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SPATIAL ASSESSMENT OF INDUSTRIAL POLLUTION, ENVIRONMENTAL DETERIORATION, AND PUBLIC HEALTH OUTCOMES IN HOWRAH DISTRICT, WEST BENGAL

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RESEARCH ARTICLE

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Abstract
This research examines the spatial dimensions of industrial growth's environmental toll and its health repercussions in Howrah District, West Bengal. Leveraging GIS mapping and mixed-methods data, it reveals pollution hotspots linked to elevated respiratory and waterborne illnesses. Findings advocate for targeted regulations and sustainable practices to harmonize economic gains with ecological and health safeguards.

Keywords: *Industrial Pollution, Environmental Health, GIS Analysis, Howrah District, Respiratory Diseases, Sustainable Policy, Public Health Risks*

Introduction

Howrah District, situated on the Hooghly River's western bank adjacent to Kolkata, has transformed into West Bengal's industrial powerhouse, hosting steel, chemical, engineering, and textile sectors. This expansion has fueled economic vitality and employment but unleashed profound environmental decay—air choked with particulate matter (PM), sulfur dioxide (SO_2), and nitrogen oxides (NO_x); waters fouled by untreated effluents; and soils laden with heavy metals. Such degradation manifests in surging health crises: asthma, bronchitis, cholera, and dysentery disproportionately burdening workers, riverside dwellers, children, and the elderly.

Geographically, Howrah's compact 1,465 km² area amplifies these vulnerabilities, with industrial clusters encroaching on residential zones. Official reports from the West Bengal Pollution Control Board (WBPCB) document exceedances of national ambient air quality standards, correlating spatially with hospital admissions for pollution-linked ailments. This interplay underscores a classic sustainable development dilemma in emerging economies: progress versus planetary health.

Prioritizing spatial analysis, this study deploys GIS to chart pollution dispersion from factories to communities, integrating primary surveys (n=500) and secondary health/environmental data. By quantifying exposure-health linkages—e.g., PM2.5 proximity raising respiratory risks 2-3 fold—it fills a void in localized, geospatial evidence. Objectives span mapping hotspots, assessing economic health costs, and gauging public willingness-to-pay (WTP) for remediation. Amid India's urban-industrial surge, these insights inform policy for resilient districts, echoing global calls like UN Sustainable Development Goal 11 (Sustainable Cities). Ultimately, the paper posits integrated land-use planning as pivotal for Howrah's livability.

Literature Review

Scholarship links rapid industrialization to multifaceted pollution in India. Kumar et al. (2015) quantify emissions from steel and chemical plants elevating PM and SO2, fostering respiratory disorders; Sengupta (2017) extends this to cardiovascular risks in urban hubs like Howrah.

Roy and Saha (2019) spotlight Howrah's Hooghly contamination, where effluents spawn waterborne epidemics—cholera rates 40% above state averages per Das et al. (2019). Soil studies by Chakraborty et al. (2016) reveal heavy metals bioaccumulation in crops, imperiling food chains. Mishra et al. (2018) affirm vulnerability gradients: children near factories face 25% higher asthma odds.

Policy critiques abound; Dutta et al. (2019) decry lax enforcement of the 1986 Environment Protection Act despite NEERI (2015) urban health burden data. Saha (2019) invokes environmental justice, noting low-income enclaves bear disproportionate loads. Sustainable pivots, per Sharma (2020), advocate green tech, yet implementation lags.

Research Gap

Existing works dissect pollution-health axes but underexplored Howrah's geospatial nuances—no GIS-integrated models correlate factory buffers with morbidity clusters. Economic valuations (e.g., health costs, WTP) remain anecdotal, sidelining vulnerable subgroups. This study bridges these via spatial econometrics and stakeholder voices.

Objectives

The main objectives of the studies are:

- Map industrial pollution hotspots and their health correlations using GIS.
- Quantify pollution-attributable health costs and public WTP for mitigation.
- Evaluate regulatory efficacy and propose sustainable interventions.

Methodology

This study adopts a mixed-methods research design, integrating quantitative, qualitative, and geospatial techniques to examine the relationship between industrial pollution and public health outcomes in Howrah District.

Study Area: The study is conducted in Howrah District, West Bengal, a major industrial hub characterized by dense population and proximity between industrial and residential zones.

Data Sources: The study uses both primary and secondary data to ensure a comprehensive and reliable analysis. Primary data were collected through a survey of 500 households, supported by semi-structured interviews with 20 stakeholders and field observations at pollution hotspots, providing detailed insights into socio-economic conditions, health status, and environmental exposure. Secondary data, including WBPCB reports, hospital records, and census statistics, were used to complement and validate the primary findings. Together, these sources enabled a well-rounded and triangulated understanding of pollution and its impacts.

Sampling Design: A stratified random sampling technique was adopted to ensure proper representation of households across different levels of pollution exposure. The study area was divided into three strata based on distance from industrial zones: high exposure (0–2 km), moderate exposure (2–5 km), and low exposure (>5 km). From each stratum, households were selected through random sampling with proportional representation, resulting in a total sample of 500 households distributed fairly across the three categories. This approach allows for meaningful spatial comparison of pollution exposure and its associated health impacts across different zones.

Data Collection Procedure: Data were collected using a structured questionnaire covering health conditions (respiratory, waterborne, and chronic diseases), socio-economic characteristics, pollution awareness, and willingness-to-pay (WTP). Household surveys were conducted through face-to-face interviews to ensure accuracy and clarity of responses. In addition, semi-structured interview schedules were used to gather insights from key stakeholders. Field observations were also undertaken to document visible pollution sources and assess environmental conditions, helping to validate and support the primary data collected.

Analytical Techniques: The study employs a mix of quantitative, geospatial, and qualitative analytical techniques. Quantitative analysis includes descriptive statistics, along with correlation and regression (using SPSS) to examine pollution–health relationships. Geospatial analysis is conducted through GIS mapping in ArcGIS, using buffer zones (0–2 km, 2–5 km, >5 km) and overlay techniques to link pollution levels with health incidence. Additionally, qualitative data from interviews are analyzed through thematic analysis using NVivo, enabling deeper interpretation of stakeholder perspectives and supporting the overall findings.

Estimation of Willingness-to-Pay (WTP): The study estimates willingness to pay (WTP) using the Contingent Valuation Method (CVM), a common approach for valuing environmental goods. A close-ended bidding format was applied, where respondents selected the maximum amount they would pay annually for pollution control from predefined values. The method assumes respondents understand the scenario and that WTP reflects their perceived health risks and economic capacity. The average WTP across households was calculated to assess potential community contribution toward pollution mitigation.

Estimation of Health Burden

The economic burden of pollution-related health impacts was estimated using the Cost of Illness (COI) approach, incorporating both direct costs (medical expenses such as consultation, medicines, and hospitalization) and indirect costs (wage and productivity loss). Data were collected for the past 12 months from 500 sampled households and extrapolated to the district level. The estimation combined treatment costs and productivity losses, assuming accurate self-reported expenses and a clear link between disease incidence and pollution exposure zones.

Results and Findings

The following results are derived using GIS-based spatial analysis and the Cost of Illness (COI) approach described in the methodology section.

GIS analysis in Howrah District unveils a stark spatial mismatch between industrial emissions and human habitats, with nearly 70% of pollutants—primarily PM2.5, effluents, and heavy metals—concentrated within a 5 km radius of densely populated residential zones. This proximity drives a 35% surge in respiratory cases, evidenced by a strong correlation ($r = 0.82$), as fine particulates from steel and chemical plants exacerbate asthma and bronchitis among 62% of surveyed residents. Riverside communities face acute waterborne threats, with 45% of low-income groups reporting cholera and dysentery linked to untreated effluents discharged into the Hooghly River, while soil contamination from heavy metals is associated with nearly 30% of chronic illnesses through the food chain.

The estimated annual health burden of ₹500 crore is calculated based on reported morbidity cases, treatment costs, and productivity losses. The estimation is based on a one-year reference period and incorporates both direct costs (medical expenditure) and indirect costs (loss of working days). The population considered includes residents living within a 5 km radius of major industrial clusters in Howrah district. Cost estimates are derived using average treatment expenses obtained from the primary survey and supported by secondary hospital data.

These estimates are based on assumptions regarding average disease incidence rates, treatment-seeking behavior, and wage loss due to illness, which together provide a realistic approximation of the economic burden of pollution-induced health risks.

To provide a clearer understanding of the relationship between pollution exposure, health outcomes, and economic burden, the estimated costs are summarized in Table 1. The table presents the major pollutants, their spatial prevalence, associated health impacts, and the corresponding economic costs derived using the Cost of Illness (COI) approach.

Table 1: Distribution of Major Pollutants, Associated Health Impacts, and Estimated Economic Costs in Howrah District

Pollutant	Hotspot Prevalence	Health Correlation	Economic Cost (₹ crore)
PM2.5	65% industrial areas	Respiratory (r=0.82)	250
Effluents	Hooghly banks (80%)	Waterborne (45%)	150
Heavy Metals	Soil (55%)	Chronic (30%)	100

Source: Author's calculation based on primary survey (n = 500) and secondary data from WBPCB and hospital records

A pivotal revelation: factories within 2 km buffers double disease odds, spotlighting zoning lapses that prioritize industry over safety. Annual health burdens total ₹500 crore, blending ₹250 crore in respiratory treatments and lost wages, ₹150 crore for water-related care, and ₹100 crore chronic costs—straining public resources amid India's urban boom.

Public sentiment, gauged via 500 surveys, shows 62% symptom prevalence and modest WTP at ₹200/household/year for remediation, signaling awareness yet economic constraints among the poor. Interviews with 20 stakeholders expose 60% regulatory non-compliance, as WBPCB norms falter against industrial lobbying and lax enforcement.

Broadly, these findings echo global patterns in developing hubs like Kanpur or Manila, where unchecked sprawl amplifies "pollution poverty traps." Spatial inequities burden vulnerable groups—children, elderly, migrants—amplifying social divides. Interventions demand GIS-informed rezoning (e.g., 5 km green buffers), effluent tech mandates, and WTP-funded monitoring. Policymakers could leverage contingent valuation for green bonds, aligning SDG 3 (Health) and 11 (Cities). Ultimately, Howrah exemplifies the imperative for "smart industrialization": tech-driven emissions tracking, inclusive zoning, and justice-focused mitigation to reclaim livable spaces.

Limitations of the Study

Data gaps in longitudinal health records hinder causality; cross-sectional surveys risk recall bias. Sample (n=500) may under represent migrants. GIS relies on proxy emissions, potentially inflating correlations. Resource constraints limited interviews. Findings generalize cautiously beyond Howrah.

Conclusion

Howrah's industrial ascent exacts a steep environmental-health toll, with GIS exposing actionable pollution-health nexuses. Empirical evidence—elevated morbidities, ₹500 crore burdens—demands urgent zoning reforms, effluent tech, and WTP-funded monitoring. Policymakers must enforce WBPCB mandates, prioritizing vulnerable clusters for equitable gains. This blueprint extends to India's industrial belts, advancing SDG-aligned sustainability. Future longitudinal probes could refine interventions, fostering resilient urban futures.

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