Poisoned for Oil: Mapping Petrochemical Emissions and Public Health Risks in the Alsen/St. Irma Lee Community, LA, USA

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Abstract

Environmental justice communities across the United States continue to experience disproportionate exposure to industrial pollution, particularly in regions dominated by petrochemical infrastructure. The Alsen / St. Irma Lee Community in East Baton Rouge Parish, Louisiana, represents one of the most vulnerable historically marginalized communities situated adjacent to major petrochemical facilities. This study integrates Geographic Information Systems (GIS), machine learning techniques, and environmental emissions data to spatially quantify petrochemical pollution exposure and associated public health risks within the community. Toxic Release Inventory (TRI) data, facility emission records, and spatial proximity analysis were employed to evaluate the distribution and intensity of airborne and waterborne pollutants. Results indicate that facilities emitting more than 500 pounds of toxic compounds pose elevated regulatory and public health risks, with the ExxonMobil Baton Rouge Plant identified as the dominant pollution contributor. Key hazardous chemicals released include cumene, styrene, trichloroethylene, and tetrachloroethylene, substances linked to neurological disorders, respiratory illnesses, and carcinogenic effects. Spatial risk mapping reveals concentrated exposure zones within residential areas, confirming long-standing environmental inequities. The findings emphasize the urgent need for strengthened emission controls, transparent monitoring systems, and targeted community health interventions to mitigate cumulative environmental and health burdens in the Alsen / St. Irma Lee community.

1. Introduction

1.1 Environmental Justice and Industrial Pollution

Environmental justice refers to the equitable treatment and meaningful involvement of all people in environmental decision-making, regardless of race, income, or social status. However, numerous studies have demonstrated that low-income and minority communities in the United States are disproportionately exposed to industrial pollution, hazardous waste facilities, and toxic emissions (Hafetz, 1998; Mohai et al., 2009). These disparities often arise from historical zoning practices, discriminatory housing policies, and limited political representation.

Louisiana's petrochemical corridor, commonly referred to as "Cancer Alley," contains one of the highest concentrations of oil refineries and chemical plants in North America. Communities located within this corridor experience elevated cancer risks, respiratory illnesses, and chronic health conditions associated with prolonged exposure to hazardous air pollutants (Johnston et al., 2018).

1.2 Historical Development of the Alsen / St. Irma Lee Community

The Alsen / St. Irma Lee Community was established in 1872 through the efforts of the Freedmen's Bureau, an agency of the United States Department of War created to assist enslaved African Americans following the Civil War. Initially developed as a rural agrarian settlement, the community relied heavily on farming, logging, and small-scale local commerce.

Over time, industrial expansion fundamentally altered the social and environmental landscape. The decline of agriculture and the mechanization of labour resulted in widespread unemployment and economic instability. Subsequently, landfill operations and petrochemical developments encroached upon residential zones, gradually transforming the community into a high-risk industrial buffer zone. These transformations occurred with limited community consent, reinforcing systemic environmental inequities that persist today (Osei et al., 2025).

1.3 Public Health Implications of Petrochemical Exposure

Exposure to petrochemical emissions has been strongly associated with adverse health outcomes, including respiratory disease, neurological disorders, reproductive complications, and increased cancer incidence (Vlaanderen et al., 2013; Cushing et al., 2015). Compounds such as styrene, trichloroethylene, and benzene derivatives are particularly concerning due to their persistence in air and groundwater systems.

In communities such as Alsen, cumulative exposure risk is intensified by proximity to multiple facilities, aging infrastructure, and insufficient environmental monitoring. These conditions create overlapping vulnerability pathways that disproportionately affect children, the elderly, and individuals with pre-existing health conditions (Osei et al., 2025).

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1.5 Role of GIS and Machine Learning in Environmental Health Studies

Geographic Information Systems (GIS) provide powerful tools for evaluating spatial patterns of pollution exposure, facility proximity, and population vulnerability. When combined with machine learning algorithms, GIS enables advanced risk zone classification and the identification of high-emission clusters (Jerrett et al., 2013; Bian et al., 2024).

Recent studies have demonstrated that spatially explicit risk modeling improves environmental health assessments by capturing cumulative impacts rather than isolated emissions (Cushing et al., 2015; Johnston et al., 2018; Mikati et al., 2018). This approach is particularly effective in environmental justice research, where exposure patterns are spatially heterogeneous and socially stratified. The primary objective of this study is to examine petrochemical pollution exposure within the Alsen / St. Irma Lee Community by integrating geospatial analysis and environmental emissions data. Specifically, the study aims to map the spatial distribution of petrochemical facilities across the community, quantify toxic chemical emissions using facility-level Toxic Release Inventory (TRI) data, and apply GIS-based spatial analysis and machine-learning classification techniques to identify high-risk exposure zones. In addition, the study evaluates the potential public health implications associated with dominant chemical pollutants released into the environment and provides evidence-based recommendations to support improved regulatory enforcement, environmental monitoring, and community protection strategies.

2. Materials and Methods

2.1 Study Area

The Alsen / St. Irma Lee Community is in northern East Baton Rouge Parish, Louisiana, adjacent to major petrochemical infrastructure, including refineries, chemical processing plants, and industrial waste facilities. The community lies within the Mississippi River industrial corridor and is surrounded by high-density emission sources (Osei et al., 2025).

Despite its proximity to Baton Rouge's economic centre, the area exhibits persistent socioeconomic vulnerability characterized by low household income, limited healthcare access, and aging housing infrastructure. The spatial juxtaposition of residential zones and industrial operations makes the community particularly susceptible to chronic environmental exposure.

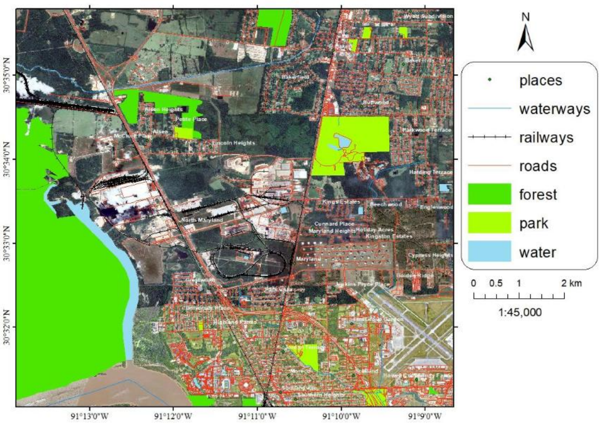

Figure 1. A Map of Alsen/St. Irma Lee Community Village in Baton Rouge, USA (Osei et al., 2025)

2.2 Materials and Data Sources

This study integrated geospatial, environmental, and demographic datasets to assess petrochemical emission exposure and public health risk in the Alsen / St. Irma Lee Community, Louisiana. The datasets were selected to capture both the spatial distribution of pollution sources and the population potentially affected by toxic emissions.

Primary emissions data were obtained from the United States Environmental Protection Agency (EPA) Toxic Release Inventory (TRI) program, which provides facility-level annual records of chemical releases to air, water, and land. TRI data have been widely used in environmental justice and exposure assessment studies due to their standardized reporting structure and national coverage (Johnston et al., 2018; Mikati et al., 2018).

Spatial locations of industrial facilities were obtained as point-based shapefiles and geocoded using facility latitude and longitude coordinates provided in the TRI dataset. Community boundaries and demographic characteristics were derived from U.S. Census Bureau block group data, enabling the identification of residential zones within the potential exposure distance of petrochemical sources.

Health impact classifications for emitted chemicals were compiled from peer-reviewed toxicological literature and EPA Integrated Risk Information System (IRIS) documentation. These classifications were used to associate chemical exposure with known or probable health outcomes, including carcinogenicity, neurological toxicity, and respiratory impairment (ATSDR, 2022).

Data / Material	**Description**	**Source**
Toxic Release Inventory (TRI)	Annual facility-level toxic chemical emissions (air, water, land)	U.S. Environmental Protection Agency (EPA)
Facility Location Shapefiles	Geographic coordinates of petrochemical facilities	EPA TRI Database
Community Boundary Data	Census block group and community polygons	U.S. Census Bureau

Data / Material	Description	Source
Population Data	Demographic and residential distribution	American Community Survey (ACS)
Chemical Toxicity Profiles	Health risk classification of pollutants	EPA IRIS; ATSDR
GIS Software	Spatial analysis and mapping	ArcGIS Pro (ESRI)
Statistical Analysis	Emission normalization and classification	Python / ArcGIS Spatial Analyst

Table 1. Materials and Data Sources Used in the Study

2.3 GIS Data Processing and Spatial Analysis

All spatial datasets were projected into a unified coordinate reference system (NAD 1983 Louisiana State Plane South) to ensure geometric consistency and minimize spatial distortion. Data preprocessing included removal of duplicate facility records, correction of spatial offsets, and validation of facility locations using high-resolution basemap imagery.

2.3.1 Proximity-Based Exposure Assessment

To quantify potential residential exposure to petrochemical emissions, buffer zone analysis was implemented around each facility. Buffers of increasing radial distance (e.g., 500 m, 1 km, and 3 km) were generated to represent zones of elevated exposure risk, consistent with prior environmental health studies (Jerrett et al., 2013; Bian et al., 2024).

The buffer distance function is mathematically represented as Equation (1).

$$B_i = \{x \in \mathbb{R}^2 : d(x, f_i) \leq r\} \qquad (1)$$

where:

- B_i = buffer zone surrounding facility *i*
- $d(x, f_i)$ = Euclidean distance between residential location *x* and facility *i*
- r = buffer radius (meters)

Residential polygons intersecting each buffer were classified as potentially exposed communities.

2.3.2 Kernel Density Estimation (KDE)

To identify emission intensity hotspots, Kernel Density Estimation (KDE) was applied to facility emission values. KDE transforms discrete emission point data into a continuous surface representing the spatial concentration of pollutants (Silverman, 2018).

The KDE function is defined using Equation (2).

$$f(x) = \frac{1}{nh^2} \sum_{i=1}^{n} K\left(\frac{d_i}{h}\right) \qquad (2)$$

where:

i. $f(x)$ = estimated emission density at location *x*
ii. n = number of facilities
iii. h = bandwidth (search radius)
iv. d_i = distance between location *x* and facility *i*
v. K = kernel function

This method allows visualization of cumulative pollution burden rather than individual facility impacts, which is critical for environmental justice evaluations (Mikati et al., 2018)

2.4 Machine Learning-Based Risk Classification

2.4.1 Emission Normalization

To allow comparison across facilities emitting different chemical compounds, total emission quantities were normalized using a logarithmic transformation to reduce skewness (Equation (3).

$$E_i' = \log_{10}(E_i + 1) \qquad (3)$$

where:

i. E_i = total emission mass (lbs/year)
ii. E_i' = normalized emission value

Normalization improves classification stability and prevents dominance by extreme outliers (Barregard et al., 2019).

2.4.2 Supervised Risk Classification Model

A supervised classification framework was developed to categorize petrochemical facilities into risk classes based on annual emission magnitude. Facilities releasing more than 500 pounds of toxic substances per year were classified as high-risk emitters, consistent with regulatory screening thresholds reported in prior exposure studies (Cushing et al., 2015).

The classification rule is expressed as Equation (4).

$$R_i = \begin{cases} 1, & \text{if } E_i \geq 500 \text{ lbs/year} \\ 0, & \text{if } E_i < 500 \text{ lbs/year} \end{cases} \qquad (4)$$

where:

i. $R_i = 1$indicates a high-risk facility
ii. $R_i = 0$indicates a lower-risk facility

The supervised model was trained using labeled emission thresholds and validated through comparison with EPA regulatory benchmarks and historical violation records.

2.4.3 Model Validation

Model performance was evaluated using emission threshold agreement and spatial consistency analysis. Facilities classified as high-risk were expected to correspond with elevated KDE hotspot values and proximity to residential zones. Agreement between classification outputs and spatial density patterns served as internal validation, a method widely adopted in environmental exposure modelling (Jerrett et al., 2013; Huang & London, 2012)

2.5 Integration of Spatial Risk Layers

Final exposure risk maps were produced by integrating three spatial components:

1. Emission intensity surface (KDE)
2. Residential proximity buffers
3. Machine learning risk classification

The composite exposure risk index (ERI) was computed using Equation (5).

$$ERI = w_1 D + w_2 P + w_3 R \qquad (5)$$

where:

i. D = normalized emission density
ii. P = proximity score
iii. R = facility risk class
iv. w_1, w_2, w_3 = weighting coefficients

This integrated framework enabled identification of high-exposure zones within the Alsen / St. Irma Lee community and supported cumulative risk interpretation rather than single-pollutant analysis. The Conceptual framework used to map petrochemical emissions and Public Health Risks in the Alsen/St. Irma Lee Community is shown in Figure 2.

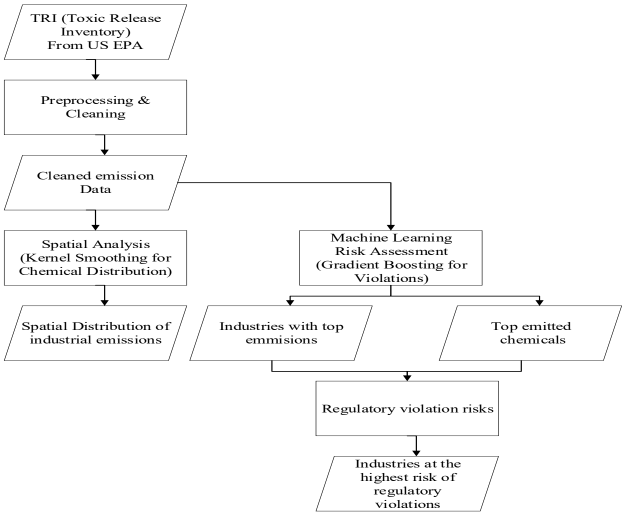

Figure 2. Conceptual Framework used to Map Petrochemical Emissions and Public Health Risks in the Alsen/St. Irma Lee Community

3. Results and Discussion

3.1 Spatial Distribution of Petrochemical Facilities

The spatial analysis revealed a pronounced clustering of petrochemical facilities surrounding the Alsen / St. Irma Lee Community (Figure 3). Figure 3 showed that multiple high-emission facilities are located within proximity to residential neighbourhoods, with several facilities situated within 1 km of homes, schools, and community centres. This spatial configuration substantially elevates the likelihood of chronic exposure to airborne and waterborne toxic compounds.

Figure 3. The kernel density surface shows the spatial distribution and intensity of toxic chemical releases (in pounds) from petrochemical facilities surrounding the Alsen / St. Irma Lee Community, East Baton Rouge Parish, Louisiana. Warmer colours (orange-red) indicate higher emission intensity, while cooler colours (green) represent lower emission concentrations. Black dots represent industrial facilities reporting releases to the EPA Toxic Release Inventory (TRI).

Kernel Density Estimation (KDE) results (Figure 3) demonstrated distinct emission hotspots concentrated along the industrial corridor bordering the Mississippi River. These hotspots coincide spatially with historically marginalized residential zones, reinforcing patterns documented in prior environmental justice studies indicating that minority communities are more likely to be located near pollution sources (Mohai et al., 2009; Mikati et al., 2018).

The concentration of emission sources within a limited geographic space indicates cumulative exposure conditions, where residents are simultaneously impacted by multiple facilities rather than isolated emitters. Such cumulative risk environments have been shown to significantly increase adverse health outcomes, particularly respiratory and cardiovascular diseases (Cushing et al., 2015).

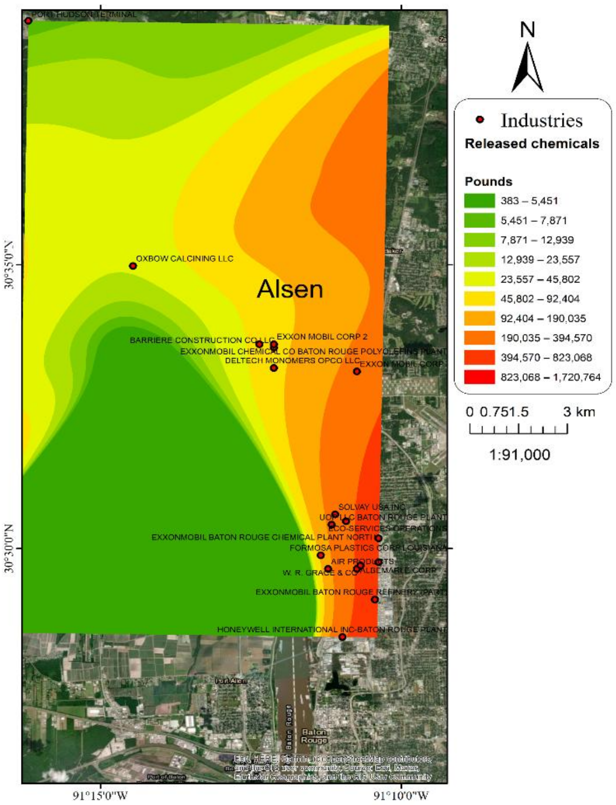

Figure 3. Spatial distribution and intensity of petrochemical emissions in the Alsen / St. Irma Lee Community, East Baton Rouge Parish, Louisiana.

3.2 Emission Magnitude and Facility Risk Classification

Application of the supervised machine learning classification revealed that facilities emitting more than 500 pounds of toxic chemicals annually represent the dominant contributors to environmental risk within the study area (Figure 4). These high-risk facilities exhibited strong spatial correspondence with KDE-identified emission hotspots, validating the robustness of the classification framework (Figure 3).

Among all industrial sources evaluated, the ExxonMobil Baton Rouge Plant emerged as the largest contributor to both airborne and waterborne toxic releases. Emission quantities from this facility exceeded those of surrounding plants by a substantial margin, positioning it as a central driver of cumulative pollution exposure in the Alsen / St. Irma Lee community.

The spatial overlap between high-risk facilities and residential buffers confirms findings from Johnston et al. (2018), who reported that petrochemical emissions in Louisiana disproportionately burden nearby low-income communities. Similar patterns have been observed nationally, where communities located within 3 km of major emitters exhibit significantly higher cancer risk indices compared to state and national averages (EPA, 2022).

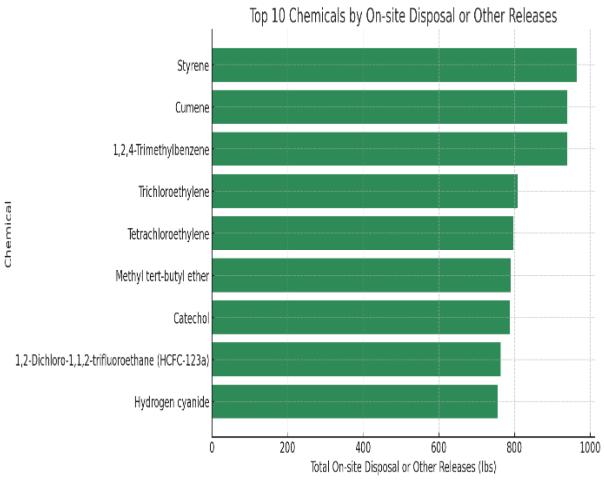

Figure 4. Distribution of the top ten toxic chemicals released through on-site disposal or other release pathways by petrochemical facilities within and surrounding the Alsen / St. Irma Lee Community. Release quantities are reported in pounds based on EPA Toxic Release Inventory (TRI) data.

3.3 Dominant Toxic Chemicals and Associated Health Risks

Analysis of TRI chemical release records identified several hazardous compounds released in significant quantities within the study area. The dominant chemicals include:

i. **Cumene (2,155 lbs):** Associated with neurological impairment, dizziness, respiratory irritation, and liver toxicity.
ii. **Styrene (1,391 lbs):** Classified as a probable human carcinogen affecting the central nervous system and respiratory tract (IARC, 2018).
iii. **1,2,4-Trimethylbenzene (940 lbs):** A volatile organic compound linked to eye irritation, lung inflammation, and headaches.
iv. **Trichloroethylene (808 lbs):** Strongly associated with kidney cancer, liver toxicity, and immune dysfunction (Rinsky et al., 2013).
v. **Tetrachloroethylene (797 lbs):** A known carcinogen with groundwater persistence and long-term exposure risk.

The presence of multiple carcinogenic and neurotoxic substances within a confined residential environment indicates a high cumulative health burden. Epidemiological studies demonstrate that long-term exposure to chlorinated solvents such as trichloroethylene and tetrachloroethylene significantly increases cancer incidence, particularly kidney and liver cancers (Guha et al., 2012).

Importantly, exposure risk is not limited to a single chemical but occurs through combined inhalation, dermal contact, and potential groundwater contamination pathways. Such multi-pathway exposure has been shown to exacerbate health disparities in environmental justice communities (Huang & London, 2016).

3.4 Spatial Exposure Risk Patterns within the Community

Integration of emission density, proximity buffers, and risk classification produced composite exposure maps highlighting zones of elevated environmental risk. High-risk zones were predominantly concentrated within the residential core of the Alsen / St. Irma Lee community, indicating direct spatial overlap between population centers and pollution sources.

Residents located within 1 km of high-risk facilities were classified as facing the greatest exposure potential. This finding aligns with prior atmospheric dispersion studies indicating that pollutant concentrations decline sharply beyond 3 km from emission sources, with the most severe exposure occurring within the first kilometer (Jerrett et al., 2013).

The spatial configuration observed in this study reflects structural environmental inequality, where industrial land use decisions systematically externalize health risks onto vulnerable populations. Such spatial injustice patterns are persistent and often reinforced through weak zoning enforcement and limited community participation in permitting processes (Mohai et al., 2009).

3.5 Implications for Environmental Justice and Public Health

The results strongly indicate that the Alsen / St. Irma Lee community functions as a cumulative impact zone characterized by overlapping environmental stressors. The dominance of petrochemical emissions, proximity of residential areas, and presence of carcinogenic compounds collectively elevate long-term health risks.

Public health studies have consistently demonstrated that communities exposed to sustained industrial emissions experience higher rates of asthma, cardiovascular disease, adverse birth outcomes, and cancer mortality (Cushing et al., 2015; Vlaanderen et al., 2013). These outcomes are not random but are spatially structured through historical and political processes that determine land use allocation.

The findings underscore the limitations of traditional regulatory frameworks that evaluate facilities individually rather than accounting for cumulative emissions. Without cumulative risk assessment, regulatory compliance may still coexist with substantial public health harm.

3.6 Implications for Emergency Planning and Risk Management

The spatial delineation of AEGL-based threat zones provides critical guidance for emergency response planning. Identifying plume extents and exposure distances supports the development of evacuation strategies, shelter-in-place decisions, and allocation of emergency resources. The findings demonstrate the importance of continuous air monitoring systems, real-time meteorological tracking, and coordinated communication between industry operators and emergency management agencies. ALOHA modeling has proven effective as a screening-level risk assessment tool, offering rapid and scientifically grounded insights that can inform both short-term emergency response and long-term regulatory strategies (Ohba et al., 2004; Zellner et al., 2000).

4. Conclusion

This study employed an integrated GIS and machine learning framework to assess petrochemical emission exposure and public health risk within the Alsen / St. Irma Lee Community in East Baton Rouge Parish, Louisiana. The results reveal a clear spatial concentration of high-emission petrochemical facilities within proximity to residential neighborhoods, confirming long-standing concerns regarding environmental injustice in the region. Analysis of Toxic Release Inventory data identified the

ExxonMobil Baton Rouge Plant as the dominant pollution contributor, releasing substantial quantities of hazardous compounds, including cumene, styrene, trichloroethylene, and tetrachloroethylene. These chemicals are widely recognized for their carcinogenic, neurological, and respiratory health effects. Spatial risk mapping further demonstrated that the highest exposure zones directly overlap with populated residential areas, placing community members at sustained health risk. The integration of proximity analysis, kernel density estimation, and supervised risk classification provided a comprehensive approach to cumulative exposure assessment. Unlike conventional single-facility evaluations, this framework captures the compounding effects of multiple emission sources and offers a more accurate representation of lived environmental risk. The findings emphasize the urgent need for strengthened emission controls, transparent real-time monitoring systems, and enforcement mechanisms that prioritize cumulative impact assessments. Community-centered health surveillance, improved regulatory oversight, and equitable land-use planning are essential to mitigate ongoing exposure and protect vulnerable populations. Ultimately, this study demonstrates that advanced geospatial techniques can play a critical role in supporting environmental justice by transforming emissions data into actionable spatial evidence. Continued application of such methods is essential for informing policy, empowering affected communities, and promoting healthier and more equitable urban environments.

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