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RESEARCH ARTICLE

Industrial Expansion and the Spatial Distribution of Stillbirths in Nineteenth-Century Cleveland

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ABSTRACT

Introduction: During the late 19th century, Cleveland experienced rapid industrial expansion alongside persistently high rates of stillbirth. While modern research has documented associations between environmental conditions and adverse birth outcomes, the historical relationship between industrial development and stillbirth remains poorly understood at the neighborhood scale. This study examines whether stillbirths in Cleveland, Ohio, between 1862 and 1885 became more spatially concentrated near major industrial sites following their opening.

Methods: Using geocoded burial records documenting 840 stillbirths and geographic information systems (GIS), stillbirth locations were analyzed within 0 to 1 mile and 1 to 2 mile buffers surrounding 5 industrial sites during standardized 5-year periods before and after site openings. The analysis emphasizes proportional change in stillbirth location rather than absolute counts or population-based risk estimates, allowing spatial comparison across sites and time periods. Spatial patterns were assessed using paired before-and-after maps and a change-focused results table.

Results: Results indicate that several industrial sites, particularly Grasselli Chemical Company and Upson Nut and Bolt, were associated with increased concentrations of stillbirths within close residential proximity following opening. These changes reflect localized spatial redistribution rather than citywide increases in stillbirth occurrence. A contextual wind-direction map provides environmental background without implying exposure measurement or causal inference.

Conclusion: This study does not establish causation. Instead, it demonstrates a spatial association between industrial expansion and the distribution of stillbirths within an industrializing city. By applying GIS methods to historical records, this research contributes to historical geography and environmental health scholarship and illustrates how industrial development reshaped neighborhood-level health patterns in 19th-century Cleveland.

Keywords: Stillbirth; Industrialization; Historical GIS; Spatial analysis; Ohio public health history

INTRODUCTION

During the late 19th century, Cleveland, Ohio, underwent rapid industrial expansion that transformed its urban landscape and residential geography. Large manufacturing complexes, steel works, rail yards, and chemical plants were established across the city, frequently adjacent to working-class neighborhoods. This growth occurred alongside extensive environmental degradation, including coal smoke from industrial combustion, chemical byproducts, and industrial waste discharged into local waterways. Contemporary municipal reports and later historical scholarship document worsening air and water conditions during this period, particularly in neighborhoods closest to industrial corridors.[1] At the same time, stillbirth and infant mortality remained persistent public health concerns in urban America, especially among populations living in dense industrial districts.

Modern epidemiological research has demonstrated associations between adverse environmental conditions and poor birth outcomes, including stillbirth. Studies have linked prenatal exposure to airborne particulate matter produced by combustion processes and to contaminated water sources with increased risks of adverse birth outcomes, including fetal loss, low birth weight, and neonatal complications.[2-5] Recent research has further demonstrated that exposure to fine particulate matter (PM2.5) during pregnancy is associated with

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an increased risk of stillbirth, with some studies reporting substantially elevated risk during later trimesters.[6,7] These findings provide a framework for understanding how environmental stressors can affect reproductive health. However, most existing evidence derives from modern contexts characterized by regulated industrial activity, automobile emissions, and systematic exposure monitoring. As a result, less is known about how early industrialization shaped reproductive outcomes in the absence of environmental regulation.

Historical research has examined the public health consequences of industrialization in 19th-century American cities, including Cleveland. Studies of sanitation and infrastructure development have shown that the introduction of clean water systems and sewerage contributed to declines in child mortality during the late 19th and early 20th centuries.[8,9] Other work has identified broader relationships between industrial pollution and mortality during this period.[10-12] While this literature has provided important insight into urban health transitions, it has largely focused on aggregate mortality trends and citywide averages. Reproductive outcomes such as stillbirth have received less attention, and few studies have examined these outcomes at fine spatial scales.

Unlike many causes of infant death linked to infectious disease, stillbirth is closely tied to maternal health, residential environment, and prenatal conditions. In the 19th century, working-class households were commonly situated near factories, rail corridors, and industrial facilities that relied heavily on coal combustion and generated substantial local pollution.[1] Examining whether stillbirths became more spatially concentrated near industrial sites following their opening provides a means of assessing how industrial expansion may have altered neighborhood-level health patterns.

Despite growing interest in environmental health history, few studies have applied geographic information systems (GIS) to examine stillbirth distributions in relation to specific industrial sites. Research on Cleveland's industrialization has documented environmental decline, urban crowding, and social inequality but has rarely integrated residential-scale spatial analysis of reproductive outcomes.[1,13] As a result, the spatial relationship between industrial expansion and stillbirth distribution during Cleveland's industrial peak remains poorly understood.

The present study addresses this gap by examining the spatial distribution of stillbirths in Cleveland, Ohio, between 1862 and 1885 in relation to the opening of 5 major industrial sites. This period predates the widespread use of automobiles, allowing the analysis to focus on industrial combustion and manufacturing activity rather than motor vehicle emissions. Rather than attempting to establish causal relationships between pollution and fetal death, the study adopts a descriptive spatial approach. Using geocoded burial records and GIS, stillbirths are examined within 0 to 1 mile and 1 to 2 mile buffers surrounding each industrial site during standardized 5-year periods before and after site opening. The analysis emphasizes proportional change in stillbirth location rather than population-based risk estimates.

By integrating historical records with spatial analysis, this study contributes to historical geography and environmental health scholarship. It demonstrates how industrial expansion reshaped urban space and localized health outcomes within an industrializing city. More broadly, the findings highlight the importance of proximity, neighborhood context, and spatial structure in understanding how industrialization influenced health patterns in the late 19th century.

METHODS

Study Design

This study employs a descriptive spatial historical design to examine whether stillbirths in Cleveland, Ohio, became more spatially concentrated near major industrial sites following their opening. The analysis focuses on spatial association using standardized before-and-after comparisons. It does not attempt to establish causation, quantify pollutant exposure, or estimate population-level risk.

Study Setting and Time Frame

The study setting is Cleveland, Ohio. The analytic dataset includes stillbirth records dated from 1862 to 1885. Although additional stillbirth records exist outside this period, the analysis is restricted to these years to bracket the opening dates of the selected industrial sites and to support consistent five-year before-and-after comparisons. This period captures Cleveland's rapid industrial expansion prior to the widespread adoption of automobiles.

Stillbirth Data and Case Definition

Stillbirth data were obtained from historical burial records documenting fetal deaths within Cleveland. The outcome was defined as stillbirth only. Stillbirths were used as the primary outcome because historical burial records provide one of the most consistent and identifiable measures of pregnancy outcome in the 19th century, whereas modern indicators such as low birth weight, preterm birth, and growth restriction are not systematically recorded in historical datasets. Records coded as neonatal death were excluded. A small number of entries coded as "premature death" were reviewed individually and included only when contextual information indicated fetal death rather than postnatal mortality. This approach reflects the ambiguity of historical cause-of-death terminology while maintaining a consistent outcome definition. A total of 840 stillbirth records met inclusion criteria and were retained for analysis.

Industrial Site Selection

Five industrial sites were selected based on historical significance, industrial scale, and geographic distribution across Cleveland: Grasselli Chemical Company (opened 1867); Cleveland Rolling Mill and Newburgh Works (opened 1868); Upson Nut and Bolt, later Republic Steel (opened 1872); Collinwood Railroad Yards (opened 1873); and Cleveland Works, later Otis Iron and Steel (opened 1880).

Cleveland contained numerous industrial facilities during this period. Including a larger number of sites would increase spatial overlap and reduce interpretability of site-specific patterns. The selected sites also opened prior to the widespread use of automobiles, reducing the likelihood that motor vehicle emissions would confound patterns

attributed to industrial activity. Historical accounts document the environmental and residential context of these industries within Cleveland's industrial landscape.[1]

Industrial site locations were represented as point features derived from historical maps and archival records and geocoded into the GIS environment.

Geocoding and Spatial Data Preparation

Geocoding refers to the process of converting residential addresses from burial records into geographic coordinates that can be mapped and analyzed spatially. A GIS environment is a digital platform used to store, manage, and analyze spatial data, allowing relationships between location and health outcomes to be examined. Planar distance refers to straight-line distance measured between 2 points on a flat map surface, which is appropriate for short distances within a single city.

Residential addresses from burial records were geocoded using historical street basemaps in ArcGIS Pro. All geocoded points were visually inspected to confirm alignment with historical street layouts and neighborhood structure.

To avoid artificially inflating apparent clustering, multiple stillbirth records associated with the same discrete residential address were consolidated into a single spatial point. An exception was applied for extended address corridors, most notably Broadway. Corridor addresses represent linear residential density across multiple structures and blocks rather than a single household location. In these cases, records were retained as separate observations to preserve meaningful spatial variation. This rule was applied consistently across the dataset.

Temporal Framework

A standardized temporal framework was applied independently to each industrial site. For each site, 2 time windows were defined: 5 years before opening and 5 years after opening. These windows were selected to capture short-term spatial redistribution associated with industrial openings while limiting the influence of longer-term citywide trends. Because sites were analyzed separately, individual calendar years may appear in multiple site-specific comparisons.

Buffer Definition and Spatial Assignment

For each industrial site, planar distance buffers were generated at 0 to 1 mile and 1 to 2 miles from the site location. Planar buffers were used because distances were short and the analysis is conducted at the city scale, making planar distance an appropriate and consistent approximation.

To prevent double-counting across industrial sites, each stillbirth was assigned to a single site based on closest geographic proximity. Stillbirths were not counted multiple times across overlapping buffers. After nearest-site assignment, stillbirths were classified into the 0 to 1 mile or 1 to 2 mile buffer zone for that site and for the corresponding time window.

Outcome Metrics and Denominator Selection

The primary outcome of interest is the spatial distribution of stillbirths rather than population-based stillbirth risk. Accordingly, buffer-zone proportions were calculated using the total number of stillbirths within each site-specific time window as the denominator. For each industry and time window, the proportion of stillbirths located within 0 to 1 mile and within 1 to 2 miles was calculated. Percentage-point change was computed as the difference between after and before proportions. Because this study is descriptive and exploratory, no formal statistical hypothesis testing was conducted; interpretation focuses on observed spatial patterns and proportional differences rather than statistical significance.

Population-based denominators were not used because reliable historical data on pregnancy occurrence, fertility timing, and residential exposure at the neighborhood scale are not available for this period. As a result, general female population counts would not provide an appropriate denominator for examining the spatial distribution of stillbirths.[14,15]

Mapping and Visualization

Before-and-after maps were produced for Grasselli Chemical Company and Upson Nut and Bolt to visualize the strongest observed spatial patterns. Each map pair uses identical extent, scale, and symbology to allow direct visual comparison. Industrial locations are marked, buffer rings are displayed, and stillbirth locations are shown as point features.

A separate contextual map displays all stillbirths recorded between 1862 and 1885 alongside all 5 industrial sites and a qualitative indicator of prevailing regional wind direction. The wind indicator provides environmental context only and does not represent historical wind reconstruction, exposure modeling, or pollutant dispersion analysis.

Ethical Considerations

This study uses historical archival records and involves no living human subjects. Data were handled conservatively, and results are presented as spatial association rather than causal inference.

RESULTS

Spatial Patterns Before and After Industrial Opening

Figure 1 illustrates the spatial distribution of stillbirths within the 5-year periods before and after the opening of the Grasselli Chemical Company in 1867. The left panel displays stillbirth locations prior to opening, while the right panel displays locations following opening. Points represent geocoded stillbirth addresses. Concentric rings indicate 0 to 1 mile and 1 to 2 mile buffers centered on the industrial site, marked by a star. Both panels use identical scale, extent, and symbology to allow direct visual comparison. Numeric callouts indicate selected residential addresses associated with multiple stillbirth records.

Visual comparison of the 2 panels shows a clear shift in spatial concentration following the opening of the Grasselli site. In the 5 years prior to opening, stillbirths were distributed across surrounding neighborhoods with relatively fewer occurrences within the immediate 0 to 1 mile buffer. In contrast, the post-opening period shows a greater concentration of stillbirths closer to the industrial site, particularly within the 0 to 1 mile zone and along nearby residential corridors.

Figure 1. Stillbirth Locations Surrounding the Grasselli Chemical Company Before and After Industrial Opening

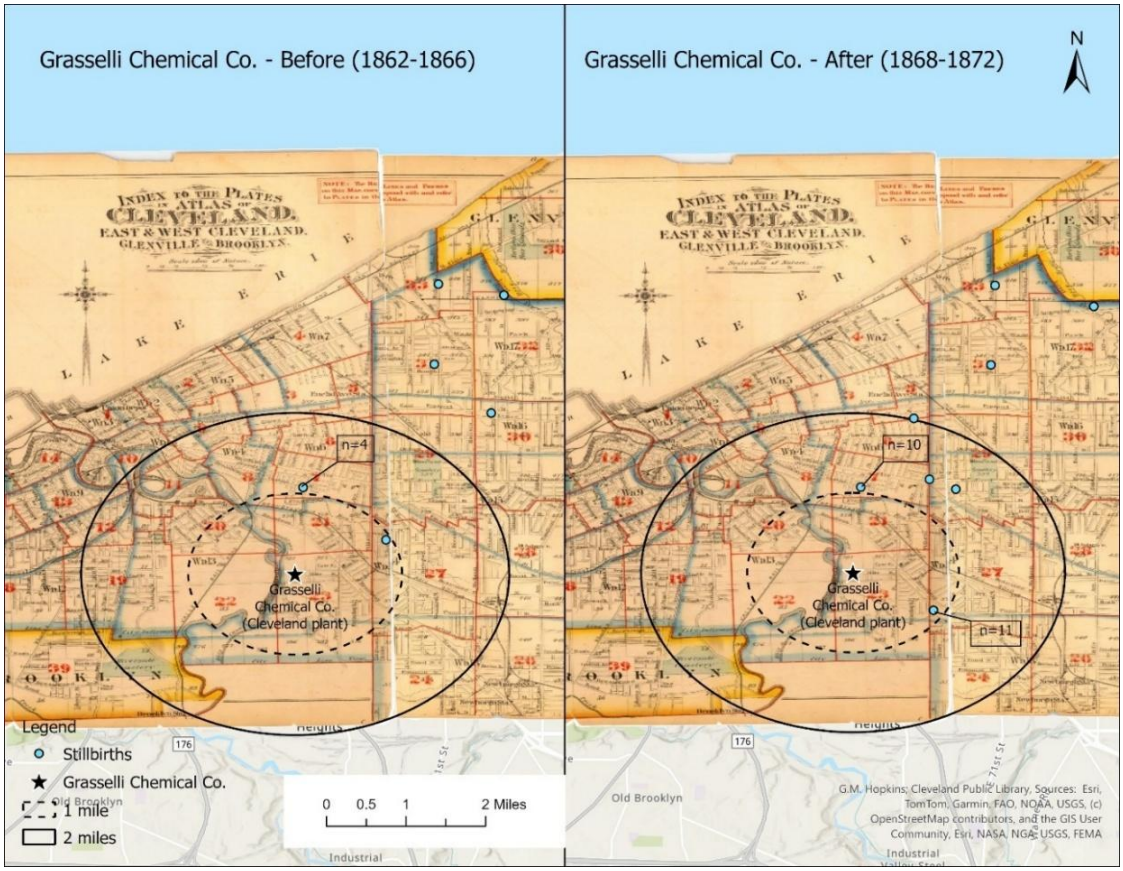


Figure 2 presents a similar comparison for Upson Nut and Bolt, which opened in 1872. As in Figure 1, the left panel displays stillbirths occurring during the 5-year period before opening, and the right panel displays stillbirths occurring during the 5-year period after opening. Identical symbology and scale are used to facilitate comparison across time periods. Numeric callouts identify selected addresses with multiple recorded stillbirths.

Prior to opening, stillbirths surrounding the Upson site were already concentrated within the immediate 0 to 1 mile buffer, reflecting dense residential development near the industrial location. Following opening, stillbirths appear more tightly clustered near the site, with a larger share occurring within the 0 to 1 mile zone. Although stillbirths were present in close proximity before opening, the post-opening pattern reflects increased spatial concentration rather than redistribution from more distant neighborhoods. Compared with Grasselli Chemical Company, the Upson site shows a larger absolute number of stillbirths, while exhibiting a similar directional pattern of increased proximity after opening.

Buffer-Based Proportional Changes

Table 1 summarizes proportional changes in stillbirth location within the 0 to 1 mile and 1 to 2 mile buffers for all 5 industrial sites examined. Values represent the proportion of stillbirths occurring within each buffer relative to the total number of stillbirths recorded during the corresponding 5-year period. Percentage-point change reflects the difference between after and before proportions. Stillbirths were assigned to a single industrial site based on closest geographic proximity to avoid double-counting.

Grasselli Chemical Company and Upson Nut and Bolt exhibit the largest increases in the proportion of stillbirths occurring within the 0 to 1 mile buffer following site opening. Grasselli shows an increase of 8 percentage points within the 0 to 1 mile zone and a corresponding increase within the 1 to 2 mile zone. Upson Nut and Bolt exhibits a 5 percentage point increase within the 0 to 1 mile buffer and a decrease within the 1 to 2 mile buffer, indicating a redistribution toward closer residential proximity.

Other industrial sites show weaker or less consistent patterns. The Cleveland Rolling Mill and Newburgh Works demonstrate limited change within the 0 to 1 mile buffer but a decline within the 1 to 2 mile zone. Collinwood Railroad Yards and Cleveland Works display minimal proportional change, reflecting smaller denominators and differences in surrounding residential density.

Environmental Context

Figure 3 presents a contextual map displaying all stillbirths recorded between 1862 and 1885 alongside the locations of the 5 industrial sites examined in this study. Arrows indicate prevailing regional wind direction and are included for qualitative environmental context only. This map does not represent historical wind reconstruction, exposure measurement, or pollutant dispersion modeling.

Figure 2. Stillbirth Locations Surrounding Upson Nut and Bolt Before and After Industrial Opening

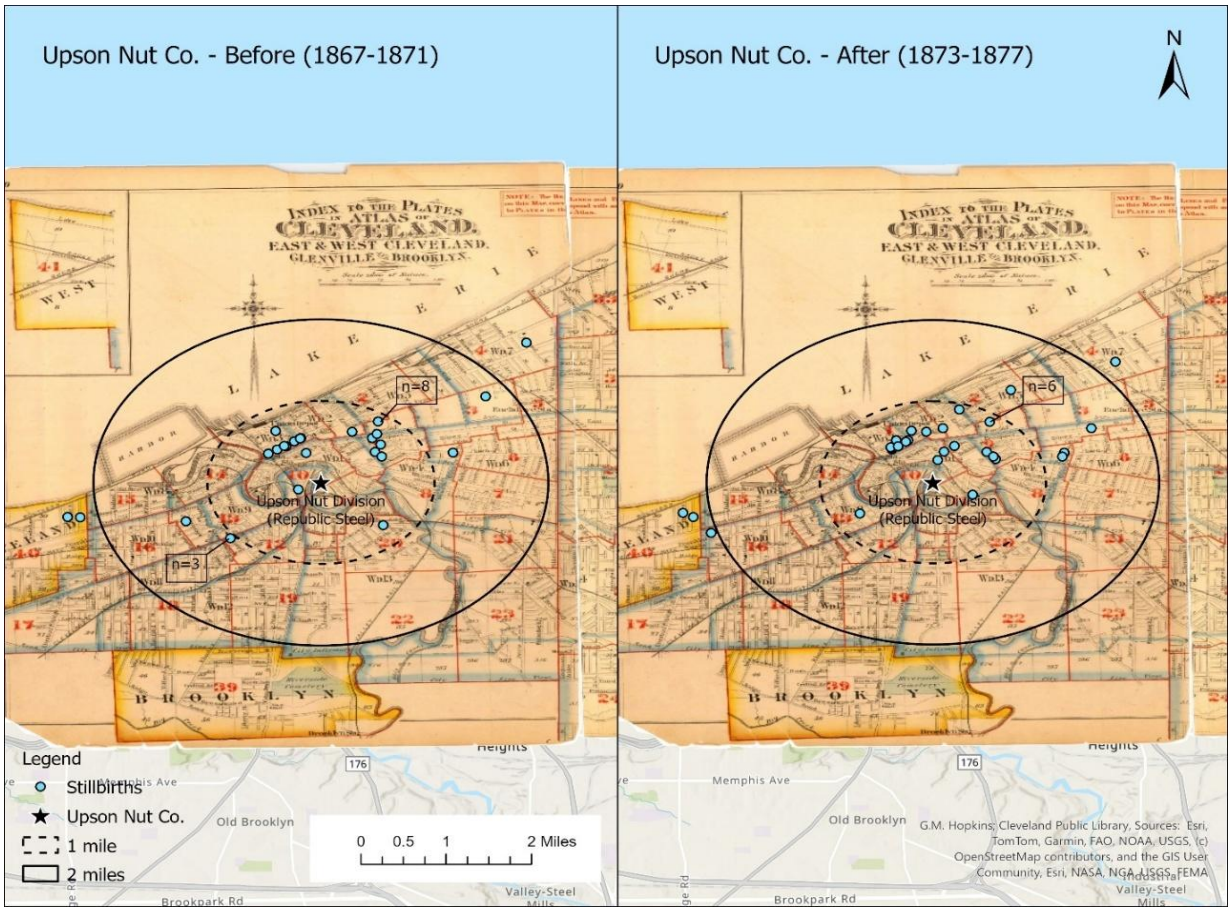


Table 1. Changes in Spatial Distribution of Stillbirths Relative to Industrial Site Openings, Cleveland, 1862 to 1885

Industry	Before Total SB	After Total SB	0–1 mile Before (%)	0–1 mile After (%)	Δ 0–1 mile (pp)	1–2 mile Before (%)	1–2 mile After (%)	Δ 1–2 mile (pp)
Grasselli	28	73	7.1	15.1	8.0	14.3	23.3	9.0
Rolling Mill	18	36	0.0	0.0	0.0	33.3	0.0	-33.3
Upson Nut	156	124	60.3	65.3	5.0	14.7	10.5	-4.2
Collinwood	19	4	21.1	0.0	-21.1	0.0	0.0	0.0
Cleveland Works	3	1	0.0	0.0	0.0	0.0	0.0	0.0

Abbreviation: SB, stillbirths; Δ, percentage point change; pp, percentage point.

The contextual map illustrates that stillbirths occurred throughout the city during the study period while also highlighting clustering along several industrial corridors. The proximity of dense residential areas to major industrial sites provides geographic context for the site-specific patterns observed in Figures 1 and 2 and the proportional changes summarized in Table 1.

DISCUSSION

This study examined whether the opening of major industrial sites in late 19th-century Cleveland was associated with a spatial redistribution of stillbirths toward those sites. Across the 5 industries analyzed, the results indicate that industrial openings were frequently followed by increases in the proportion of stillbirths occurring within close residential proximity, particularly within the 0 to 1 mile buffer. These spatial shifts were not uniform across all sites but were most pronounced for Grasselli Chemical Company and Upson Nut and Bolt. The observed patterns suggest that industrial expansion coincided with localized changes in neighborhood-level health outcomes rather than citywide increases in stillbirth occurrence.

Interpretation of Spatial Patterns

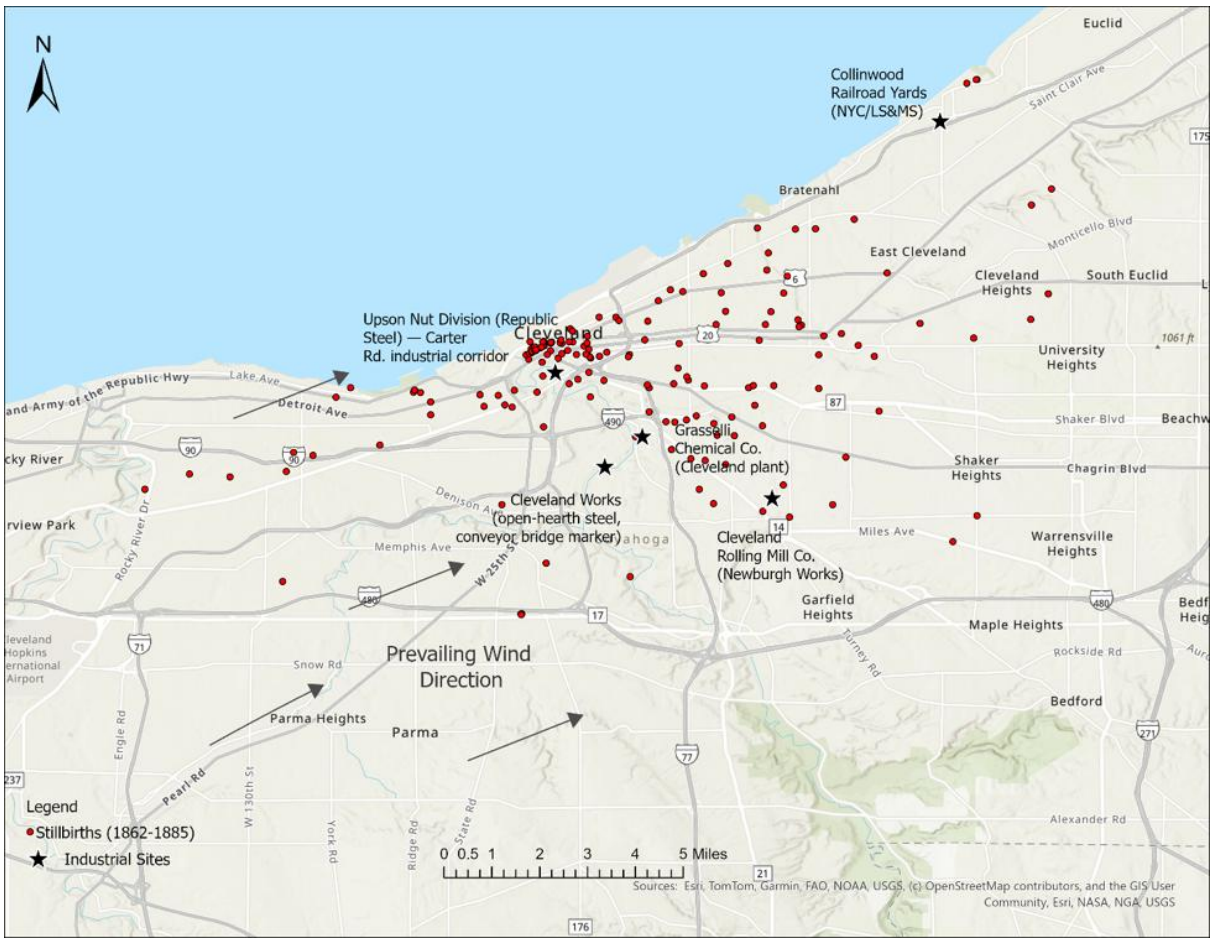
The most pronounced spatial redistribution was observed near Grasselli Chemical Company. Visual comparison of before-and-after maps shows a tightening of stillbirth locations toward the industrial core following the site's opening, particularly along nearby residential corridors. This pattern aligns with historical accounts describing dense working-class housing developing adjacent to large industrial operations during this period.[1] Although this study does not assess individual-level exposure or causal mechanisms, the consistent increase in stillbirth proximity following industrial opening suggests that industrial development coincided with meaningful spatial restructuring of reproductive health outcomes.

A similar, though contextually distinct, pattern was observed for Upson Nut and Bolt. While stillbirths were already present near the site prior to opening, the post-opening period shows a clearer concentration within the immediate 0 to 1 mile buffer. The proportional changes observed for Upson Nut and Bolt were among the largest in the study, despite smaller overall denominators than those for Grasselli. This indicates that even moderate-scale industrial facilities may have been associated with localized spatial shifts in health outcomes when situated within densely populated residential areas.

In contrast, other sites such as the Cleveland Rolling Mill and Newburgh Works, Collinwood Railroad Yards, and Cleveland Works exhibited weaker or less consistent spatial patterns. These differences likely reflect variation in surrounding land use, residential density, and the timing of neighborhood development relative to industrial expansion. The absence of strong signals at all sites underscores the importance of site-specific analysis and cautions against aggregated approaches that may obscure localized spatial dynamics.

Importantly, the absence of consistent spatial patterns across all industrial sites does not diminish the relevance of the strongest observed associations. Several sites, including Collinwood Railroad Yards and Cleveland Works, were associated with relatively small numbers of stillbirths within the defined buffers, limiting the interpretability of proportional changes. In contrast, sites such as Grasselli Chemical Company and Upson Nut and Bolt had substantially larger denominators and demonstrated more consistent spatial clustering within close residential proximity following industrial opening. These patterns suggest that the most densely populated and industrially integrated environments were associated with the clearest spatial shifts in stillbirth distribution, while sites with smaller case counts provide limited inferential value.

Figure 3. Contextual Map of Stillbirths and Industrial Sites in Cleveland, 1862 to 1885



Urban and Environmental Context

Urban crowding appears to have played an important role in shaping the observed distributions. Many stillbirth records were associated with repeated residential addresses, particularly along extended corridors such as Broadway. Rather than treating these overlaps as data artifacts, this study interprets them as evidence of high residential density within industrial neighborhoods. Such density would have amplified the spatial visibility of adverse health outcomes regardless of the specific environmental mechanisms involved.

The inclusion of a qualitative wind-direction map provides additional geographic context for interpreting the spatial patterns observed. Prevailing west to east regional wind directions align with the orientation of several industrial corridors and adjacent residential neighborhoods. While this study does not model pollutant dispersion or historical exposure, the wind context supports the plausibility of localized environmental influences operating alongside broader social and spatial processes. Importantly, this contextual evidence is not presented as a basis for inference but as part of a broader geographic framing.

Implications for Historical Geography and Public Health

These findings contribute to historical geographic scholarship by demonstrating how industrial expansion reshaped urban space and localized health outcomes within an industrializing city. By focusing on stillbirths, an outcome closely linked to maternal health and residential conditions, this study highlights a dimension of industrialization that is often underexamined in historical mortality research. The use of proportional measures relative to stillbirth totals within each time window allows for spatial comparison across time windows without relying on population denominators that are difficult to reconstruct at fine geographic scales.

More broadly, the results underscore the uneven spatial distribution of health outcomes during periods of rapid industrial growth. Industrialization did not affect urban populations uniformly but interacted with neighborhood structure, residential proximity, and socioeconomic constraints to produce localized concentrations of adverse outcomes. This spatial perspective complements existing historical accounts of industrial growth by foregrounding its neighborhood-level health implications.

Limitations

Several limitations should be acknowledged. First, this study is descriptive and does not establish causation. Stillbirths were analyzed spatially in relation to industrial openings, but no individual-level exposure data are available, and multiple unmeasured factors may have contributed to the observed patterns. Although 2 industrial sites, Grasselli Chemical Company and Upson Nut and Bolt, showed increases in the proportion of stillbirths following opening, the remaining sites did not demonstrate consistent changes. This variability indicates that industrial presence alone does not uniformly explain spatial differences in stillbirth distribution.

Second, alternative explanations for stillbirth during the 19th century must be considered. Infectious diseases, including diarrheal illness, dysentery, and complications related to poor sanitation, were major contributors to infant and maternal mortality during this period. Overcrowding, limited access to clean water, and poor living conditions in rapidly expanding industrial neighborhoods likely played a substantial role in shaping stillbirth patterns. The clustering of stillbirths observed at specific residential addresses, particularly near the Grasselli site, may reflect the effects of high residential density in addition to environmental exposures.

As a result, it is not possible to isolate the specific contribution of industrial air pollution from these broader environmental and social conditions. The observed spatial patterns should therefore be interpreted as associations within a complex urban environment rather than evidence of a single causal mechanism.

Third, historical burial records are subject to inconsistencies in reporting and classification, including ambiguity between stillbirth and premature death designations. Additionally, some industrial sites were associated with relatively small numbers of stillbirths within specific buffers, which can inflate proportional changes and should be interpreted cautiously. The 5-year before-and-after framework, while useful for standardization, may not capture longer-term trends or delayed effects of industrial development.

Finally, even in modern contexts, a substantial proportion of stillbirths, often classified as unexplained, have no clearly identified cause.[16] This inherent uncertainty further limits the ability to attribute observed historical patterns to any single factor. Wind direction is included solely as qualitative context and does not represent exposure modeling.

PUBLIC HEALTH IMPLICATIONS

Although this study is historical and does not establish causation, the findings highlight the importance of place-based analysis for understanding public health patterns in Ohio cities. The observed clustering of stillbirths near major industrial sites following their opening suggests that neighborhood context and residential proximity played a meaningful role in shaping reproductive health outcomes during Cleveland's industrial expansion. These results reinforce the value of examining health outcomes at fine spatial scales rather than relying solely on citywide averages, which can obscure localized disparities.

For public health practitioners and researchers in Ohio, this study demonstrates how historical records and geographic methods can be used to identify long-standing spatial patterns in health outcomes. Understanding the historical roots of neighborhood-level health disparities can inform contemporary discussions of environmental justice, urban planning, and community health surveillance. By illustrating how industrial development reshaped health patterns within specific neighborhoods, this research underscores the continued relevance of spatial context in public health research and supports the integration of geographic approaches into the study of health inequities in Ohio.

Despite these limitations, the results demonstrate consistent and interpretable spatial shifts in stillbirth distributions following the opening of major industrial sites in late 19th-century Cleveland. The strongest spatial signals occurred near large industrial operations embedded within dense residential neighborhoods, suggesting that industrial expansion coincided with localized restructuring of reproductive health outcomes. By integrating historical records with GIS-based spatial analysis, this study illustrates the value of geographic approaches for examining health patterns during early industrialization and contributes to a deeper understanding of how place and proximity shaped health outcomes in the 19th-century city.

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AUTHOR CONTRIBUTIONS

Taysir Karakra conceptualized the study, conducted data collection and spatial analysis, and drafted and revised the manuscript. Anne Su and Melissa Clark provided research supervision, methodological guidance, and critical feedback on the manuscript.

DATA SOURCES

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Cuyahoga County Archives. Historical industrial site records and maps used to identify factory locations and opening dates in 19th-century Cleveland.

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