researchers developed a measure of the monthly intensity oil and gas well activity around mothers' residences from three months prior to conception through the second month of pregnancy, including the phase of oil and gas development, the size of well sites, and production volumes. These considerations as well as other features of this study, such as additional checks on the infants' diagnoses, built on previous research documenting the link between proximity to oil and gas and CHDs. Some of the most common hazardous air pollutants emitted from drilling and fracking sites are "suspected teratogens that are known to cross the placenta." CHDs are a leading cause of developmental problems, brain injury, and death among infants with birth defects. The four specific defects addressed were aortic artery and valve (AAVD), pulmonary artery and valve (PAVD), conotruncal (CTD), and tricuspid valve (TVD) defects. Authors concluded that the study provided further evidence of a link between maternal proximity to drilling and fracking and several types of CHDs, particularly in rural areas, where chances of an infant born with AAVD, CTD, or TVD were 2.6 to 4.6 times more likely in the high exposure group compared to the low exposure group. With regard to urban areas, authors wrote that it is likely that other sources of air pollution obscured possible links.

- July 12, 2019 – The driver of a tractor-trailer rig and four oil field workers riding in a pickup truck were killed in a head-on crash along New Mexico State Route 128, one of several highways experiencing increased crashes in "the busiest oil and gas region in the

[77] Joan A. Casey et al., "Unconventional Natural Gas Development and Adverse Birth Outcomes in Pennsylvania: The Potential Mediating Role of Antenatal Anxiety and Depression," *Environmental Research* 177 (October 2019): 108598, https://doi.org/10.1016/j.envres.2019.108598.
[78] Lisa M. McKenzie, William Allshouse, and Stephen Daniels, "Congenital Heart Defects and Intensity of Oil and Gas Well Site Activities in Early Pregnancy," *Environment International* 132 (November 2019): 104949, https://doi.org/10.1016/j.envint.2019.104949.

United States.[79] Crashes along this route, as well as New Mexico State Route 31 and U.S. 285, have increased over the last year, as upkeep, patrols, and interventions such as safety corridors do not keep pace with the significant increase in traffic and driver behavior issues brought by the fracking boom.

- June 26, 2019 – The investigative journalism organization *Searchlight New Mexico* examined trends in fracking-region highway deaths, their circumstances, and community reactions, reporting, "Locals have a new name for the section of US 285 where [local men] Ponce and Martinez perished: Death Highway."[80] In 2018, there were 49 crashes, up from 31 crashes in 2017. There were five deaths resulting from the crashes along this highway in 2017 and two in 2018. "For local residents—especially those living in rural areas—the combination of congestion, roads thick with truck traffic, unsafe driver behavior, poorly maintained vehicles and deteriorating pavement can make even a routine trip to the farm supply store a white-knuckle obstacle course." According to research by an Albuquerque engineering and planning firm, most of the crashes were caused by speeding. Another group said that a scarcity of local qualified drivers, and many drivers hired by oil companies unfamiliar with the region, are key to the problem. Finally, government funding for needed road improvements is inadequate, according to the *Searchlight* report.

- May 22, 2019 – Exposure of laboratory mice to an environmentally relevant mixture of 23 fracking chemicals altered developmental programming, resulting in changed energy expenditure and activity in adult female offspring.[81] Part of an ongoing set of studies examining the endocrine disruption effects of this mixture using laboratory animals and human tissue culture cells (see also March 4, 2020 and July 25, 2019, above), this was the first study to examine these direct developmental effects of exposure to fracking chemicals. Researchers exposed female mice the mixture of five weeks prior to mating, and from the first day of gestation day to the 21st day postnatally. Pre- and post-natal exposure to the fracking chemical mixture decreased total and resting energy expenditure in some of the groups, but it was not linked with altered body weight or body composition in the adult females. Researchers wrote that although "one would typically expect higher body mass or fat mass to track with lower energy expenditure, this is not always the case."

- May 14, 2019 – A pilot study in northeastern British Columbia reported elevated levels of barium and strontium in urine and hair samples of pregnant indigenous women living in an area of intense fracking activity. These trace metals, released during hydraulic fracturing, are known developmental toxicants. The researchers cited the need for systematic water monitoring program in the region, and, following this small pilot study,

[79] Susan Montoya Bryan, "Police: Texas Oilfield Workers, Truck Driver Killed in Fiery Crash," *Midland Reporter-Telegram*, July 12, 2019, sec. News, https://www.mrt.com/news/article/State-Police-5-dead-in-collision-in-southeastern-14091816.php.
[80] April Reese, "Death Highway," *Searchlight New Mexico*, June 27, 2019, https://searchlightnm.org/death-highway/.
[81] Victoria D. Balise et al., "Preconceptional, Gestational, and Lactational Exposure to an Unconventional Oil and Gas Chemical Mixture Alters Energy Expenditure in Adult Female Mice," *Frontiers in Endocrinology* 10 (May 22, 2019): 323, https://doi.org/10.3389/fendo.2019.00323.

they intend to "carry out a multi-faceted study to assess exposure to contaminants including trace metals with more precision."[82]

- May 14, 2019 – An investigation by the *Pittsburgh Post-Gazette* documented 27 cases of Ewing's sarcoma, a rare bone cancer that tends to strike children and young adults, in four counties in southwestern Pennsylvania (Fayette, Greene, Washington, and Westmoreland) that are at the heart of the Marcellus fracking boom and where more than 3,500 wells have been drilled since 2008.[83] Six cases occurred in the same school district. (The typical rate is 250 cases of Ewing's sarcoma per year in the United States as a whole.) This cancer has no known cause but does not appear to have hereditary links. There are also high numbers of other rare cancers in the region, which is home to several polluting legacy industries. The *Post-Gazette* documented ten such rare cancers Washington County's Canon-McMillan School District alone and tallied 13 childhood and young adult cancer deaths in the region since 2011, including three since 2015 in the West Greene School District. In April 2019, the Pennsylvania Department of Health reported "no conclusive findings" of a cancer cluster in the Canon-McMillan School District and Washington County.[84] Subsequently, additional cases came to light, and public calls for more comprehensive investigations continued.[85, 86, 87, 88]

- April 15, 2019 – Overall, oil and gas booms had very modest effects on local alcohol consumption in a U.S.-wide study using county-level data, but the effects varied greatly across states and by gender.[89] Taken as a whole, oil and gas production slightly increased heavy drinking for males and slightly decreased binge drinking for females. Researchers

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[82] Élyse Caron-Beaudoin et al., "Urinary and Hair Concentrations of Trace Metals in Pregnant Women from Northeastern British Columbia, Canada: A Pilot Study," *Journal of Exposure Science & Environmental Epidemiology* 29, no. 5 (September 2019): 613–23, https://doi.org/10.1038/s41370-019-0144-3.
[83] David Templeton and Don Hopey, "Are the 27 Cases of Ewing's Sarcoma near Pittsburgh a Cluster?," *Pittsburgh Post-Gazette*, May 14, 2019, https://newsinteractive.post-gazette.com/blog/ewing-sarcoma-cancer-cluster-pittsburgh-washington-westmoreland/.
[84] Pennsylvania Department of Health, "Ewing's Family of Tumors, Childhood Cancer, and Radiation-Related Cancer Incidence Review for Washing County and Canon-McMillan School District in Pennsylvania" (Bureau of Epidemiology, Division of Community Epidemiology, April 22, 2019), https://www.documentcloud.org/documents/5975464-Ewings-Washington-Fmt.html.
[85] Reid Frazier, "'Something's Wrong Here': Washington County Parents Want Pa. to Look Deeper at Whether Fracking Could Be Related to Cancer Cases," *State Impact Pennsylvania*, June 28, 2019, https://stateimpact.npr.org/pennsylvania/2019/06/28/somethings-wrong-here-washington-county-parents-want-pa-to-look-deeper-at-whether-fracking-could-be-related-to-cancer-cases/.
[86] Deb Erdley, "Southwestern Pennsylvania Residents Renew Calls for Research on Possible Health Impact of Fracking," October 12, 2019, https://triblive.com/local/regional/southwestern-pennsylvania-residents-renew-calls-for-research-on-possible-health-impact-of-fracking/.
[87] David Templeton and Don Hopey, "The Human Toll-Risk and Exposure in the Gas Lands," *Pittsburgh Post-Gazette*, May 14, 2019, https://newsinteractive.post-gazette.com/childhood-cancer-pittsburgh-pennsylvania-canon-mcmillan-pollution/.
[88] Editorial Board, "Young Lives at Stake: Rural Areas Deserve Answers on Child Cancers," *Pittsburgh Post-Gazette*, May 22, 2019, https://www.post-gazette.com/opinion/editorials/2019/05/22/childhood-cancer-pittsburgh-pennsylvania-canon-mcmillan-pollution-rural-areas-greene-fayette-washington-westmoreland/stories/201905220064.
[89] Adam Mayer and Shawn Olson Hazboun, "Does Fracking Drive You to Drink? Unconventional Oil and Gas Production and Alcohol Consumption in U.S. Counties," *The Extractive Industries and Society* 6, no. 3 (2019): 823–30, https://doi.org/10.1016/j.exis.2019.04.002.

recommended that data be gathered at smaller spatial scales rather than by county, and that hospital admissions or arrest records could provide further insight into this question.

- January 21, 2019 – Increased hospitalizations for diseases of the genitourinary system, such as urinary tract infections, kidney infections, and kidney stones, were "strongly and positively associated with cumulative [unconventional natural gas] well density" in Pennsylvania.[90] The strongest association for the genitourinary hospitalization rates was for women aged 20 to 64, particularly for kidney infections, stones in the ureter, and urinary tract infections. The researchers compared yearly hospitalization rates for each of Pennsylvania's 67 counties with the number of new fracking wells drilled, the total number of wells, and the density of wells by land area for each county by year, from 2003-2014. Noting that hospitalizations, in contrast with outpatient physician visits, reflect acute illness or serious exacerbations of chronic disease, the research team pointed out that these same health problems addressed in an outpatient setting, or not addressed at all, were likely also rising but would not have been counted in this study. The findings also revealed a link between cumulative gas well exposure measures and hospitalization rates for skin problems, particularly among men aged 20 to 64.

- December 12, 2018 – University of Oklahoma public health scientists found a significantly increased prevalence of neural tube defects among children whose birth residence was located within two miles of a drilling and fracking site, compared to those which were not.[91] The researchers examined records of all 476,600 singleton births and congenital anomalies in Oklahoma from 1997 through 2009, together with historical location and production data on active natural gas wells for each year of the study. No stillbirths were included in this study. Hence, as the researchers note, the link they found would likely be an underestimate "if natural gas activity is related to severe anomalies with high prenatal mortality."

- December 6, 2018 – Early signs of cardiovascular disease—including high blood pressure, changes in the stiffness of blood vessels, and markers of inflammation—occurred more often in people who live in communities with more intense oil and gas development, according to a study of 97 adults living in northeastern Colorado between October 2015 and May 2016.[92] Artery stiffness, as measured by augmentation index, was highest among people living in areas with the greatest drilling and fracking activity, as was systolic and diastolic blood pressure (for those not taking prescription medications). This was the first study to evaluate, with direct measurements, indicators of cardiovascular disease and the intensity of oil and gas activity. The results are consistent with previous research showing increased rates of cardiology inpatient hospital admission in these areas.

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[90] A. Denham et al., "Unconventional Natural Gas Development and Hospitalizations: Evidence from Pennsylvania, United States, 2003–2014," *Public Health* 168 (2019): 17–25, https://doi.org/10.1016/j.puhe.2018.11.020.
[91] Amanda E. Janitz et al., "The Association between Natural Gas Well Activity and Specific Congenital Anomalies in Oklahoma, 1997–2009," *Environment International* 122 (2019): 381–88, https://doi.org/10.1016/j.envint.2018.12.011.
[92] Lisa M. McKenzie et al., "Relationships between Indicators of Cardiovascular Disease and Intensity of Oil and Natural Gas Activity in Northeastern Colorado," *Environmental Research* 170 (2019): 56–64, https://doi.org/10.1016/j.envres.2018.12.004.

- August 28, 2018 – The top 10 oil and gas producing counties in Colorado had higher truck accident rates than the remaining 54 counties in an analysis by Colorado School of Public Health researchers. Researchers also performed an additional geospatial study technique called a "grid level analysis" using the Colorado Oil and Gas information System (COGIS), census population information, and home locations. These results showed that grid cells with more homes and/or wells were associated with more truck accidents, as well as with more multi-vehicle truck accidents with an injury.[93]

- August 13, 2018 – Babies in Pennsylvania whose mothers lived near at least one gas well during their pregnancies were at higher risk for adverse birth outcomes, according to a study published in the *Journal of Health Economics.* This investigation examined state-based data on the locations of 2,459 natural gas wells drilled between 2006 and 2010 together with restricted-access birth and mortality data for the years 2003–2010.[94] Mothers living within 2.5 kilometers (1.5 miles) of gas wells gave birth to infants with increased incidence of low birth weight and small for gestational age (SGA). SGA generally increases with exposure to environmental pollution and helps determine immediate health care needs, as well as predicting long-term adverse health outcomes. In addition, the study found term birth weight for these infants was lower on average, and the prevalence of APGAR scores less than eight was increased by 26 percent. APGAR scores are used to evaluate the health of infants immediately after birth. This study builds on growing evidence that air pollution from shale gas development damages infant health and stands out for thoroughly controlling for predictors of infant health and for estimating the extensive and intensive margins of drillings. Within the intensive margin (which includes an estimation of the impact of well density), one additional well was associated with a seven percent increase in low birth weight, a five gram reduction in term birth weight, and a three percent increase in premature birth. Each of these adverse outcomes carries high associated medical costs. The author conservatively estimated the added cost associated with one low birth weight infant to be $96,500 in the first year alone, not counting any loss of parent income. The author noted that these impacts are "likely to persist throughout these children's lives."

- August 10, 2018 – A study of Pennsylvania counties focusing on the period 2003–2012 found that counties with fracking activities have higher rates of gonorrhea and chlamydia infections (up 7.8 percent and 2.6 percent, respectively), as well as a 19.7 percent higher rate of prostitution-related arrests.[95] Authors found no evidence that confounding factors such as opioid prescription rates, viral hepatitis deaths, or drug abuse arrests influenced these results. These findings provide "strong evidence that unconventional or shale gas development poses significant risks to public health and that unconventional or shale gas

[93] Benjamin Blair et al., "Truck and Multivehicle Truck Accidents with Injuries Near Colorado Oil and Gas Operations," *International Journal of Environmental Research and Public Health* 15, no. 9 (2018): 1861, https://doi.org/10.3390/ijerph15091861.
[94] Elaine L. Hill, "Shale Gas Development and Infant Health: Evidence from Pennsylvania," *Journal of Health Economics* 61 (2018): 134–50, https://doi.org/10.1016/j.jhealeco.2018.07.004.
[95] Trinidad Beleche and Inna Cintina, "Fracking and Risky Behaviors: Evidence from Pennsylvania," *Economics & Human Biology* 31 (2018): 69–82, https://doi.org/10.1016/j.ehb.2018.08.001.

development has policy implications beyond the economic and environmental impacts often cited."

- July 28, 2018 – Road fatalities in the Permian Basin region of west Texas have risen and fallen with the price of oil, according to an investigative piece in *Bloomberg* using New York Mercantile Exchange and Texas Department of Transportation data.[96] Interviewees in the article pointed to inexperienced and exhausted drivers, sinkholes, oversized trucks on roads not designed for the amount of traffic they now carry, and other factors as reasons for the ongoing fatalities.

- July 27, 2018 – In this study of almost 5,000 Pennsylvanians, a team of medical and public health scientists found a link between living closer to more and bigger unconventional shale gas wells and increased symptoms of depression. This is the first epidemiologic study to address a mental health outcome with regard to proximity to fracking and related operations. The researchers combined information from a mailed questionnaire, electronic health record data, and residential proximity to more and bigger wells, using well data from three agencies. Size of wells was ascertained by combining data on total well depth and volume of natural gas produced. Researchers concluded that drilling and fracking activities "may be associated with adverse mental health in Pennsylvania" and called for including potential mental health consequences in future risk-benefit calculations.[97]

- June 21, 2018 – Using individual inpatient data for the whole state of Pennsylvania from 2003 through 2014, researchers found consistent associations between childhood asthma hospitalizations and nearby drilling and fracking activity. When they compared unexposed children to children in the top third of patients exposed to shale gas drilling, the research team found that, during the same calendar quarter a gas well was drilled, the odds of children and adolescents being hospitalized for asthma increased by 25 percent. If there was ever a well drilled within a zip code, the odds of these pediatric asthma-related hospitalizations increased by 19 percent. This finding demonstrates that the increased risk remains for years after wells are drilled.[98] This study is notable because it is the first to control for 180 pre-existing respiratory health risks. Researchers also considered specific air emissions from drilling and fracking sites. They found that increased levels of 2,2,4-trimethylpentane, carbon dioxide, formaldehyde, nitrous oxide, volatile organic compounds (VOCs), and x-hexane were associated with increased risks of pediatric asthma hospitalizations across age groups, as well as links for younger children to additional pollutants.

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[96] Ryan Collins and Rachel Adams-Heard, "`Death Highway' Is Where Oil Prices, Truck Fatalities Intersect," *Bloomberg.Com*, July 28, 2018, https://www.bloomberg.com/news/articles/2018-07-28/-death-highway-is-where-oil-prices-truck-fatalities-intersect.

[97] Joan A. Casey et al., "Associations of Unconventional Natural Gas Development with Depression Symptoms and Disordered Sleep in Pennsylvania," *Scientific Reports* 8, no. 1 (2018): 11375, https://doi.org/10.1038/s41598-018-29747-2.

[98] Mary D. Willis et al., "Unconventional Natural Gas Development and Pediatric Asthma Hospitalizations in Pennsylvania," *Environmental Research* 166 (2018): 402–8, https://doi.org/10.1016/j.envres.2018.06.022.

- May 21, 2018 – Using the most stringent classification within and across countries internationally, researchers examined reproductive toxicity among chemicals used in drilling and fracking operations for oil and gas. They found that 43 chemicals are classified as known or presumed human reproductive toxicants, while 31 others are suspected human reproductive toxicants. The team, which included Yale School of Medicine and School Public of Health researchers, further analyzed the 43 reproductive toxicants for their carcinogenic and mutagenic properties and found that seven reproductive toxicants doubled as carcinogens and mutagens. They are potassium dichromate, cadmium, benzene, ethylene oxide, nickel sulfate, N,N-dimethylformamide, and lead. Of these, benzene and lead are found in both fracking fluid and in fracking wastewater. Researchers noted that their study was limited to 157 chemicals previously identified as having evidence of reproductive toxicity, which is only a fraction of the more than 1000 chemicals identified as being present in fracking fluid, fracking wastewater, and fracking-related air emissions. They recommended that their framework be extended to all those chemicals.[99] (See also entry for January 6, 2016 in Water Contamination.)

- May 1, 2018 – In a laboratory study, prenatal exposure to fracking-related chemicals triggered immune problems in mice, especially females. All three immune system illnesses tested—a house dust mite-induced allergic disease, influenza A virus, and a disease similar to multiple sclerosis—were impaired in mice exposed in the womb to a mixture of fracking chemicals.[100] Using a chemical mixture "laced with chemicals at levels similar to those found in groundwater near fracking sites" and already demonstrated to have harmful developmental and reproductive effects, the researchers found sex-linked effects.[101] The exposed female mice showed more severe damage to their immune systems and ability to resist disease. In addition, the multiple scleroris-like disease, experimental autoimmune encephalomyelitis, developed earlier and more severely in female mice as compared to male mice. Authors concluded, "These observations suggest that developmental exposure to complex mixtures of water contaminants, such as those derived from [drilling and fracking] operations, could contribute to immune dysregulation and disease later in life."

- March 23, 2018 – Yale University public health scientists investigated possible connections between shale gas drilling and sexually transmitted diseases in Ohio. They found that, compared to counties with no shale gas activity, counties with high activity had 21 percent increased rates of chlamydia and 19 percent increased rates of

[99] Salmaan H. Inayat-Hussain et al., "Prioritization of Reproductive Toxicants in Unconventional Oil and Gas Operations Using a Multi-Country Regulatory Data-Driven Hazard Assessment," *Environment International* 117 (2018): 348–58, https://doi.org/10.1016/j.envint.2018.05.010.
[100] L. A. Boulé et al., "Developmental Exposure to a Mixture of 23 Chemicals Associated With Unconventional Oil and Gas Operations Alters the Immune System of Mice," *Toxicological Sciences* 163, no. 2 (2018): 639–54, https://doi.org/10.1093/toxsci/kfy066.
[101] Beth Adams, "Exposure to Chemicals Used in Fracking Impairs Immune System of Mice in URMC Study," *WXXI News*, May 1, 2018, https://www.wxxinews.org/post/exposure-chemicals-used-fracking-impairs-immune-system-mice-urmc-study.

gonorrhea.[102] They classified all 88 counties in the state as having none, low, and high shale gas activity in each year from 2000 through 2016, using Ohio Department of Natural Resources data. Their findings showed magnitude of effect for the association with gonorrhea that is similar to a prior analysis, adding strength to observed associations. Speaking to the *Columbus Dispatch*, the lead author noted, "Although there has been a decrease in new permits in recent years, [sexually transmitted infection] rates continue to climb because once a disease is introduced… it can be exchanged within the communities even after the workers leave."[103]

- March 20, 2018 – In the Texas Barnett Shale, women with homes within a half-mile radius of the most dense gas drilling activity or gas production activity at the time of their child's birth had, respectively, 20 percent and 15 percent higher risk of preterm birth, compared with women with no such activity near their residence. The greatest proximity-related risk was for extremely premature births (prior 28 weeks' gestation): mothers living near the densest drilling activity and the densest production activity were, respectively, 100 percent and 53 percent more likely to give birth to extremely premature babies.[104, 105] For purposes of this study, the drilling phase included drilling of the wellbore, installation of casing, and fracking, whereas the production phase, which can last for years, included the flowback of gas, condensate, and produced water, as well as possible on-site storage of these materials. Researchers noted that they did not have access to information that would have allowed more refined classification of phases. The study included 13,332 preterm birth cases and 66,933 term births in the 24-county Barnett Shale region between 2010 and 2012. The study also addressed trimester-specific differences in risk, finding little evidence for that factor. (See also entry for September 19, 2017.)

- March 13, 2018 – A research team found higher rates of hospitalizations for pneumonia among individuals ages 65 and older in Pennsylvania counties with drilling and fracking operations compared to those without. This result is consistent with other studies reporting links between respiratory problems and air pollution. This study, which used enhanced county-specific data from 2001 to 2013, expands on earlier research in its geographical reach and longer time horizon. The research team also found higher average hospitalization rates for other air pollution-sensitive diseases (acute myocardial infarction, chronic obstructive pulmonary disease, asthma, and upper respiratory infections) in counties containing unconventional natural gas wells than in those without

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[102] Nicole C. Deziel et al., "Shale Gas Activity and Increased Rates of Sexually Transmitted Infections in Ohio, 2000–2016," ed. Jaymie Meliker, *PLoS ONE* 13, no. 3 (2018): e0194203, https://doi.org/10.1371/journal.pone.0194203.
[103] Abbey Marshall, "Study Suggests Potential Link between Fracking Industry and Increased Sexually Transmitted Infections," *The Columbus Dispatch*, July 22, 2018, https://www.dispatch.com/news/20180722/study-suggests-potential-link-between-fracking-industry-and-increased-sexually-transmitted-infections.
[104] Kristina Walker Whitworth, Amanda Kaye Marshall, and Elaine Symanski, "Drilling and Production Activity Related to Unconventional Gas Development and Severity of Preterm Birth," *Environmental Health Perspectives* 126, no. 3 (2018): 037006, https://doi.org/10.1289/EHP2622.
[105] Lindsey Konkel, "Drilling into Critical Windows of Exposure: Trimester-Specific Associations between Gas Development and Preterm Birth," *Environmental Health Perspectives* 126, no. 10 (2018): 104002, https://doi.org/10.1289/EHP3762.

wells, but those links were not as strong statistically as for pneumonia among the elderly. Noting that their study design may actually underestimate the impact of natural gas development on pneumonia, the research team stated that their study "helps establish a consistent link between unconventional natural gas extraction and higher rates of disease."[106]

- February 7, 2018 – Female mice exposed to a mixture of 23 fracking chemicals during early life developed dose-specific abnormalities in their mammary glands. The researchers saw changes in tissue morphology, cell proliferation, "and the induction of unique intraductal hyperplasias."[107] (Intraductal hyperplasia is an overgrowth of cells that is considered a marker for future breast cancer risk.) Researchers used four doses; the lower two used were equivalent to concentrations found in drinking water in fracking regions and the highest dose represented concentrations that have been measured in industry wastewater. Mammary gland effects varied for each the doses, but all groups developed intraductal hyperplasia. According to a co-author, "This study shows that a mixture of [fracking] chemicals can affect the long-term health of the mouse mammary gland, even after low level exposures in the womb."[108]

- January 15, 2018 – A study of urban oil drilling in two Los Angeles neighborhoods found elevated asthma rates among residents living within 1,500 feet of oil wells. Researchers compared diagnosed asthma rates in these areas to a representative comparison area (the California Health Interview Survey's "SPA6" in South Los Angeles) and to Los Angeles County as a whole.[109] The diagnosed asthma rates in the two study areas were statistically significantly higher (16.1 percent and 23.6 percent) than the comparison area (9.8 percent). Asthma prevalence in one of the two study areas was significantly higher than that in Los Angeles County as a whole. Households with smokers were excluded from the analysis. This interdisciplinary team worked in partnership with the local residents to conduct this community-based survey with limited resources and urged further studies with more complex scientific design.

- December 13, 2017 – A team of health economists analyzed fracking's health impacts on infants. They examined birth certificates for all 1.1 million infants born in Pennsylvania between 2004 and 2013 and combined these data with maps showing when and where gas wells were drilled in the state. Their results indicated that the introduction of fracking "reduces health among infants born to mothers living within 3 km (1.9 miles) of a well site during pregnancy." For mothers living within one kilometer (.6 miles), they found a

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[106] Lizhong Peng, Chad Meyerhoefer, and Shin-Yi Chou, "The Health Implications of Unconventional Natural Gas Development in Pennsylvania," *Health Economics* 27, no. 6 (2018): 956–83, https://doi.org/10.1002/hec.3649.
[107] Sarah A Sapouckey et al., "Prenatal Exposure to Unconventional Oil and Gas Operation Chemical Mixtures Altered Mammary Gland Development in Adult Female Mice," *Endocrinology* 159, no. 3 (2018): 1277–89, https://doi.org/10.1210/en.2017-00866.
[108] University of Massachusettsat Amherst, "Changes in Mouse Breast Tissue after Exposure to Fracking Chemicals: UMass Amherst, University of Missouri Led First Study of Such Effects," *ScienceDaily*, February 7, 2018, https://www.sciencedaily.com/releases/2018/02/180207090108.htm.
[109] Bhavna Shamasunder et al., "Community-Based Health and Exposure Study around Urban Oil Developments in South Los Angeles," *International Journal of Environmental Research and Public Health* 15, no. 1 (2018): 138, https://doi.org/10.3390/ijerph15010138.

25 percent increase in the probability of low birth weight, "significant declines" in average birth weight, as well as declines in other measures of infant health. They also observed reductions in infant health when mothers lived within one to three kilometers of a fracking site; these were about one-third to one-half of the declines of those mothers living closer.[110] The researchers estimated that "about 29,000 out of the nearly 4 million U.S. births (0.7 percent) annually occur within 1 kilometer of a fracking site and 95,500 are born within 3 kilometers." "For policymakers weighing the costs and benefits of fracking before deciding whether to allow it in their communities, this study provides a clear cost: an increase in the probability of poorer health for babies born near these sites."[111]

- November 6, 2017 – As part of a pilot project, a team of Montreal-based public health researchers evaluated exposure of pregnant mothers to VOCs in an area of intensive fracking in northeastern British Columbia. At least 28,000 unconventional natural gas wells had been drilled to date in the Peace River Valley. Analyzing the urine of 29 pregnant women, researchers found high concentrations of muconic acid, which is a degradation product of benzene, a widely studied developmental toxicant and an air contaminant in the vicinity of gas wells. The median concentration of this chemical was approximately 3.5 times higher in the study group than in the general Canadian population. In five of the 29 women, the concentration of muconic acid exceeded an exposure index by the American Conference of Governmental Industrial Hygienists that was designed for workplace settings. (No guidelines for the public exist.) By design, this small pilot study sets the groundwork for more extensive biomonitoring and environmental analysis.[112]

- September 19, 2017 – University of Texas Health Science Center researchers conducted a case-control study nested within their larger cohort of women with single births (see entry for July 21, 2017, below) in the 24-county Barnett Shale between November 30, 2010 and November 29, 2012. Its specific purpose was to consider timing of unconventional gas development activity "during potentially sensitive windows of exposure," as well as "potential differences in risk by UGD drilling phase," with regard to preterm births. Results suggest a link between maternal residential proximity to UGD-activity and preterm births, which were similar by drilling phase and "slightly stronger in the first two trimesters of pregnancy."[113]

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[110] Janet Currie, Michael Greenstone, and Katherine Meckel, "Hydraulic Fracturing and Infant Health: New Evidence from Pennsylvania," *Science Advances* 3, no. 12 (2017): e1603021, https://doi.org/10.1126/sciadv.1603021.
[111] Janet Currie, Michael Greenstone, and Katherine Meckel, "Hydraulic Fracturing and Infant Health: New Evidence from Pennsylvania," Research Summary (Energy Policy Institute at the University of Chicago, 2017), https://epic.uchicago.edu/wp-content/uploads/2019/07/Research-Summary-5.pdf.
[112] Élyse Caron-Beaudoin et al., "Gestational Exposure to Volatile Organic Compounds (VOCs) in Northeastern British Columbia, Canada: A Pilot Study," *Environment International* 110 (2018), https://doi.org/10.1016/j.envint.2017.10.022.
[113] Amanda Marshall, Elaine Symanski, and Kristina Whitworth, "The Association Between Unconventional Gas Development and Preterm Birth: Evaluating Drilling Phases and Critical Windows of Susceptibility," *Annals of Epidemiology* 27, no. 8 (2017): 530.

- September 14, 2017 – Researchers reviewed health assessments taken between February 2012 and October 2015 of adults in Pennsylvania communities with intense unconventional natural gas development (UNGD). The most frequently reported symptoms were sleep disturbance, headache, throat irritation, stress/anxiety, cough, shortness of breath, sinus problems, fatigue, wheezing, nausea, each occurring in over 20 percent of the sample. Over 43 percent of the sample reported sleep disturbance. To meet the inclusion criteria, as developed and implemented by a physician and nurse practitioner, the symptoms were reviewed to ensure no plausible cause relating to "past medical and surgical history, concurrent medical conditions, family and social history, and environmental exposures unrelated to UNGD. For example, if the social history indicated a ½ pack/day smoking history, the symptom of 'difficulty breathing' was not included." Independently, the timing of the exposure for each symptom that met the inclusion criteria was determined, using the beginning drilling date for each unconventional natural gas well within one kilometer (.6 miles) of the patient's residence; records were excluded if it was not possible to verify at least one gas well within this distance.[114]

- August 21, 2017 – Using county-level data from 2003 to 2013, researchers found that, all together, counties in the Marcellus Shale region that experienced a boom in hydraulic fracturing showed a 20 percent increase in the incidence rate of gonorrhea.[115]

- July 21, 2017 – A University of Texas Health Science Center School of Public Health team assessed the links between the residential proximity of pregnant mothers to unconventional natural gas development activity and various newborn health problems: preterm birth, small-for-gestational age (SGA), fetal death, and low birth weight. They found evidence of a "moderate positive association" between residential proximity to UGD-activity and increased odds of preterm birth, and a "suggestive association" with fetal death. Nearly 159,000 births and fetal deaths from November 30, 2010 to November 29, 2012 in the 24-county Barnett Shale area were considered.[116]

- February 15, 2017 – A study from the University of Colorado School of Public Health and Anschutz Medical Campus showed that children and young adults between the ages of 5 and 24 with acute lymphocytic leukemia (ALL) were 4.3 times more likely to live in area dense with active oil and gas wells. The researchers did not find such a link with ALL cases in 0-4 year olds, or with incidence of non-Hodgkin lymphoma. The study focused on rural areas and towns in 57 Colorado counties and did not include cities of more than 50,000 people. Authors wrote, "Because oil and gas development has potential

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[114] Beth Weinberger et al., "Health Symptoms in Residents Living near Shale Gas Activity: A Retrospective Record Review from the Environmental Health Project," *Preventive Medicine Reports* 8 (2017): 112–15, https://doi.org/10.1016/j.pmedr.2017.09.002.
[115] Tim Komarek and Attila Cseh, "Fracking and Public Health: Evidence from Gonorrhea Incidence in the Marcellus Shale Region," *Journal of Public Health Policy* 38, no. 4 (2017): 464–81, https://doi.org/10.1057/s41271-017-0089-5.
[116] Kristina W. Whitworth, Amanda K. Marshall, and Elaine Symanski, "Maternal Residential Proximity to Unconventional Gas Development and Perinatal Outcomes among a Diverse Urban Population in Texas," ed. Jaymie Meliker, *PLoS ONE* 12, no. 7 (2017): e0180966, https://doi.org/10.1371/journal.pone.0180966.

to expose a large population to known hematologic carcinogens, such as benzene, further study is clearly needed to substantiate both our positive and negative findings."[117]

- October 26, 2016 – A study that investigated possible links between fracking and cancer incidence in southwest Pennsylvania found elevated rates of bladder and thyroid cancers in six counties with shale gas activity.[118] Bladder cancer was elevated in both males and females, with a 10 percent increase in the number of observed cases from 2000 to 2012. Over the same time period, thyroid cancer jumped even more dramatically. "There was a huge 91.2% increase in the number of observed cases from 2000 to 2012." Patterns of leukemia incidence were less clearly related to shale gas activity. The author expressed caution in attributing these trends solely to shale gas development due to "the multiple sources of potentially toxic, harmful exposures in southwest Pennsylvania, many dating back decades," the long latency time required for many cancers to develop, and possible synergisms between exposures from shale gas development and past toxic exposures.

- August 25, 2016 – Researchers found that Pennsylvanians residing near intensive unconventional gas well activity were significantly more likely to experience chronic rhino sinusitis (at least three months of nasal and sinus symptoms), migraine headaches, and higher levels of fatigue than residents who do not live near such activity.[119] Data were gathered from nearly 8,000 patients of Geisinger Health System from 40 counties in north and central Pennsylvania, and matched with the proximity of respondents to all phases of gas drilling activity and intensity, using information from the Pennsylvania Departments of Environmental Protection (PA DEP) and Conservation and Natural Resources, as well as satellite imagery. According to lead author Aaron W. Tustin, MD, MPH, resident physician in the Department of Environmental Health Sciences at the Johns Hopkins Bloomberg School of Public Health, "[t]hese three health conditions can have debilitating impacts on people's lives… In addition, they cost the health care system a lot of money."[120]

- July 18, 2016 – Living near fracking operations significantly increases asthma attacks, according to a Johns Hopkins University study of 35,000 medical records of people with asthma in north and central Pennsylvania, from 2005 to 2012.[121] The data show that those who live near a higher number of, or larger, active gas wells were 1.5 to 4 times more likely to suffer from asthma attacks compared to those who live farther away, with the

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[117] Lisa M. McKenzie et al., "Childhood Hematologic Cancer and Residential Proximity to Oil and Gas Development," ed. Jaymie Meliker, *PLoS ONE* 12, no. 2 (2017): e0170423, https://doi.org/10.1371/journal.pone.0170423.
[118] M.L. Finkel, "Shale Gas Development and Cancer Incidence in Southwest Pennsylvania," *Public Health* 141 (2016): 198–206, https://doi.org/10.1016/j.puhe.2016.09.008.
[119] Aaron W. Tustin et al., "Associations between Unconventional Natural Gas Development and Nasal and Sinus, Migraine Headache, and Fatigue Symptoms in Pennsylvania," *Environmental Health Perspectives* 125, no. 2 (2017): 189–97, https://doi.org/10.1289/EHP281.
[120] Susan Phillips, "New Study Links Gas Drilling to Migraines, Fatigue and Chronic Sinus Symptoms," *State Impact Pennsylvania*, August 25, 2016, https://stateimpact.npr.org/pennsylvania/2016/08/25/new-study-points-to-association-between-gas-drilling-to-migraines-fatigue-and-chronic-sinus-symptoms/.
[121] Sara G. Rasmussen et al., "Association Between Unconventional Natural Gas Development in the Marcellus Shale and Asthma Exacerbations," *JAMA Internal Medicine* 176, no. 9 (2016): 1334, https://doi.org/10.1001/jamainternmed.2016.2436.

closest group having the highest risk. There was increased risk in all three types of exacerbations defined: mild (new oral corticosteroid medication order), moderate (emergency department encounter), or severe (hospitalization). In addition, researchers identified increased risk during all four phases of well development: pad preparation, drilling, stimulation (fracking), and production. The study was praised for its "rigorous research methods," by a scientist not part of the team.[122]

- July 5, 2016 – Researchers from five universities and the U.S. Geological Survey (USGS) identified a link between exposure to fracking and drilling chemicals and adverse reproductive and developmental outcomes in laboratory mice. The study used 23 oil and gas chemicals in four different concentrations, representing concentrations found in drinking water and groundwater, to higher concentrations found in oil and gas industry wastewater. Offspring of pregnant laboratory mice consuming these mixtures were compared to those that did not. Results suggested "numerous potential threats to fertility and reproductive success … including altered pituitary hormone levels, reproductive organ weights, and disrupted ovarian follicle development." Researchers observed these negative outcomes even in the offspring exposed to the lowest dose of chemicals. Building on previous research showing reduced sperm counts in male offspring, they also reported on "tentative mechanistic information for the observed adverse health effects."[123]

- February 9, 2016 – An exploratory study of hospitalization rates for three study areas in Queensland, Australia showed rates for specific types of hospital admissions increased more quickly in a coal seam gas study area than in other study areas (a coal mining area and a rural/agricultural area). Coal seam gas is the methane trapped in pores and fractures in underground coal deposits; its exploitation is a form of unconventional natural gas development. A portion of coal seam gas extraction uses fracking. This preliminary study found the strongest link between increased hospitalization rates over time in a coal seam gas area to be for the category of 'Blood/immune' diseases.[124]

- October 14, 2015 – Using an animal model, an interdisciplinary research team measured the endocrine-disrupting activities of 24 chemicals used and/or produced by oil and gas operations, finding that 23 of them "can activate or inhibit the estrogen, androgen, glucocorticoid, progesterone, and/or thyroid receptors, and mixtures of these chemicals can behave synergistically, additively, or antagonistically." Further, the researchers tested prenatal exposures to the chemicals and found effects on multiple organs, including

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[122] Nicholas Kusnetz, "Increased Asthma Attacks Tied to Exposure to Natural Gas Production," *Inside Climate News*, July 18, 2016, https://insideclimatenews.org/news/18072016/asthma-study-marcellus-shale-pennsylvania-natural-gas-fracking/.

[123] Christopher D. Kassotis et al., "Adverse Reproductive and Developmental Health Outcomes Following Prenatal Exposure to a Hydraulic Fracturing Chemical Mixture in Female C57Bl/6 Mice," *Endocrinology* 157, no. 9 (2016): 3469–81, https://doi.org/10.1210/en.2016-1242.

[124] Angela K. Werner et al., "All-Age Hospitalization Rates in Coal Seam Gas Areas in Queensland, Australia, 1995–2011," *BMC Public Health* 16, no. 1 (2015): 125, https://doi.org/10.1186/s12889-016-2787-5.

adverse reproductive effects on the matured offspring.[125] This study is the first to demonstrate that endocrine-disrupting chemicals, which are commonly used in fracking operations, can harm the reproductive health of mice, at levels of exposure that are realistic for humans. The study's senior author told *ScienceDaily,* "In addition to reduced sperm counts, the male mice exposed to the mixture of chemicals had elevated levels of testosterone in their blood and larger testicles. These findings may have implications for the fertility of men living in regions with dense oil and/or natural gas production."[126]

- October 8, 2015 – Pregnant women who live near active fracking operations in Pennsylvania were at a 40 percent increased risk of giving birth prematurely and at a 30 percent increased risk for having obstetrician-labeled high-risk pregnancies, according to a study by Johns Hopkins Bloomberg School of Public Health and other researchers. High-risk pregnancies were those that included hypertension, high pre-pregnancy body mass index, and asthma. The study used data from the Geisinger Health System on 9,384 pregnant women and their 10,496 newborns between January 2009 and January 2013; Geisinger covers 40 counties in north and central Pennsylvania. Researchers developed an index for proximity to fracking wells based on distance from the women's homes, stage of drilling and depth of wells dug, and the amount of gas that was produced at those wells during the pregnancies. The highest-activity quartile had the highest rates of premature births and high-risk pregnancies.[127, 128]

- July 22, 2015 – Using a mammal model, New York University School of Medicine scientists, together with other U.S. and Chinese researchers, demonstrated cancerous changes linked to exposure to wastewater from Marcellus fracking operations. Their study also documented elevated levels of barium and strontium in exposed animal cells. The wastewater studied originated in Pennsylvania and was stored for a time to allow radioactivity and levels of short-lived VOCs to decline. The results suggest that "even aged flow back water could pose substantial health threats to exposed humans."[129]

- July 15, 2015 – A study by University of Pennsylvania and Columbia University researchers found that drilling and fracking activity was associated with increased rates of hospitalization in Pennsylvania. During a period of dramatic increase in drilling and fracking activity between 2007 and 2011, inpatient prevalence rates surged for people living near shale gas wells. Cardiology inpatient prevalence rates were significantly associated with number of wells per zip code and their density, while neurology inpatient

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[125] Christopher D. Kassotis et al., "Endocrine-Disrupting Activity of Hydraulic Fracturing Chemicals and Adverse Health Outcomes After Prenatal Exposure in Male Mice," *Endocrinology* 156, no. 12 (2015): 4458–73, https://doi.org/10.1210/en.2015-1375.
[126] Endocrine Society, "Fracking Chemicals Tied to Reduced Sperm Count in Mice," *ScienceDaily*, October 14, 2015, https://www.sciencedaily.com/releases/2015/10/151014134533.htm.
[127] Joan A. Casey et al., "Unconventional Natural Gas Development and Birth Outcomes in Pennsylvania, USA," *Epidemiology* 27, no. 2 (2015): 163–72, https://doi.org/10.1097/EDE.0000000000000387.
[128] Johns Hopkins Bloomberg School of Public Health, "Study: Fracking Industry Wells Associated With Premature Birth," October 8, 2015, https://publichealth.jhu.edu/2015/study-fracking-industry-wells-associated-with-premature-birth.
[129] Yixin Yao et al., "Malignant Human Cell Transformation of Marcellus Shale Gas Drilling Flow Back Water," *Toxicology and Applied Pharmacology* 288, no. 1 (2015): 121–30, https://doi.org/10.1016/j.taap.2015.07.011.

prevalence rates were significantly associated with density of wells. Hospitalizations for cancer, skin conditions, and urological problems also rose significantly. During the same time period, no such increase in health problems was observed in a control Pennsylvania county without any drilling and fracking activity. In communities with the most wells, the rate of cardiology hospitalizations was 27 percent higher than in control communities with no fracking. "While the clinical significance of the association remains to be shown, [fracking] has just begun in Pennsylvania, and thus observing a significant association over this short time is striking.… Our study also supports the concept that health care utilization should be factored into the value (costs and benefits) of hydraulic fracturing over time."[130] In a related *Newsweek* story, lead researcher Reynold Panettieri, Jr. said, "At this point, we suspect that residents are exposed to many toxicants, noise and social stressors due to hydraulic fracturing near their homes and this may add to the increased number of hospitalizations."[131]

- July 9, 2015 – As part of a scientific assessment of well stimulation treatments, including fracking, the California Council on Science and Technology studied the potential impacts of well stimulation on human health in California. The risk factors directly attributable to well stimulation stem largely from the use of a very large number and quantity of stimulation chemicals. The unknown number and toxicity of chemicals that are mixed together in well stimulation fluids made it difficult to fully quantify risk to the environment and to human health, but the study highlighted the potential health risks from exposure to fracking-related air pollution for the people of Los Angeles, 1.7 million of whom live or work within one mile of an active oil or gas well.[132] Jane Long, co-author, said, "officials should fully understand the toxicity and environmental profiles of all chemicals before allowing them to be used in California's oil operations," according to the *Los Angeles Times*.[133]

- June 22, 2015 – A longtime midwife reported her personal analysis of an ongoing spike in infant deaths, miscarriages, and placental abnormalities in Utah's Uintah Basin that has followed the advent of drilling and fracking activity there and appears linked to air pollution episodes.[134]

- June 3, 2015 – A University of Pittsburgh study linked fracking to low birthweight in three heavily drilled Pennsylvania counties. The more exposure a pregnant woman had to gas wells, the higher her risk for a smaller-than-normal baby. Exposure was determined as proximity and density of wells in relation to the residence of the pregnant woman. Compared to mothers whose homes had the fewest surrounding gas wells, mothers whose

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[130] Thomas Jemielita et al., "Unconventional Gas and Oil Drilling Is Associated with Increased Hospital Utilization Rates," ed. Jaymie Meliker, *PLoS ONE* 10, no. 7 (2015): e0131093, https://doi.org/10.1371/journal.pone.0131093.
[131] Zoë Schlanger, "Living Near Fracking Wells Linked to Increased Hospitalization Rates," Newsweek, July 15, 2015, https://www.newsweek.com/living-near-fracking-wells-linked-increased-hospitalization-rates-354093.
[132] Shonkoff et al., "Chapter 6: Potential Impacts of Well Stimulation on Human Health in California."
[133] Julie Cart, "Water and Wildlife May Be at Risk from Fracking's Toxic Chemicals, Panel Finds," *Los Angeles Times*, July 10, 2015, sec. California, https://www.latimes.com/local/lanow/la-me-california-science-panel-warns-that-fracking-poses-unknown-risk-20150709-story.html.
[134] Paul Solotaroff, "What's Killing the Babies of Vernal, Utah?," *Rolling Stone*, June 22, 2015, https://www.rollingstone.com/culture/culture-news/whats-killing-the-babies-of-vernal-utah-33666/.

homes were nearest to a high density of wells were 34 percent more likely to have babies who were "small for gestational age," meaning they weighed significantly less than expected for the number of weeks of pregnancy. Although the study did not investigate mechanisms, researchers identified air as the likely route of exposure. They supported this argument by referencing another study done in Western Pennsylvania where airborne particulate pollution correlated with low birth weight and by noting that particulates are established shale gas infrastructure emissions.[135, 136] Low birth weight is a leading cause of infant mortality.

- March 3, 2015 – A follow-up study of 21 case studies from five states found that the distribution of symptoms in animals and humans affected by nearby fracking operations was, since 2012, unchanged for humans and companion animals. In food animals, reproductive problems decreased over time while respiratory problems and growth problems increased. "This longitudinal case study illustrates the importance of obtaining detailed epidemiological data on the long-term health effects of multiple chemical exposures and multiple routes of exposure that are characteristic of the environmental impacts of unconventional drilling operations."[137]

- March 3, 2015 – A cross-sectional study by Yale University School of Medicine researchers using companion animals as sentinels of human exposure to fracking-related chemicals investigated possible associations between reported health conditions of companion and backyard animals in Southwest Pennsylvania and household proximity to drilling and fracking operations. Among dogs living in households located less than one kilometer from a gas well, risks for health problems were elevated, especially for dermal conditions, compared to animals living more than two kilometers from a well.[138]

- January 1, 2015 – A Yale-led team studied the relationship between household proximity to drilling and fracking operations and reported health symptoms in Washington County, Pennsylvania where 624 gas wells were in active operation, most of which had been drilled in the past five to six years. Researchers found that health symptoms reported by residents increased in frequency as distance between household and gas wells decreased. Among persons living less than one kilometer from drilling and fracking operations, rashes and upper respiratory problems were more prevalent. The authors of this study, the largest to date on the link between reported symptoms and natural gas drilling activities, say that their findings are "… consistent with earlier reports of respiratory and dermal conditions in persons living near natural gas wells." They also cite literature

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[135] Shaina L. Stacy et al., "Perinatal Outcomes and Unconventional Natural Gas Operations in Southwest Pennsylvania," ed. Jaymie Meliker, *PLoS ONE* 10, no. 6 (2015): e0126425, https://doi.org/10.1371/journal.pone.0126425.
[136] Robert Preidt, "'Fracking' Linked to Low Birth Weight Babies," WebMD, accessed September 17, 2021, https://www.webmd.com/baby/news/20150603/fracking-linked-to-low-birth-weight-babies.
[137] Michelle Bamberger and Robert E. Oswald, "Long-Term Impacts of Unconventional Drilling Operations on Human and Animal Health," *Journal of Environmental Science and Health, Part A* 50, no. 5 (2015): 447–59, https://doi.org/10.1080/10934529.2015.992655.
[138] I. B. Slizovskiy et al., "Reported Health Conditions in Animals Residing near Natural Gas Wells in Southwestern Pennsylvania," *Journal of Environmental Science and Health, Part A* 50, no. 5 (2015): 473–81, https://doi.org/10.1080/10934529.2015.992666.

demonstrating the biological plausibility of a link between oil and gas extraction activities and both categories of health effects reported.[139]

- December 17, 2014 – As part of a lengthy review that became the foundation for New York State's ban on high volume hydraulic fracturing, the New York State Department of Health (NYS DOH) identified environmental problems associated with fracking that could contribute to adverse public health impacts. Among them: air pollution (particulate matter, ozone, diesel exhaust, and VOCs) that could affect respiratory health; drinking water contamination from underground migration of methane and/or fracking chemicals associated with faulty well construction or seismic activity; drinking water contamination from inadequate water treatment of fracking waste or from surface spills of fracking chemicals or wastewater; earthquakes and the creation of fissures; increased vehicle traffic; increased noise; increased demand for housing and medical care; and public health problems related to climate change impacts from methane and other greenhouse gas emissions into the atmosphere. The NYS DOH Public Health Review also discussed findings from surveys of health symptoms among residents living near high volume hydraulic fracturing activities. These included skin rash, nausea or vomiting, abdominal pain, breathing difficulties, cough, nosebleed, anxiety, stress, headache, dizziness, eye irritation, and throat irritation in populations living near drilling and fracking operations. The NYS DOH Public Health Review noted that ongoing studies by both government agencies and several academic institutions were exploring the public health risks and impacts of fracking but that many of these studies were years from completion. The review concludes:

  > … significant gaps exist in the knowledge of potential public health impacts from [high volume hydraulic fracturing]…. The existing science investigating associations between [high volume hydraulic fracturing] activities and observable adverse health outcomes is very sparse and the studies that have been published have significant scientific limitations. Nevertheless, studies are suggestive of potential public health risks related to [high volume hydraulic fracturing] activity that warrant further careful evaluation.

  In an accompanying letter to the New York State Department of Environmental Conservation, Health Commissioner Howard Zucker, MD, concluded,

  > … the overall weight of the evidence from the cumulative body of information contained in this Public Health Review demonstrates that there are significant uncertainties about the kinds of adverse health outcomes that may be associated with [high volume hydraulic fracturing], the likelihood of the occurrence of adverse health outcomes and the effectiveness of some of the mitigation measures in reducing or preventing environmental impacts which could adversely affect public health. Until the science provides sufficient information to determine the level of risk to public health from [fracking] to all New Yorkers and whether the

[139] Peter M. Rabinowitz et al., "Proximity to Natural Gas Wells and Reported Health Status: Results of a Household Survey in Washington County, Pennsylvania," *Environmental Health Perspectives* 123, no. 1 (2015): 21–26, https://doi.org/10.1289/ehp.1307732.

risks can be adequately managed, DOH recommends that high volume hydraulic fracturing should not proceed in NYS.[140]

- October 13, 2014 – According to the North Dakota Health Department, the number of HIV and AIDS cases in North Dakota more than doubled between 2012 and 2014, and cases were shifting to the state's western oil fields, where 35-40 percent of all new cases occurred. Previously, only 10 percent of cases were in that region.[141] This trend followed on the heels of an upsurge in sexually transmitted chlamydia cases in the same region. The North Dakota state director of disease control, Kirby Kruger, attributed the uptick in HIV cases to the drilling and fracking industry and attempted to spread HIV prevention messages at the "man camps" that house young male workers in the oil industry.[142] Human trafficking for purposes of prostitution accompanied the fracking boom, but there was a shortage of medical professionals to address this public health crisis, according to Kruger, who noted that it was difficult to hire nurses and medical staff who could live in the area on a public health wage.

- October 2, 2014 – According to researchers from the University of Pennsylvania's Center of Excellence in Environmental Toxicology, an increasing number of gas wells in Pennsylvania is significantly correlated with inpatient rates of hospitalization. The research team collected data from seven different insurance providers for three counties; the study's publication is forthcoming.[143]

- September 11, 2014 – In Texas, commercial vehicle accidents have increased more than 50 percent since 2009 when the state's ongoing drilling and fracking boom began, according to an investigation by the *Houston Chronicle* and Houston Public Media News 88.7. "For six decades, highway deaths have dropped steadily all across the United States…. But in Texas all motor vehicle fatalities – and accidents involving commercial trucks – have turned back upward since the state's oil drilling and fracking boom began in 2008." This rising motor vehicle death toll is especially felt in formerly rural counties in the Eagle Ford and Permian Basin, now places of heavy drilling and fracking. A new Department of Public Safety "Road Check" program finds annually, "27 to 30 percent of Texas' commercial trucks shouldn't be operating at all due to potentially life-threatening

[140] New York State Department of Health, "A Public Health Review of High Volume Hydraulic Fracturing for Shale Gas Development," December 17, 2014, http://www.health.ny.gov/press/reports/docs/high_volume_hydraulic_fracturing.pdf.
[141] Associated Press, "North Dakota HIV/AIDS Rate Rises with Population Growth," *The Billings Gazette*, October 13, 2014, https://billingsgazette.com/news/state-and-regional/montana/north-dakota-hiv-aids-rate-rises-with-population-growth/article_a939fed6-f737-5cfb-957f-ab800673f4d7.html.
[142] Andy Birkey, "Around the Region: HIV Rates Skyrocket in North Dakota," *The Column*, October 6, 2014, http://thecolu.mn/13773/around-region-hiv-rates-skyrocket-north-dakota.
[143] Elizabeth Skrapits, "Study: More Gas Wells in Area Leads to More Hospitalizations," *Wilkes-Barre Citizens' Voice*, accessed September 17, 2021, https://www.citizensvoice.com/news/study-more-gas-wells-in-area-leads-to-more-hospitalizations/article_31eec203-76fc-5b9e-9a8a-f4a552bdd4f6.html.

safety problems like defective brakes, bald tires, inoperable safety lights and unqualified, unfit or intoxicated drivers."[144, 145]

- August 3, 2014 – Hospitals in the Bakken Shale region reported a sharp rise in ambulance calls and emergency room visits after 2006. "Mercy Medical Center in Williston and the Tioga Medical Center in neighboring Williams County saw their ambulance runs increase by more than 200 percent. Tioga's hospital saw a staggering leap in trauma patients by 1,125 percent. Mercy had a 373 percent increase." Drugs (including overdoses of prescription drugs, methamphetamine, and heroin) explain many of the cases, with oilfield related injuries such as "fingers crushed or cut off, extremity injuries, burns and pressure burns" accounting for 50 percent of the cases in one of the region's hospital emergency rooms.[146]

- May 21, 2014 – Raising questions about possible links to worsening air pollution from the Uintah Basin's 11,200 oil and gas wells, health professionals reported that infant deaths in Vernal, Utah, rose to six times the normal rate over the past three years. Physician Brian Moench said, "We know that pregnant women who breathe more air pollution have much higher rates of virtually every adverse pregnancy outcome that exists…. And we know that this particular town is the center of an oil and gas boom that's been going on for the past five or six years and has uniquely high particulate matter and high ozone."[147] Although it formerly had pristine air quality, Uintah County, Utah received a grade "F" for ozone in the American Lung Association's 2013 State of the Air Report.[148]

- January 28, 2014 – Congenital heart defects, and possibly neural tube defects in newborns, were associated with the density and proximity of natural gas wells within a 10-mile radius of mothers' residences in a study of almost 25,000 births from 1996 to 2009 in rural Colorado. The researchers note that natural gas development emits several chemicals known to increase risk of birth defects (teratogens).[149]

- January 4, 2014 – Preliminary data from researchers at Princeton University, Columbia University, and MIT showed elevated rates of low birthweight among infants born to mothers living near drilling and fracking operations during their pregnancies.[150]

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[144] Lise Olsen, "Fatal Truck Accidents Have Spiked during Texas' Ongoing Fracking and Drilling Boom," *Houston Chronicle*, September 11, 2014, sec. News, https://www.houstonchronicle.com/news/article/Fracking-and-hydraulic-drilling-have-brought-a-5747432.php.
[145] Andrew Schneider, "In Texas, Traffic Deaths Climb Amid Fracking Boom," *NPR*, October 12, 2014, sec. National, https://www.npr.org/2014/10/02/352980756/in-texas-traffic-deaths-climb-amid-fracking-boom.
[146] K. J. Bryan, "Drugs, Oilfield Work, Traffic Pushing More People through Doors of Watford City ER," *Bakken Today*, August 3, 2014, http://www.bakkentoday.com/event/article/id/37101/.
[147] Zoë Schlanger, "In Utah Boom Town, a Spike in Infant Deaths Raises Questions," *Newsweek*, May 21, 2014, https://www.newsweek.com/2014/05/30/utah-boom-town-spike-infant-deaths-raises-questions-251605.html.
[148] American Lung Association, "American Lung Association State of the Air 2013," 2013.
[149] Lisa M. McKenzie et al., "Birth Outcomes and Maternal Residential Proximity to Natural Gas Development in Rural Colorado," *Environmental Health Perspectives* 122, no. 4 (2014): 412–17, https://doi.org/10.1289/ehp.1306722.
[150] Mark Whitehouse, "Study Shows Fracking Is Bad for Babies," *Bloomberg*, January 4, 2014, https://www.bloomberg.com/opinion/articles/2014-01-04/study-shows-fracking-is-bad-for-babies.

- August 26, 2013 – Medical experts at a rural clinic in heavily-drilled Washington County, Pennsylvania reported case studies of 20 individuals with acute symptoms consistent with exposure to air contaminants known to be emitted from local fracking operations.[151, 152]

- May 2, 2013 – A community-based participatory research study in Pennsylvania tested air and water quality and surveyed self-reported health symptoms of more than 100 residents living near drilling and fracking operations. The team detected a total of 19 VOCs in ambient air sampled outside of homes. The reported health symptoms closely matched the established effects of chemicals detected through air and water testing at those nearby sites. Moreover, those symptoms occurred at significantly higher rates in households closer to the gas facilities than those farther away.[153] Indicative of the growing prevalence of such health impacts in the state, a poll showed that two-thirds of Pennsylvanians support a moratorium on fracking because of concern about negative health impacts.[154]

[151] Lindsay Abrams, "Fracking's Real Health Risk May Be from Air Pollution," *Salon*, August 26, 2013, sec. News, https://www.salon.com/2013/08/26/frackings_real_health_risk_may_be_from_air_pollution/.
[152] Larysa Dyrszka, Kathleen Nolan, and Sandra Steingraber, "Statement on Preliminary Findings from the Southwest Pennsylvania Environmental Health Project Study," Press Release (Concerned Health Professionals of NY, August 27, 2013), https://concernedhealthny.org/2013/08/statement-on-preliminary-findings-from-the-southwest-pennsylvania-environmental-health-project-study/.
[153] Nadia Steinzor, Wilma Subra, and Lisa Sumi, "Investigating Links between Shale Gas Development and Health Impacts through a Community Survey Project in Pennsylvania," *New Solutions: A Journal of Environmental and Occupational Health Policy* 23, no. 1 (2013): 55–83, https://doi.org/10.2190/NS.23.1.e.
[154] Susan Phillips, "Poll Shows Support for a Drilling Moratorium in Pennsylvania," *State Impact Pennsylvania*, May 14, 2013, https://stateimpact.npr.org/pennsylvania/2013/05/14/poll-shows-support-for-a-drilling-moratorium-in-pennsylvania/.