The Health Impact of Shale Gas Development on Birthing People and Their Infants: A Critical Literature Synthesis

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Abstract

Shale gas development (SGD) has boomed over the past few decades, often operating near residential communities. The process and emissions from SGD contain toxicants like volatile organic compounds and naturally occurring radioactive material. Some of these toxicants can cause adverse health effects if someone has been exposed to a significant dosage. The health effects of the emitted harmful compounds are known, but the evidence of their connections to SGD is still limited. Epidemiological studies have linked SGD to cancer, endocrine disruption, and respiratory symptoms. It is pertinent that the health impacts to birthing people and their infants be understood as they are particularly vulnerable to chemical toxicity. Fetal development is a sensitive period. Infants that were exposed to toxic chemicals in the womb can experience developmental abnormalities or poor birth outcomes, like premature birth. Poor birth outcomes can lead to other health problems in childhood. Understanding what health risks there are from SGD for birthing people and their infants is of public health importance. In this critical literature synthesis, 14 articles sourced from PubMed were reviewed to assess birth outcomes associated with SGD for birthing people and infants. The results suggest there could be some evidence, but there is not consensus of any health association. In articles that found positive associations of a health condition to SGD, the association was stronger the closer the residence was to SGD.

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1.0 Introduction

Shale gas development (SGD) has grown over the past several decades supplying the United States, Canada, and other countries as a source of energy and heating. With this boom, 17.6 million people in the US live within one mile of a fracking oil or gas well.[1] SGD emits naturally occurring radioactive material (NORMs) and volatile organic compounds (VOCs) that have been linked to adverse health conditions.[2, 3] NORMs and VOCs have the potential to cause cancer and harm the respiratory and endocrine systems.[4, 5] These health impacts could pose more harm to vulnerable populations, such as birthing people and their infants, because during pregnancy there is specific periods of development for each body part. This specified growth is called the critical period of development for whenever a body part is expected to grow.[6] The birthing person's health and exposures impact the fetus, which can put the infant at risk for being born with health conditions. The fetus is small, so any exposure to a toxicant the birthing person experience will be proportionately higher for the fetus.[7]

This critical literature synthesis will provide a brief background to the process of shale gas development, operations and restrictions of SGD, and the chemicals emitted from SGD that are associated with adverse health effects. This will provide context to what SGD is and how it may impact the health conditions of birthing people and their infants. Next, the literature synthesis will survey the existing published, peer reviewed literature about SGD and health conditions experienced by birthing people and their infants. The goal is to understand what health conditions birthing people and child may experience living near SGD.

2.0 Background

This section briefly describes the process of SGD, introduces states and countries that do SGD or restrict it, and reviews the chemical compounds emitted from SGD that are linked to adverse health effects.

2.1 Process of Shale Gas Development

SGD is the process that obtains, transports, and stores methane gas and other natural gases.[8] Natural gas is taken from the ground by hydraulic fracturing, or fracking, in a manner considered "unconventional" because the process involves horizontal drilling in addition to fracking to release and collect natural gas.[9] To frack, wells are drilled vertically into rock formations thousands of feet deep and then can be drilled horizontally.[10] Fractures are made by injecting fluids consisting of water, sand, and other additives to create microfractures in the rock to extract natural gas.[11, 12] SGD includes active production wells, and infrastructure such as compressor stations and processing plants.[13] Natural gas is transported in pipelines and trucks. Natural gas gets stored underground in depleted oil and natural gas fields, depleted aquifers, or in salt formations for later use.[14] Injection wells, which place fluid into porous geologic formations, also store SGD byproducts.[15] SGD creates solid and liquid waste.[16] Well development waste consists of rock and drill lubricant. Fracking and production processes creates wastewater and sand waste. SGD waste needs to be stored or disposed of, sometimes ending up in landfills.[17, 18] Components of natural

gas and crude oil are processed by petrochemical plants to other chemicals to make plastics, rubbers, and pesticides.[19]

40% of injected fluid comes back as produced water which contains high concentrations of salt and naturally occurring radioactive material (NORMs).[20] In addition to produced water, flowback water also returns to the surface and both contain the injected chemicals, brines, metals, NORMs, and hydrocarbons.[21] Produced water and flowback water are stored on site in tanks or pits before treatment, disposal, or recycling—typical injected underground for disposal.[22] These fluids that are injected underground fall under Underground Injection Control Class II wells, which exclusively used for injected fluids from oil and natural gas production.[23]

Fracking uses 25 million liters of fresh water per well.[24] The amount of water needed to do fracking has some countries, like South Africa, unable to frack due to a lack of drinking water supply for its citizens.[25] An article published in 2019 states that the natural gas industry increasingly is reusing produced water for drilling and fracking.[26] Additionally, the industry is urging the EPA to allow produced water to have more uses and treated produced water be allowed as drinking water to ease concern about overusing fresh groundwater resources.[27] Produced water typically is just disposed, but it can be recycled for additionally drilling but it is more expensive than disposing it.[28] However, using treated produced water for drinking water has risks because of the undetermined amount of radium and other harmful compounds that can accumulate in drinking water sources.[29]

2.2 Fracking Operation and Restriction

SGD boomed in the early 2000s in the United States.[30, 31] The oil and gas industry promotes natural gas as a cleaner alternative to coal and oil.[32] In 2021, natural gas usage accounted for 37% electric power and 15% as a heating resource for US homes.[33] Texas and Pennsylvania make up a significant portion of the natural gas supply, (24.6% and 21.8%, respectively).[34] Louisiana is the 3rd highest producer in the US at 9.9%.[35] Pennsylvania sits on top of the Marcellus Shale, where most PA fracking occurs, and the Utica Shale which more recently has been used as a natural gas source. Other countries like China and Argentina have large shale rock reserves.[36, 37] As of 2023, the United States is the world's top suppliers of natural gas.[38]

States like Maryland and New York that also sit on the Marcellus Shale have placed bans or moratoriums on fracking to protect the environment and public health.[39] Vermont has banned fracking and prohibits the collection, treatment, and storage of fracking wastewater.[40] Multiple states, provinces, and countries globally have restrictions on fracking either banning, prohibiting, or placing moratoriums on it.[41] Some countries have cited the precautionary principle behind their reasoning for restricting fracking. The health and environmental risks are too unknown to allow fracking without having solid evidence of its safety. For a full list of places that restrict fracking, view Appendix Table 1.

2.3 Significance of Birthing People and Their Infants

Birthing people and infants are vulnerable populations. During pregnancy, the fetus is exposed to whatever the pregnant person is exposed to and lacks autonomy to decide what their

exposure may be. Fetal development happens quickly, so exposures to harmful chemicals can alter development or end a pregnancy. The most sensitive period is the embryonic period, which lasts between implantation (~14 days) to 60 days.[42] This period has a higher likelihood of the fetus experiencing a malfunction from a chemical.[43] In addition to physical malformations, chemical exposure during fetal development may lead to other health problems like cancers and low birth weight.[44, 45] Section 2.4.1 further discusses fetal health risks as it relates to SGD.

2.4 Overview of Chemicals Emitted From SGD

During SGD, various chemicals are used and emitted that have known health impacts. Naturally occurring radioactive materials (NORMs), volatile organic compounds (VOCs), and heavy metals can be emitted or brought to the surface from SGD.[46] Emissions from fracking fluid additives, controlled venting, flaring, storage tanks, pipelines, and equipment leakage can contain hydrogen sulfide and aromatic and polycyclic aromatic hydrocarbons which can impact people's health.[47] Produced water and flowback water can contain radium. From one study that sampled produced water from the Marcellus Shale found it had median radium levels of 2460 pCi/L.[48] The drinking water limit and industrial limit for radium is 5 pCi/L and 60 pCi/L, respectively.[49]

Benzene, radium, formaldehyde, and polycyclic aromatic hydrocarbons (PAHs) are known human carcinogens and have been measured at higher than safe concentrations at SGD sites.[50, 51, 52] Formaldehyde is formed from a component of natural gas from combustion, such as flaring, and sunlight on methane.[53] Polycyclic aromatic hydrocarbons (PAHs) have been found in high concentrations at well sites, known human carcinogen.[54] VOCs have the potential to affect the endocrine system, and benzene, a known human carcinogen, has been observed in the air near

SGD.[55] A pilot study sampled urine in 29 pregnant women living near SGD for two benzene metabolites, S-PMA and t,t-MA.[56] The authors compared their results to another study, and found that this sample of pregnant women had 3.5 times amounts of t,t-MA in their urine. However, others studies assessing VOC emissions found emission levels did not exceed levels that warrant community-wide public health concern.[57]

2.4.1 SGD Associated Chemicals Impact to Birthing People and Infants

The endocrine system is responsible for producing, storing, and secreting hormones.[58] Chemical induced endocrine disruption can cause developmental malformations, reproduction interference, increased cancer risk, and disturbed immune and nervous system function.[59] Chemicals that disrupt the endocrine system do so by mimicking the body's hormones, blocking hormones, or overproducing or underproducing hormones.[60, 61] In addition to benzene, other endocrine disruptive chemicals detected at SGD sites are ethane and n-pentane.[62] VOCs like benzene and formaldehyde can impact reproductive hormones and result in decreased fertility, increase risk of miscarriage, stillbirth, preterm birth, and birth defects.[63] Fetal exposure to benzene also increases the risk of low birth weight, spina bifida, cleft palette, and other birth defects.[64, 65, 66]

Studies have been published that measured the association of SGD and cancer. [67] One study looked at Acute Lymphoblastic Leukemia (ALL) in children aged 2 to 7. Children with one gas well within 2km of their birth residence had 1.98 (95% CI: 1.06, 3.69) times the odds and children with at least one well with the perinatal window had 2.80 (95% CI: 1.11, 7.05) times the odds of developing ALL compared to children with no gas wells within 2km.[68] Acute lymphoblastic leukemia (ALL) in children is associated to petroleum, solvents, and paint exposure during

pregnancy.[69] Petroleum, solvents, and paint contain benzene. There has not yet been an exposure pathway to directly link benzene from SGD to an adverse health condition.

2.5 Public Health Significance

Research about the potential community impacts from SGD have been growing over the past decade. There are multiple studies and monitoring efforts about the compounds emitted from SGD activity. Some of these compounds have known health effects and could affect air and water quality if in high enough concentration. Poor air and water quality have adverse health effects on people and the environment. Air pollution is linked to diseases like stroke and ischemic heart disease and increased risk of adverse pregnancy outcomes like low birthweight.[70] Poor water quality may lead to disease or chemical toxicity if the water is contaminated.[71] SGD can exacerbate present air and water quality issues, which causes concern for the well-being of the people exposed. For birthing people and their infants, the embryonic period is sensitive. High exposure with a long enough duration could harm the health of a fetus and impact their health in infancy. The public health significance of SGD is that it poses a threat to vulnerable populations, like birthing people and their infants.

2.6 Gaps in Knowledge

Most published studies measure the air or water quality around SGD for specific chemicals, are observational studies about the health impacts from SGD, or are critical literature reviews

synthesizing the literature. This essay will review whether the published literature has linked SGD to health conditions for birthing people and their infants.

3.0 Objective

The objective of this critical literature synthesis is to survey the existing published, peer reviewed literature about SGD and related health conditions experienced by birthing people and their infants. This synthesis uses the PICO strategy to identify relevant articles. PICO is a commonly used mnemonic device used in research for developing search strategies to answer research or clinical questions.[72, 73] It stands for "population" or "patient," "intervention," "control," and "outcome."

4.0 Methods

This critical literature synthesis searched PubMed to see how birthing people and their infants' health are impacted by SGD.

4.1 Eligibility Criteria

Articles were required to be peer reviewed, sample birthing people and their infants for either's health outcome, SGD is the exposure, and measure or assess a health outcome. Articles were excluded that were commentary or comments on other publications, did not focus on the population of interest, did not have a health-related outcome, and were not formally published peer reviewed articles.

4.2 Information Sources

Articles were sourced from PubMed. PubMed is a free online resource for biomedical and life sciences articles.[74]

4.3 Search Strategy

In January 2023, PubMed was used to search for articles using the PICO strategy. PICO is a research tool used to answer frame and answer a health-related question. Table 1 describes the terms of interest and separates them into their proper PICO elements. PICO elements were used in PubMed's advanced search engine with each like-element separated by "OR" and then connected with "AND." In addition to search terms, articles were filtered to include only "human" studies and no reviews. The search used in PubMed can be seen in Table 2.

Table 1 PICO Elements

Population	Pregnancy, infant, fetal, gestation
Item of Interest	Hydraulic fracturing, shale gas, unconventional natural gas, gas, oil
Comparison	*Not used in search.*
Outcome	Health, well-being

Table 2 Search Terms

Database	Search
PubMed	(("pregnancy"[MeSH Terms] OR "pregnancy"[All Fields] OR "pregnancies"[All Fields] OR ("infant"[MeSH Terms] OR "infant"[All Fields] OR "infants"[All Fields] OR ("fetale"[All Fields] OR "fetally"[All Fields] OR "fetals"[All Fields] OR "fetus"[MeSH Terms] OR "fetus"[All Fields] OR "fetal"[All Fields] OR "foetal"[All Fields])) AND ("hydraulic fracking"[MeSH Terms] OR ("hydraulic"[All Fields]

	AND "fracking"[All Fields]) OR "hydraulic fracking"[All Fields] OR ("hydraulic"[All Fields] AND "fracturing"[All Fields]) OR "hydraulic fracturing"[All Fields] OR ("unconventional"[All Fields] AND ("natural gas"[MeSH Terms] OR ("natural"[All Fields] AND "gas"[All Fields]) OR "natural gas"[All Fields] OR ("shale"[All Fields] AND "gas"[All Fields]) OR "shale gas"[All Fields])) OR ("natural gas"[MeSH Terms] OR ("natural"[All Fields] AND "gas"[All Fields]) OR "natural gas"[All Fields] OR ("shale"[All Fields] AND "gas"[All Fields]) OR "shale gas"[All Fields])) AND ("health"[MeSH Terms] OR "health"[All Fields] OR "health s"[All Fields] OR "healthful"[All Fields] OR "healthfulness"[All Fields] OR "healths"[All Fields] OR ("health"[MeSH Terms] OR "health"[All Fields] OR "well"[All Fields] OR "well being"[All Fields])) NOT (review) AND (human)

4.4 Selection Process

The search result yielded 164 results, which was further narrowed down. During the first pass through the initial 164 article result, any article that included the exposure and population of interest were selected for closer examination. This process ended with 29 articles. These articles were reviewed again to ensure they all fit the inclusion criteria and any article that did not fit was immediately excluded. Most of these were studies that did not have a health-related outcome or were not a peer reviewed articled. After excluding articles that did not fit the criteria, 14 articles were identified.

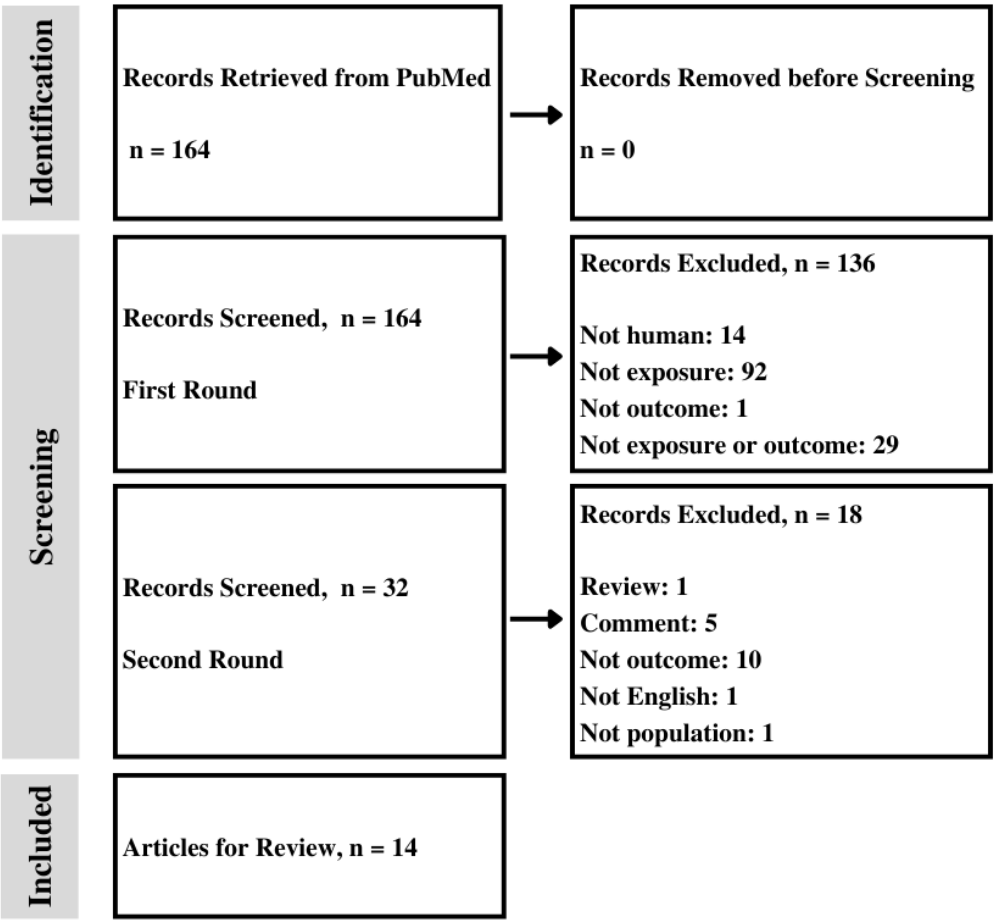

Figure 1 Article Screening Process

4.5 Data Charting Process

After identifying articles for review, data items were identified and put into a table. Articles were uploaded into EndNote to help organize. Data items were pulled from the articles' abstract or summary, whichever was used in publication. Then the results and discussion sections of the articles were reviewed to add detail if necessary.

4.6 Data Items

For this review, the following study characteristics were extracted: author and year, title of article, location, study design and sample, exposure, outcome, analytic method, and findings of the study. These study characteristics can be seen in Table 3.

Table 3 Article Results

Author & Year	Title	Location	Design & Sample	Exposure	Outcome	Analytic Method	Findings
Aker, Whitworth, Bosson-Rieutort, Wendling, Ibrahim, Verner, et al.; 2022	Proximity and density of unconventional natural gas wells and mental illness and substance use among pregnant individuals: An exploratory study in Canada	British Columbia, Canada	Retrospective Cohort Study - 6278 pregnant individuals 2006-2016	Density & proximity of unconventional natural gas (UNG) wells around residential postal codes. Measured with the inversive distance weighted (IDW) sum.	Birthing people's mental illness and substance use (self-reported on prenatal registration questionnaire: cannabis, heroin, opioids, solvents, cocaine, methadone, other).	Bivariate analyses. Logistic regression.	There were positive associations (OR 95% CI) between depression diagnosis and UNG wells within 10 and 5 km buffers around residential post codes [Q2 1.34 (1.07-1.69) and Q3 1.36 (1.08-1.71); Q2 1.23 (0.98-1.55), Q3 1.24 (0.99-1.57), and Q4 1.04 (0.82-1.32) respectively]. Substance use OR in the 10 km buffer: Q2 (1.22, 0.921-1.62) and Q3 (1.15, 0.86-1.53), with the Q4 (0.8, 0.59-1.1) showing it's protective. The 5 km for substance use buffers Q2 (1.1, 0.83-1.46) and Q4 (1.02, 0.76-1.36), while Q3 (0.91, .067-1.22). and the 2.5 km buffer has Q2, Q3, and Q4 (0.79 (0.59–1.06), 0.74 (0.56–1.00), and 0.86 (0.65–1.14) are less associated to SGD.
Apergis, Hayat, Saeed; 2019	Fracking and infant mortality: fresh evidence from Oklahoma	Oklahoma, US	Cohort Study- 556,794 Infants 2006-2017	Proximity to fracking wells from residence modeled by IDW.	Infant health, total birth weight, low birth weight.	Pooled Mean Group (PMG) estimators. Dumitrescu-Hurlin test.	Total birthweight had stronger effects at 1km and 5km (PMG -0.084 and -0.078, respectively). This means that total birthweight had a standard deviation decline of -0.084 and -0.078. Low birthweight PMG 1km 0.056 at 1km, 0.046 at 5km, and 0.039 at 10km. This would suggest an increase in low birthweight. The Dumitrescu-Hurlin causality tests showed a unilateral

							relationship only from fracking side to infant health.
Cairncross, Couloigner, Ryan, McMorris, Muehlenbachs, Nikolaou, et al.; 2022	Association Between Residential Proximity to Hydraulic Fracturing Sites and Adverse Birth Outcomes	Alberta, Canada	Retrospective Cohort Study 26,193 pregnant individuals 2013-2018	Proximity and density to fracking sites (n=4871) preconception and/or pregnancy from postal delivery code, within 10 km of 1 or more wells fracked during 1 year preconception or during pregnancy.	Infant health – small for gestational age, congenital anomalies, preterm birth, neonatal morbidity or mortality.	Modified Poisson regression. to get adjusted risk ratios with 95% CI.	SGA associated with major congenital anomalies within 10km of fracking site in preconception or pregnancy (aRR, 1.12; 95% CI, 1.03-1.23) and (aRR, 1.31; 95% CI, 1.01-1.69), respectively. Risk of spontaneous preterm birth and SGA significantly increased within 10 km of 100 or more wells (aRR, 1.64; 95%CI, 1.04-2.60) and (aRR, 1.65; 95% CI, 1.10-2.48), respectively. There were no associations at other levels of exposure.
Caron-Beaudoin, Whitworth, Bosson-Rieutort, Wending, Liu, Verner; 2021	Density and proximity to hydraulic fracturing wells and birth outcomes in Northeastern British Columbia, Canada	British Columbia, Canada	Cohort Study 6,333 infants Nov 30 2010-Nov 29 2012	Density and proximity to fracking wells. Measured with the inversive distance weighted (IDW) sum	Infant health- birth weight, head circumference, preterm birth, and small for gestational age.	Multiple linear regression	No association between well density/proximity to head circumference and SGA. There were inconsistent associations between postal code density/proximity to wells for preterm birth and low birthweight. Preterm birth had one significant association in the 2nd quartile of the 2.5 km buffer (OR 1.60 95% CI [1.30; 2.43]). Significant decreases in birthweight were seen in the Q2 of 10km buffer β [95% confidence interval (CI)]: −47.28 g [−84.30; −10.25] and then the Q2 and Q3 of 5km buffer were β [95% CI]: −40.87 g [−78.01; −3.73]) and (β [95% CI]: −42.01 g [−79.15; −4.87], respectively.

Casey, Goin, Rudolph, Schwartz, Mercer, Elser, et al.; 2019	Unconventional natural gas development and adverse birth outcomes in Pennsylvania: The potential mediating role of antenatal anxiety and depression	Pennsylvania, US	Retrospective Cohort Study 8,371 infant births to 7,715 pregnant individuals Jan 2009-Jan 2013	UNGD measured with IDW between conception and the week prior to anxiety or depression for cases or the pregnancy-average daily metric for non-cases. Exposed cases Q4, unexposed Q1-3.	Antenatal anxiety and depression in birthing people and how, if any, these associate to birth outcomes (preterm birth, low birthweight, and term birthweight).	Targeted maximum likelihood estimate (TMLE).	There was 4.3 cases of antenatal anxiety or depression per 100 women (95% CI 1.5-7.0) for those living in the highest quartile of UNGD activity. A higher risk difference was observed for mothers receiving Medical Assistance 5.6 (0.5-10.6 95% CI) per 100 women compared to mothers who did not receive this assistance 2.9 (-.07, 6.5 95% CI) per 100 women. No relationship was found between anxiety/depression and birth outcomes.
Casey, Savitz, Rasmussen, Ogburn, Pollak, Mercer, et al.; 2015	Unconventional Natural Gas Development and Birth Outcomes in Pennsylvania, USA	Pennsylvania, US	Retrospective Cohort Study 10,946 neonates to 9,384 pregnant individuals Jan 2009-Jan 2013	Dates and duration of well pad development, drilling, fracking, and production volume during pregnancy. Measure with IDW.	Infant health - Term birthweight, preterm birth, low 5-minute Apgar score, and small for gestational age.	Multilevel linear and logistic regression models.	The odds of preterm birth was 1.4 (CI 95% 1.0-1.9) between the 1st and 4th quartile. There was no association found for Apgar score, SGA, or low birthweight. Results for Apgar score and SGA were not presented in this article. Low birthweight was found in a sensitivity analysis for infants born in 2006 who would have been in the 4th quartile had they been born in 2012.

Currie, Greenstone, Meckel; 2017	Hydraulic fracturing and infant health: New evidence from Pennsylvania	Pennsylvania, US	Cohort Study, infants born to mothers at different distances to SGD and before and after SGD initiated >1.1 million infants. 2004-2013	Maternal residence proximity to fracking sites.	Infant health – low birthweight and average birthweight.	Difference in means and regression equations.	The low birthweight mean baseline for maternal residence within 1km was 0.065. The estimated effect on the probability of low birthweight is 0.016 relative to the baseline within 1km. Total birthweight difference in means from baseline of 3,319.6g are -7.092g at 2-3km, -3.341g at 1-2km, and -38.654g at <1km. Comparisons of t tests of the hypothesis suggests mothers whose infants were exposed in utero are more likely to be younger, unmarried, and less educated at time of birth.
Cushing, Vavra-Musser, Chau, Franklin, Johnston; 2020	Flaring from Unconventional Oil and Gas Development and Birth Outcomes in the Eagle Ford Shale in South Texas	Texas, US	Retrospective Cohort Study 23,487 infant births 2012-2015	Residential proximity to flaring events from natural gas, Occurrences low 1-9, high >=10, and 0 exposure. IDW	Infant health - preterm birth, small for gestational age, continuous gestational age, and term birthweight.	Multivariate logistic and linear regression models.	Exposure to a high number of nightly flaring had higher odds of preterm birth and shorter gestation OR =1:50 (95% CI: 1.23, 1.83) and [mean difference = −1:9 (95% CI: −2:8, −0:9), respectively. Preterm birth, shorter gestation, and a low average birthweight had positive associations when birthing people lived within high number of wells (>=27) within 5km [OR=1:31 (95% CI: 1.14, 1.49)], [−1:3 (95% CI: −1:9, −0:8) d], and [−19:4 (95% CI: −36:7, −2:0) g], respectively. A stratified analysis showed Hispanic women were more likely to experience preterm birth from flaring than non-Hispanic white women OR=1:61 (95% CI: 1.25, 2.08).

McKenzie, Allshouse, Daniels; 2019	Congenital heart defects and intensity of oil and gas well site activities in early pregnancy	Colorado, US	Case-control study 3324 infants. 2005-2011	Birthing persons' proximity to oil and gas well sites. IDW	Infant health-congenital heart defects: aortic artery and valve (AAVD), pulmonary artery and valve (PAVD), conotruncal (CTD), or tricuspid valve (TVD) defect.	Logistic regression models.	CHDs overall were 1.4 (1.0, 2.0) and 1.7 (1.1, 2.6) times more likely in the control groups for the high and medium intensity exposures. PAVs in control groups were 1.7 (0.93, 3.0) and 2.5 (1.1, 5.3) times more likely in the high and medium intensity, respectively. Infants born in the medium and high intensity groups for well density in rural areas had higher odds of AAVDs (1.8 (0.97, 3.3) & 2.6 (1.1, 6.1)), CTDs (2.1 (0.96, 4.5) &4.0 (1.4, 12), and TVDs (3.4 (0.95, 12) & 4.6 (0.81, 26).
McKenzie, Witter, Savitz, Newman, Adgate; 2014	Birth outcomes and maternal residential proximity to natural gas development in rural Colorado	Colorado, US	Retrospective Cohort Study 124,842 births 1996-2009	Birthing persons' proximity to natural gas sites. IDW	Infant health – congenital heart defects (CHDs), neural tube defects (NTDs), oral clefts, preterm birth, and term low birth weight.	Logistic regression models.	The association of CHDs increased as groups were more exposed with highest tertile OR 1.3 95% CI 1.2, 1.5. NTDs was associated OR 2.0 95% CI 1.0, 3.9 in highest tertile group compare with the absence of gas wells within a 10mi radius. There was a negative association of preterm birth, low term birthweight, and oral clefts.
Stacy, Brink, Larkin, Sadovsky, Goldstein, Pitt et al.; 2015	Perinatal Outcomes and Unconventional Natural Gas Operations in Southwest Pennsylvania	Pennsylvania, US	Retrospective Cohort Study 15,451 live births. 2007-2010	Proximity and density to unconventional gas wells. Measured by (IDW).	Infant health - small for gestational age and premature and birthweight	Logistic regression. Multivariate linear regression.	Only the highest exposure group was found to have a lower birthweight than the reference group (-21.83, standard error 9.39). SGA had a steady increase across the four exposure groups, with the highest exposure groups adjusted OR = 1.34, 95% CI = 1.10–1.63. No associations were found for premature birth and well density.
Walker-Whitworth, Kaye Marshall, Symanski; 2018	Drilling and Production Activity Related to Unconventional Gas Development and	Texas, US	Case-control 13,328 1 case to 5 controls. UGD phase and trimester specific.	UGD measured by IDW.	Infant health - preterm birth	Logistic regression.	Preterm birth during drilling activity during pregnancy in adjusted OR CI 95% Q1 1.03 (0.90, 1.18), Q2 1.03 (0.90, 1.18),

	Severity of Preterm Birth		Nov 30 2010-Nov 29 2012				and Q3 1.20 (1.06, 1.37). During UGD production activity during pregnancy Q1 1.07 (0.97, 1.17), Q2 1.13 (1.02, 1.24), Q3 1.15 (1.05, 1.26). Authors also looked at trimester specific associations of drilling and UGD production activity to preterm birth. During drilling: Trimester one: Q1 1.03 (0.88, 1.19), Q2 0.96 (0.80, 1.14), Q3 1.24 (1.03, 1.49); Trimester two: Q1 1.10 (0.94, 1.28), Q2 1.15 (0.96, 1.33), Q3 1.21 (1.00, 1.45); Trimester three Q1 1.13 (0.93, 1.39), Q2 0.95 (0.73, 1.22), Q3 1.19 (0.89, 1.60). During UDG production activity: Trimester one Q1 1.03 (0.95, 1.12), Q2 1.20 (1.09, 1.33), Q3 1.18 (1.02, 1.37); Trimester two Q1 1.02 (0.94, 1.11), Q2 1.19 (1.08, 1.31), Q3 1.14 (0.99, 1.31), Trimester three Q1 1.10 (1.02, 1.19), Q2 1.19 (1.06, 1.33), and Q3 0.89 (0.72, 1.10).
Whitworth, Marshal, Symanski; 2017	Maternal residential proximity to unconventional gas development and perinatal outcomes among a diverse urban population in Texas	Texas, US	Retrospective Cohort Study 158,894 women with birth or fetal death Nov 30 2010-Nov 29 2012	Proximity UGD activity around maternal address. IDW.	Infant health – term birthweight, small for gestational age, fetal death, and preterm birth	Logistic regression. Linear regression (birthweight).	In adjusted models, there was no association between SGA and UGD [OR ½ mi: Q1 0.95(CI 0.89, 1.00), Q2 & Q3 1.01(0.96, 1.06); 2mi Q1&Q3 0.95(0.90, 1.00), Q2 0.96(0.91, 1.01) 10mi: Q1 1.03(0.98, 1.08), Q2 0.95(0.91, 1.00), Q3 0.96(0.92, 1.01)]. In adjusted models, preterm birth was positively associated in the highest quartiles of ½, 2, and 10 mile ranges [OR Q1 1.18 (1.08, 1.29), Q2 1.21 (1.09, 1.33), Q3 1.14 (1.03, 1.25); Q1 1.11 (1.04,

							1.19), Q2 1.16 (1.09, 1.24), Q3 1.14 (1.07, 1.22); Q1 1.02 (0.96, 1.08), Q2 1.13 (1.06, 1.20), Q3 1.15 (1.08, 1.22), respectively]. Also in adjusted models, fetal death had the following associations at ½, 2, and 10 mile buffers: OR CI 95% Q1 1.07 (0.69, 1.65), Q2 1.10 (0.72, 1.71), Q3 1.27 (0.82, 1.97); Q1 1.14 (0.83, 1.56), Q2 1.56 (1.16, 2.11), Q3 1.16 (0.86, 1.58); Q1 1.26 (0.99, 1.60), Q2 1.22 (0.95, 1.57), Q3 1.34 (1.04, 1.72); respectively]. Associations of birthweight ½mi Q1 0.12 (-11.80, 12.04), Q2 -8.20 (-18.36, 1.96), Q3 -0.83 (-12.24, 10.58); 2mi Q1 -4.39 (-12.33, 3.56) -7.75 (-15.94, 0.44) -6.68 (-14.38, 1.02); and 10mi Q1 -7.36 (-14.79, 0.08), Q2 -2.58 (-9.75, 4.59), Q3 -6.56 (-13.68, 0.56).
Willis, Hill, Boslett, Kile, Carozza, Hystad; 2021	Association 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	Texas, US	Retrospective Cohort Study 2,598,025 mother-infant dyads, difference-in-difference (DID) quasi-experimental study design. 1996-2009	Residence proximity to oil and gas drilling site. IDW.	Infant health - term birth weight and small for gestational age (OR).	Difference-in-difference.	Control births were births with maternal residence within 10 km of a drilling site prior to drilling or if the active drill was 3km away. Exposed births were maternal residence within 3 km of active drilling. Term birthweight DiD before and after drilling: −4:3 g (95% CI: −11:0, 2.5) at 0–1 km, −7:1 g (95% CI: −13:3, −0:9) at 1–2 km, and −8:0 (95% CI: −15:0, −1:0) for 2–3 km. SGA OR: 1.05 (95% CI: 0.99, 1.12) at 0–1 km, 1.02 (95% CI: 0.97, 1.08) at 1–2 km, and 1.04 (95% CI: 0.98, 1.10) at 2–3 km. However, when living within 0-1km (near) and 3-10km

							(far) of an active drilling site there's no associations between low birthweight and SGA (1:8 g, 95% CI: −0:7, 4.2) (1.00, 95% CI: 0.98, 1.02). There was some larger, though imprecise effects (as described by authors), that Hispanic women, women of low economic status, and women living in cities had infants born with low birthweight or SGA.

5.0 Results

The following section synthesizes the results from Table 3. Health outcomes, including mental health diagnoses, premature birth, SGA, low birthweight, and others discussed below were associated with SGD at close proximities and/or higher densities of SGD activity. Most studies (n=12) yielded from the search results were about infant health outcomes. Few studies examined birthing people's health outcomes (n=2). SGD exposure tended to be distance to and density of fracking wells, but flaring and drilling were also considered.

5.1 Synthesis of Results

Results from the literature search yielded articles focused on North American populations from six states or providences with SGD: British Columbia, Canada[75, 76]; Alberta, Canada[77]; Oklahoma, US[78]; Pennsylvania, US[79, 80, 81, 82]; Texas, US[83, 84, 85, 86]; and Colorado, US[87, 88]. Observational studies investigated the proximity of birthing persons' residences to SGD activity, such as wells, drilling, or flaring and the density or frequency of the SGD activity. Two studies, by McKenzie et al. and Walker-Whitworth et al., used a case-control design. [89, 90] The remaining 12 studies were retrospective cohort designs. [91, 92, 93, 94, 95, 96, 97, 98, 99, 100, 101, 102] McKenzie et al. and Walker-Whitworth had a cohort study that preceded the publication of their case-control study. All the studies had large sample sizes ranging from 3,324 to 2,598,025 participants.

Common analytic methods were logistic regression n=8 and linear regression n=5. A difference in difference of means (n=3) was used in two studies. Other analytic methods used were

Pooled Mean Group (PMG) n=1, Dumitrescu-Hurlin test n=1, modified Poisson regression n=1, targeted maximum likelihood estimate (TMLE) n=1, and one non-specified regression n=1.

5.1.1 Exposure

Exposures were measured as density and proximity to SGD, just proximity to SGD, or operation periods of SGD. The SGD activity included flaring (n=1),[103] fracking wells (n=11) [104, 105, 106, 107, 108, 109, 110, 111, 112, 113, 114] drilling (n=3),[115, 116, 117] and production volume (n=1).[118]

Most studies (n=12) measured the relationship between the exposure and sample population with the inverse distance weighted sum (IDW). IDW is a mathematical equation that assumes closer values are more related than values further away plotted on an interpolation.[119] In these studies, the IDW known values were the residential address or postal code (depending on which the authors used) and the number of wells within set distances.[120, 121, 122, 123, 124, 125, 126, 127, 128, 129, 130, 131] These formed the exposure groups which were analyzed with a chosen statistical method.

To set the point to measure proximity and density, authors used either postal code centroids, town or city centroid, or specific birthing person's address. The Canadian studies used the postal code centroid of the birthing person n=3.[132, 133, 134] Casey et al. 2019 was only study to use the town or city based off postal zip code to categorize birthing person's residence.[135] The remaining studies used the specific birthing person's address listed on the birth certificate or other hospital records n=10.[136, 137, 138, 139, 140, 141, 142, 143, 144, 145] Casey et al. used the 2013 address found for their cohort and assumed that was the address for the entire period of residence for their cohort.[146]

5.1.2 Infant Health

Table 4 Infant Health Outcomes by Effect

Health Condition	No effect	Effect in All Exposure Groups	Effect in Highest Exposure Groups	Inconsistent Effects Across Exposure Groups
Preterm Birth	n=2 [147, 148]	n=2 [149, 150]	n=3 [151, 152, 153]	n=2 [154, 155]
Shorter Gestation			n=1 [156]	
Low Birthweight	n=4 [157, 158, 159, 160]		n=3 [161, 162, 163]	n=1 [164]
Total, Term, or Average Birthweight		n=1 [165]	n=2 [166, 167]	
SGA	n=4 [168, 169, 170, 171]	n=1 [172]	n=2 [173, 174]	
Congenital Anomalies		n=1 [175]		
Congenital Heart Defects		n=1 [176]	n=1 [177]	
Oral Clefts	n=1 [178]			
5-minute Apgar Score	n=1 [179]			
Head Circumference	n=1 [180]			
Fetal Death	n=1 [181]	n=1 [182]		

Table 4 shows the number of articles for a health outcome and what level of exposure the health outcome was associated to SGD activity. Blank boxes mean no articles. The “Effect in All Exposure Groups” column notes that the overall exposure group or each quartile in an exposure group showed some effect. The “Effect in Highest Exposure Groups” indicates that the outcome was seen in the high exposure groups. It also indicates when effects grew stronger as exposure increased. “Inconsistent Effects Across Exposure Groups” indicates when the health outcome effects differed based on exposure, such as the strongest effect was not the group most exposed. Some articles for the same health outcome appear twice. This could be because a health outcome had effects in all exposure groups but the highest effect in the most exposed, therefore is cited in both “Effect in All Exposure Groups” and “Effect in Highest Exposure Groups.”

The majority of studies focused on infant health.[183, 184, 185, 186, 187, 188, 189, 190, 191, 192, 193,194] Infant health outcomes included term birthweight (n=6 studies), low birthweight (n=3), total birthweight (n=1), average birthweight (n=1), small for gestational age (SGA) (n=7), preterm birth (n=8), short gestation period (n=1), fetal death or infant mortality (n=2), congenital heart defects (CHDs) (n=2), congenital anomalies (n=1), 5-minute Apgar score (n=1), and head circumference (n=1).

For infant health, findings for a birth outcome were mixed, meaning some studies found positive associations between the health outcome and exposure to SGD, while others found no significant effect between the outcome and exposure. In studies that found positive associations, the strongest effect tended to be those most exposed to SGD.

5.1.2.1 Preterm Birth

Preterm birth was found to have positive associations in five studies. Preterm birth had an increased risk with SGD at less than 10km with 100 gas wells (aRR 1.64 95% CI 1.04, 2.60) and increased odds within 2.5km (1.60 95% CI 1.30, 2.43).[195 , 196] Cushing et al. found associations to preterm birth and shorter gestation in participants that were close to flaring events from natural gas (OR 1.50 95% CI 1.23, 1.83 and mean difference -1.9 95% CI -2.8, -0.9, respectively).[197] Three studies found preterm birth for the high exposure groups. Whitworth et al. found positive associations to preterm birth in all exposure groups, but the strength of those effects were inconsistent.[198] One other study found inconsistent effects for preterm birth. Two studies found no effects to preterm birth.

Out of 8 studies, four articles found positive associations between preterm birth and SGD. Three of these found stronger effects when there was more SGD, such as flaring or wells. However, the other four articles found no or inconsistent effects between preterm birth and SGD.

5.1.2.2 Birthweight

A decrease in low birthweight and total birthweight was found in high with high exposure to SGD.[199 , 200, 201, 202] The closer the proximity or more dense of SGD site, the larger effect sizes.[203, 204, 205] Caron-Beaudoin et al. found inconsistent associations between SGD and low birthweight at 5km and 10km.[206] Stacy et al. found significance between low birthweight and SGD at the highest exposed group.[207] Four studies found no associations between SGD and low birthweight. In the 8 studies that looked at any kind of birthweight outcome, one found inconsistent associations, four positive associations, and four no associations.

5.1.2.3 Small for Gestational Age

Six studies looked at SGA. Four did not see any association between SGA and SGD. Two studies found positive associations between SGA and SGD (OR 1.35 95% CI 1.10,1.63) and (aRR 1.65 95% CI 1.10, 2.48).[208 , 209] Stacy et al. only saw SGA in the highest exposed group to SGD.[210] Cairncross et al. found positive associations across exposure groups and found that the effect grew stronger as the exposure increased.[211]

5.1.2.4 Congenital Defects

Congenital defects have a higher association when a pregnancy occurred within 10km or 15km of a gas well. Two studies with the same first author, McKenzie et al. 2014 and McKenzie et al. 2019 measured associations between proximity to gas well and infant congenital heart defects (CHDs). The 2014 McKenzie study was a cohort study and the 2019 study a case-control. The 2014 study found a higher prevalence of CHDs and neural tube defects within a 10mi radius.[212] In the 2019 study, authors found that infants born in the medium and high intensity groups for well density had higher odds of any CHD.[213] The CHD looked at in the study were aortic artery and

valve, pulmonary artery and valve, conotruncal, and tricuspid valve defects. When specifically looking at rural areas, McKenzie et al. found higher odds that infants would be born with aortic artery and valve (OR 95% CI 1.8, (0.97, 3.3) & 2.6 (1.1, 6.1), conotruncal (OR 2.1 (0.96, 4.5) & 4.0 (1.4, 12), and tricuspid valve (OR 3.4 (0.95, 12) & 4.6 (0.81, 26) defects in medium and high intensity exposure groups.[214] Another considered congenital anomalies, but did not specify any particular ones, and found an increased risk for congenital anomalies within 10km of at least one gas well (aRR 1.64 95% CI 1.04, 2.60).[215]

5.1.2.5 Other Birth Outcomes

Of the two studies that looked at fetal death, only one study found a positive association between fetal death and SGD. The other study saw no effect.

Oral clefts, head circumference, and 5-minute Apgar score had no association to SGD.

5.1.3 Birthing People's Health

Aker et al. and Casey et al. focused on birthing people and the associations between mental health conditions and SGD.[216, 217] Both studies measured density and proximity to SGD and found higher odds of new diagnoses of a mental health condition in high exposure groups. Aker et al. found positive associations to depression in some quartiles within 5km and 10km.[218] Casey et al. found higher occurrences of antenatal anxiety or depression, with 4.3 new diagnoses per 100 people in the highest exposure group.[219] The distance away of the most exposed groups were 10km in the Aker study and a median of 11.2km for the Casey study. Both of these studies did not use the specific birthing person's address, rather a centroid of some kind. However, in the 5km buffer

zone from the Aker et al. study, the densest quartiles, 3 and 4, showed no association to a new depression diagnosis.[220]

5.1.4 Other Factors

There were a few studies (n=4) that found an increased the effect size between SGD exposure and a health outcome for certain populations. Willis et al. noted small increases in effect sizes between SGD and low birthweight and SGA for Hispanic women, women with low socioeconomic status, and women living in cities in stratified analyses.[221] Hispanic women were also more likely than non-Hispanic white women to experience a preterm birth from flaring events.[222] Currie et al. found declines in average birthweight were more likely with younger, unmarried, and less educated mothers.[223] Casey et al. higher risk difference for an anxiety or depression diagnosis for women receiving Medical Assistance 5.6 compared to 4.3 new diagnoses per 100 people.[224]

5.2 Strengths and Limitations

The studies had large sample sizes, ranging from 3,324 to 2,598,025, giving them sufficient power to test associations. The location of the studies also aligns to where there are natural gas deposits. Pennsylvania and Texas, two of the top suppliers of natural gas, are represented across eight articles. As these studies are observational, the internal validity may not be as strong since there is not much control over the exposure. However, the large sample sizes help increase the studies' validity.

Studies used similar measurement for residence and proximity/density to wells, the IDW. However, different buffer distances were used (i.e. kilometers vs miles) and distance was calculated with different starting points (i.e. centroids vs home address). Authors divided IDW into quartiles and chose which quartiles were considered exposed. Some studies like Aker et al. 2022 measured each quartile, whereas others like Casey et al. 2019 only considered the fourth quartile as exposed as that quartile had the number of SGD sites wanted by the authors.

Studies tended to report the limitations of their studies well. Commonly authors addressed limitations to determining residence distance (zip code centroid vs home address) and not knowing the exact dates of SGD activity. Using a centroid does not have as much precision as using a home address to determine an individual's level of exposure to SGD. Not knowing the exact dates of SGD, authors would need to make assumptions that everyone had the same level of exposure throughout nine months of pregnancy.

The cohort studies used hospital and birth records for finding the address and health outcomes. There is a possibility of selection bias. Hospital or birth records may be incomplete or have missing information. Though studies accounted for missing information by excluded that participant from the sample. Missing data from when wells were active could impact the effect of association between outcome and exposure. There were few studies focused on birthing person's health in this review (n=2).

5.3 Limitations and Potential Bias

Articles were excluded by reviewing the titles and summaries given by PubMed. Some search terms, despite using filtering for human studies, gave multiple animal studies using mice or

lambs. Further, studies about indoor or outdoor air quality or gas-spectrometry came up because of “gas” in the search field. Articles were selected based on my perception of whether it fit the criteria, which may not match how someone else would exclude articles.

6.0 Discussion

Findings from the synthesis suggest birthweight, preterm birth, and congenital defects may be associated with high exposure to SGD. However, besides CHDs, there was not an infant health outcome that showed a positive association across all the studies yielded from the results of this review. Low birthweight or total birthweight and preterm births were associated with SGD, particularly when exposure is high. SGA mostly was not associated with SGD. There is not enough evidence to determine if SGD causes poor infant health outcomes. Based on the review, there is some evidence that infants are impacted by SGD, but needs more research to better understand the magnitude of risk.

Poor birth outcomes may have lasting impacts as preterm birth and low birthweight are linked to other health conditions. Preterm birth is linked to learning, vision, and hearing disabilities.[225] Low birthweight is linked to low oxygen levels at birth, trouble staying warm, trouble feeding and gaining weight, infection, breathing problems and immature lungs (infant respiratory distress syndrome), nervous system problems, such as bleeding inside the brain (intraventricular hemorrhage), digestive problems, such as serious inflammation of the intestines (necrotizing enterocolitis), and Sudden infant death syndrome (SIDS).[226] Low birthweight also is linked to later in life complications such as cerebral palsy and developmental delays.[227]

An increased risk for negative infant health outcomes and mental health outcomes for birthing people were seen at close distances and high density of SGD activity. These outcomes were typically seen within 1 mile and 10 kilometers of SGD activity. Setback laws regulate how close SGD can operate to residences. The US states' laws allow SGD to operate within the distances the studies' results show. PA Act 13 allows unconventional SGD activity within 500 feet

of existing buildings and water wells, unless consented by owner.[228] Texas has no setback laws for oil and gas.[229] Oklahoma Statutes title 52 contains all laws about oil and gas. 52 Okl.St.Ann. § 320.1 cannot have a habitable structure located within 125 feet radius of an active wellbore, nor within 50 feet of equipment needed to operate an active well.[230] In 2020, Colorado implemented a 2000 feet setback law for residences and schools.[231] Setback requirements for wells are 100 meters in British Columbia, Canada.[232] Current setback laws allow SGD to operate within distances closer than the buffer zones used in the review studies. Studies found positive effects at 2.5 kilometers (8202.1feet), 5 kilometers (6404.2 feet), and 10 kilometer (32808.4 feet).

In four studies, there is evidence that effect sizes are stronger for Hispanic women, low socioeconomic status, and other social factors.[233, 234, 235, 236] These findings suggest a possibility for health disparities from SGD for populations for people that experience health disparities due to low socioeconomic status and their race or ethnicity.[237, 238] The reason for these inequities should be explored further to understand if SGD has a stronger role in these outcomes or other exposures create a syndemic issue.

A challenge to achieving health equity regarding SGD is that the industry is well-supported politically and the industry has monetary influence. In the 2020 election cycle, oil and gas lobbyists spent 63.6 million dollars to Republican and 12.3 million dollars to Democrats in donations.[239] One study found that the oil and gas industry tend to reward politicians that vote against environmental protection legislation.[240] PA and TX rely on natural gas for their economies. Plus, in the US, Republicans tend to support the oil and gas industry. Introducing state legislature and passing amendments or laws to increase setback distances likely will not pass in republican controlled state houses. Even if state residents are living near current or prospective SGD sites, state legislators may not vote in favor of the residents. The influence the oil and gas industry can

contribute to health inequities for those living near SGD activity by supporting legislators that vote against stricter SGD regulation.

6.1 Recommendations and Future Research

Based on the findings of this research, SGD at close proximity to residences may increase the risk of preterm birth, low birthweight, and CHDs for infants. More research is needed to determine how much risk, if any, there is to birthing people and infants. In the meantime, taking precautions for new SGD could help reduce potential future harm to infants and birthing people. Setback laws control the distance allowable between SGD and other structures, such as residences. New SGD should have increased setback distances away from residences or limit the number of SGD, like wells, near residences. This may help reduce the health impacts linked to SGD for infants and birthing people.

Future research should account for specific chemical exposures from SGD. This could be done with a prospective cohort study following from pregnancy through stages of adolescent development to track both chemical emissions and health conditions of infants. Starting with this design could make observations about new incidences of health conditions. This could help strengthen the association of risk between SGD and health outcomes by monitoring emissions of chemicals that have better evidence of their health risks.

There should be more studies exploring the health impacts birthing people may experience during pregnancy from SGD. The only two studies from this review considered birthing people's health. The evidence, from this review, is not strong enough to suggest that SGD does lead to more mental health diagnoses.

6.2 Conclusion

There is some evidence to suggest infants' health may be impacted by SGD. The known health conditions that can result from preterm birth, low birthweight, and SGA warrants public health intervention. Infants are more vulnerable due to their small size and rapid development that make them sensitive to chemical toxicity. The chemicals emitted from SGD have known human health consequences. Despite a lack of evidence linking a specific chemical to a specific health outcome resulting from SGD exposure, the vulnerability of infants warrants concern. Efforts should be made to prevent adverse health effects for infants by implementing protections for birthing people. Waiting until there is sufficient evidence may jeopardize the health of communities living near SGD. Action should be taken to limit the amount of exposure residents experience until the health impacts of SGD are proven. A precautionary approach ensures people experience less harm from potential hazards.

Appendix Table 1

Appendix Table 1 SGD Restrictions[241]

Place	Position on Fracking	Year Initiated
New York, USA	Ban	2014
Vermont, USA	Ban	2012
Maryland, USA	Ban	2017
Delaware River Basin, USA	Considering ban	
Oregon, USA	Ban	2019
Washington, USA	Ban	2019
Florida, USA	Strongly Oppose	2019
New Brunswick, Canada	Ban	2015?
Quebec, Canada	Prohibits fracking shale gas	?
France	Ban	2011
Bulgaria	Ban	2012
Denmark	Moratorium	2012
Netherlands	Moratorium for 5 years	2015
Germany	Ban	2016
Spain	Considering prohibiting	2017
Republic of Ireland	Ban	2017
Northern Ireland, UK	Moratorium	2011
Wales, UK	Moratorium	2015
Scotland, UK	Ban	2017
England, UK	Moratorium	2019
Uruguay	Ban for 4 years	2017
Entre Ríos, Argentina	Prohibits	2017
Colombia	Moratorium	2018
Costa Rice	Moratorium	2019
Paraná, Brazil	Prohibits	2019
Santa Catarina, Brazil	Prohibits	2019
Mexico	Pending legislations to ban	2019
Tasmania, Australia	Moratorium until 2020, renewed to 2025	2014, renewed 2018
Victoria, Australia	Moratorium for 2 years	2018

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