GIS 5577 Final Paper

Title: Analyzing the Relationship Between Industrial Facilities, Demographics, and Air Quality in Minneapolis

Introduction:

Environmental justice and equity are increasingly crucial subjects in urban development, public health, and environmental regulations. The inequitable presence of environmental risks, particularly in communities with low-income and minority populations, has prompted questions about the possible consequences of industrial installations on human health and welfare. The geographical arrangement of industrial sites and their emissions can result in uneven exposure to air pollution, dangerous chemicals, and other environmental stressors, intensifying existing social and health inequalities.

Minneapolis, a diverse and expanding city in the Midwest, is not exempt from these issues. The existence of industrial establishments, especially those listed in the Toxic Release Inventory (TRI), can present substantial hazards to local air quality, ecosystems, and public health. Understanding the geographical distribution of these facilities and their potential impacts on nearby populations is crucial for devising successful mitigation methods and policies to protect vulnerable communities.

With this in mind, the primary objective of this project is to examine the connection between TRI facilities, demographic attributes, and air quality in Minneapolis using geospatial SQL queries. This analysis intends to detect potential environmental justice issues, uncover disparities in exposure to harmful chemicals, and offer valuable insights into the distribution of industrial facilities and their potential influence on local demographics and air quality.

The detailed objectives of this project are as follows:

- Analyze the spatial distribution of TRI facilities within the Minneapolis city boundary, identifying potential clusters and patterns.
- Examine the demographic characteristics of populations within a 1-km radius of each facility, focusing on income and racial composition.
- Investigate the relationship between TRI facilities and air quality, calculating the average concentration of each chemical within a 1 km radius of each facility.
- Identify the top 10 facilities with the highest average non-white population percentage within the city boundary, highlighting potential environmental justice concerns.
- Explore the potential socioeconomic factors associated with facility location choices, calculating the average income for each facility within the city boundary.

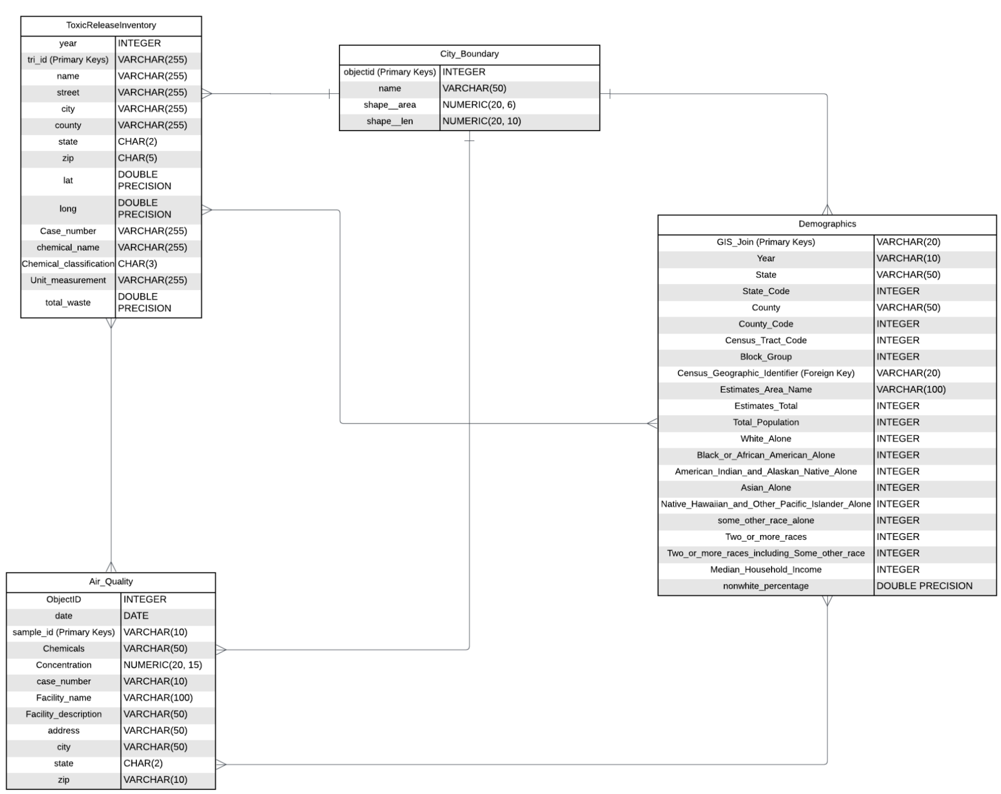
To achieve these objectives, this project employs a combination of geospatial analysis techniques and multiple datasets, including the TRI data, racial demographics, income data, air quality data, and the Minneapolis city boundary shapefile. The analysis uses spatial SQL queries and displays the results in GIS software, providing a comprehensive overview of the spatial relationships between industrial facilities, demographics, and air quality in Minneapolis.

Data:

For this project, I used multiple datasets to analyze the relationship between TRI facilities, demographic characteristics, and air quality in Minneapolis. I will describe each dataset, its source, purpose, and format, providing a comprehensive overview of the data used in this project.

- Toxic Release Inventory (TRI) Data:
    - Source: United States Environmental Protection Agency (EPA)
    - Purpose: This dataset provides information on the location, types, and quantities of toxic chemicals released by industrial facilities in the United States.
    - Format: Tabular data containing facility name, address, latitude, longitude, chemical name, and release quantities.
- Demographics Data:
    - Source: National Historical Geographic Information System (NHGIS)
    - Purpose: This dataset contains detailed demographic information, including racial composition and median household income at the block group level for the entire state of Minnesota.
    - Format: Tabular data with columns for geographic identifiers, total population, racial breakdown, median household income, and nonwhite population percentage.
- Air Quality Data:
    - Source: Minneapolis Air Survey
    - Purpose: This dataset contains air quality measurements for various chemicals in the Minneapolis area, collected through air sampling and monitoring.
    - Format: Tabular data with columns for sample date, chemical name, concentration, and geographic coordinates.
- Minneapolis City Boundary Shapefile:
    - Source: City of Minneapolis
    - Purpose: This dataset provides the official city boundary of Minneapolis, which filters and focuses the analysis on the study area.
    - Format: Vector polygon shapefile with columns for object identifier, city name, shape area, and shape length.

The entity diagram is shown below:



Before the analysis, the data was preprocessed and integrated using GIS software and SQL queries. This process involved georeferencing the tabular datasets, converting coordinates to a common spatial reference system (e.g., WGS 84), and joining the datasets based on spatial relationships and geographic identifiers. This preprocessing step was crucial for ensuring data compatibility and facilitating the geospatial analysis.

Methods and Data Analysis:

The primary goal is to investigate the relationships between toxic release inventory (TRI) facilities, air quality, and demographic characteristics within the city limits of Minneapolis. The methodology and data analysis applied to achieve this objective involved a series of steps:

1. Data Preparation: The first step in the methodology was to prepare and preprocess the four datasets: TRI Data, Air Quality Data, Demographics Data, and Minneapolis City Boundary Shapefile. The data were cleaned and standardized, ensuring that attribute names, data types, and coordinate reference systems were consistent across all datasets. Additionally, Demographics Data was created by querying racial and income Data from the NHGIS website.

2. Spatial Relationships: The primary relationships between the datasets were established using spatial analysis techniques. Spatial joins and spatial filtering operations, such as ST_DWithin and ST_Within, were employed to identify TRI facilities and air quality measurement points within a specified distance of each other, as well as to filter data based on the Minneapolis city boundary. These spatial relationships allowed us to link the TRI facilities, air quality measurements, and demographic block groups based on their geographic proximity.

3. Calculating Averages and Aggregates: Once the spatial relationships were established, I calculated various averages and aggregates to gain insights into the relationships between the datasets. For instance, I calculated the average concentration of each chemical within a 1 km radius of each facility, as well as the total population, average income, and average nonwhite population percentage for each facility within a 1 km radius. These calculations provided essential information for understanding the potential impacts of TRI facilities and air quality on the surrounding communities.

4. Ranking and Filtering: To further refine the analysis, I ranked and filtered the data based on specific criteria. For example, I identified the top 10 facilities with the highest average non-white percentage in Minneapolis and calculated the average income for each facility in the TRI table within the city limits. These rankings and filters allowed us to focus on the most relevant and significant results in the analysis.

5. Spatial Analysis and Visualization: Throughout the analysis process, I utilized various spatial analysis techniques and tools to visualize the relationships between the datasets. This included creating maps to display the spatial distribution of TRI facilities, air quality measurements, and demographic characteristics in Minneapolis. These visualizations aided in interpreting the results and facilitated a better understanding of the complex relationships between the datasets.

6. Evaluation and Interpretation: Finally, I evaluated and interpreted the analysis results, considering the potential implications of the findings on the communities within Minneapolis. This involved examining the relationships between TRI facilities, air quality, and demographic factors such as population density, income levels, and racial composition. Through this evaluation and

interpretation, I was able to draw conclusions about the potential impacts of these factors on the health and well-being of the communities surrounding the TRI facilities.

In conclusion, the methodology and data analysis for this project involved a combination of data preparation, spatial analysis techniques, and statistical interpretation to investigate the relationships between TRI facilities, air quality, and demographic characteristics in Minneapolis. By applying these methods, I was able to gain valuable insights into the complex interactions between these datasets and their potential impacts on the surrounding communities.

<u>**Results and challenges**</u>:

The results of this project revealed several key findings regarding the relationships between toxic release inventory (TRI) facilities, air quality, and demographic characteristics within Minneapolis. However, there are challenges as well as limitations encountered during the project's completion, and they are as follows:

- Spatial Distribution of TRI Facilities and Air Quality Measurements: The analysis showed that TRI facilities were not uniformly distributed across the city of Minneapolis. Some areas had a higher concentration of facilities, while others had few or none. Similarly, the distribution of air quality measurement points also varied across the city. These patterns indicate that certain communities may be disproportionately affected by TRI facilities and poor air quality. However, one limitation of the analysis was that the spatial distribution of TRI facilities and air quality measurements might not fully capture the actual exposure levels experienced by residents in different areas of the city, as factors such as wind patterns and topography can influence the dispersion of pollutants.

- Average Chemical Concentrations: By computing the average concentration of each chemical within a 1-km radius surrounding each facility, I was able to identify which facilities and regions had the highest potential exposure to hazardous chemicals. City planners and policymakers can use this information to pinpoint areas that require targeted interventions, such as enhanced monitoring, pollution control efforts, or community engagement programs. Nonetheless, the analysis was constrained by the accessible data on chemical concentrations, which might not be all-inclusive or current, possibly resulting in underestimations or overestimations of the actual exposure levels.

- Demographic Characteristics and TRI Facilities: The analysis revealed that some TRI facilities were located in areas with a higher total population, lower average income, and higher non-white population percentages. This suggests that certain socioeconomically disadvantaged and minority communities may be disproportionately affected by TRI facilities and the associated environmental and health risks. Local authorities and organizations can prioritize resources and interventions to address the potential environmental justice issues by identifying these facilities and the surrounding communities. One limitation of the demographic analysis was the reliance on aggregated data, which may mask variations in exposure and vulnerability within individual neighborhoods or population subgroups.

- Top 10 Facilities with the Highest Average Non-White Percentage: The ranking of the top 10 facilities with the highest average non-white percentage within Minneapolis highlighted the potential disparities in exposure to toxic chemicals and air pollution among different racial and ethnic groups. These findings underscore the importance of considering environmental justice issues in the planning and regulation of industrial activities, as well as in the allocation of resources for monitoring and mitigating the impacts of air pollution on vulnerable communities. However, the analysis was limited by the available demographic data, which may not fully capture the diversity and complexity of the communities surrounding TRI facilities.

- Average Income for Each Facility: The calculation of the average income for each facility within Minneapolis allowed us to further explore the relationships between TRI facilities, air quality, and socioeconomic factors. The results indicated that some facilities are located in areas with lower average incomes, suggesting that economically disadvantaged communities may bear a greater burden of exposure to toxic chemicals and air pollution. One limitation of the income analysis was the reliance on median household income, which may not fully represent the economic status of all residents in the affected areas.

Solutions:

To sum up, this project has offered significant insights into the connections among toxic release inventory (TRI) facilities, air quality, and demographic traits within the city of Minneapolis. The conclusions drawn from this research can act as a basis for local authorities, policymakers, and community organizations to pinpoint and tackle potential environmental justice concerns, as well as prioritize resources and initiatives in the areas where they are needed most.

The investigation uncovered that specific socioeconomically challenged and minority neighborhoods may be unequally impacted by the existence of TRI facilities and the correlated environmental and health hazards. Identifying facilities with the highest average non-white populations and those situated in regions with lower mean incomes underscores the necessity to factor in environmental justice when planning and regulating industrial operations. By confronting these imbalances, local authorities can strive towards a more balanced distribution of environmental and health risks among diverse population segments.

Determining the average chemical concentrations within a 1-km radius surrounding each facility and the mean income for each facility enabled a deeper understanding of the possible exposure levels experienced by residents in various parts of the city. City planners and policymakers can use this information to devise targeted strategies, such as enhanced monitoring, pollution control efforts, or community engagement programs, with the aim of lessening the exposure to hazardous chemicals and air pollution in the affected neighborhoods.

While the analysis yielded valuable insights, several limitations were faced throughout the project, including the dependence on consolidated demographic data, the accessibility of complete and current data on chemical concentrations, and the utilization of median household income as an indicator of economic status. These constraints underscore the need for more extensive and current data repositories and the creation of more advanced techniques for examining the intricate connections between environmental and demographic factors.

In the future, the research could profit from incorporating additional data sources, such as real-time air quality monitoring information, and applying cutting-edge statistical and geospatial analysis methods to further enhance the comprehension of the associations between TRI facilities, air quality, and demographic traits. Furthermore, collaborating with community stakeholders and integrating their viewpoints and experiences into the research process can help guarantee that the findings are pertinent, practical, and fair.