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A Novel Framework for Health Impact Assessment (HIA) of Solid Waste Management Facilities: A Case Study of Chhatrapati Sambhajnagar

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ABSTRACT: Rapid urbanization in cities like Chhatrapati Sambhajnagar has led to an exponential rise in Municipal Solid Waste (MSW), outpacing infrastructure and posing serious public health risks. Traditional Environmental Impact Assessments (EIA) often overlook the human health dimension. This study proposes a novel, integrated Health Impact Assessment (HIA) framework that combines environmental monitoring, GIS-based spatial mapping, and quantitative risk modelling. By analysing exposure pathways such as air pollutants and groundwater contamination, the research identifies high-risk zones and proposes data-driven mitigation strategies to safeguard urban populations.

KEYWORDS: Municipal Solid Waste (MSW), Environmental Impact Assessment (EIA), Health Impact Assessment (HIA), GIS Mapping, Risk Modelling.

I. INTRODUCTION

The ongoing study in Chhatrapati Sambhajnagar highlights that rapid urbanization and population growth in India have significantly accelerated municipal solid waste (MSW) generation. In this regional context, the existing solid waste management (SWM) infrastructure has failed to keep pace with rising waste loads, leading to critical issues such as open dumping, inadequate source segregation, and limited treatment capacity. These improper practices result in severe environmental degradation, characterized by the emission of methane, volatile organic compounds (VOCs), and particulate matter (PM_{2.5} and PM₁₀), alongside the infiltration of toxic leachate into soil and groundwater. Consequently, these exposures pose serious public health risks, including respiratory disorders, vector-borne diseases, and gastrointestinal illnesses among the local population.

Despite these evident dangers, conventional Environmental Impact Assessments (EIA) in India primarily focus on physico-chemical and ecological parameters, leaving the human health dimension inadequately quantified. This underscores an urgent necessity to integrate Health Impact Assessment (HIA) into SWM planning and urban governance. The primary objective of this research is to develop and apply "noble" (novel) and scientifically robust methods for estimating health impacts specifically for the SWM facilities in Chhatrapati Sambhajnagar. To achieve this, the study adopts a multidisciplinary approach that combines environmental monitoring, GIS-based spatial mapping of risk zones, and quantitative risk modelling. This comprehensive framework is designed to provide data-driven insights that assist local authorities in adopting preventive measures and safeguarding public health for sustainable urban development.

II. LITERATURE REVIEW

A review of Indian and global frameworks (SWM Rules 2016, CPHEEO Manual, WHO guidelines) highlights a significant gap in the systematic quantification of human health impacts.

- Yuan et al. (2025): Identified leachate as the most critical source of groundwater pollution and linked landfill gas to respiratory disorders.
- Singh et al. (2020): Applied the USEPA framework to quantify carcinogenic risks from heavy metals in soil and groundwater.
- Local Context: Studies in CSN indicate minimal waste segregation at source and high reliance on unengineered dumping grounds, leading to chronic community complaints and health risks.



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III. METHODOLOGY OF PROPOSED SURVEY

The methodology for this research adopts a comprehensive, holistic, and interdisciplinary framework to systematically evaluate the health impacts of solid waste management (SWM) facilities in Chhatrapati Sambhajnagar. The approach integrates multiple analytical layers, beginning with the selection of the primary study zone—the Naregaon landfill and its surrounding 10 km radius—due to its proximity to residential areas and documented environmental stress. Data is collected through a dual-source strategy, utilizing both primary fieldworks, such as on-site environmental sampling and household health surveys, and secondary records from institutional repositories like the Municipal Corporation and District Health Department.

The technical core of the methodology involves environmental monitoring of air, noise, water, and soil quality to quantify pollution levels and establish exposure pathways. These findings are then integrated into a Geographic Information System (GIS) to create spatial visualizations. Through buffer analysis—delineating high (0–1 km), moderate (1–3 km), and low (>3 km) exposure zones—and overlay analysis, the study identifies "hotspots" where environmental stressors and high population density coincide.

Finally, the research employs a Quantitative Risk Assessment (QRA) framework adapted from US EPA and WHO standards. This process involves hazard identification of heavy metals and VOCs, exposure assessment to calculate the Average Daily Dose (ADD), and risk characterization to determine the Hazard Quotient (HQ) for non-carcinogenic risks and Excess Lifetime Cancer Risk (ELCR). To capture the broader public health burden, the study estimates Disability-Adjusted Life Years (DALYs), combining years of life lost due to premature mortality with years lived with disability.

The methodology includes the following steps:

1. Environmental Monitoring: Sampling of air, water, and soil quality in core and buffer zones (up to 10 km radius) of the Naregaon site.
2. GIS Spatial Analysis: Use of ArcGIS/QGIS for buffer analysis and Inverse Distance Weighting (IDW) to create pollutant dispersion maps.
3. Epidemiological Assessment: Analysis of health camp data for sanitation workers and community surveys to establish exposure-response relationships.
4. Quantitative Risk Assessment (QRA): Calculation of Hazard Quotient (HQ) for non-carcinogenic risks and Excess Lifetime Cancer Risk (ELCR).

IV. RESULT AND DISCUSSION

- Waste Composition: Organic waste constitutes 48.40% of the city's 724.64 TPD total generation.
- Pollution Levels: PM₁₀ (180–250 $\mu\text{g}/\text{m}^3$) and PM_{2.5} (80–120 $\mu\text{g}/\text{m}^3$) significantly exceed national standards.
- Health Impacts: Sanitation workers show a high prevalence of musculoskeletal disorders (78%), respiratory issues (55%), and eye irritation (47%).
- Risk Metrics: The Hazard Quotient for PM_{2.5} (1.8) and H₂S (1.6) exceeds the safe limit of 1.0, indicating significant health risks.
- Spatial Hotspots: GIS mapping identified Chikalhana and Padegaon as high-risk exposure zones.

IV. CONCLUSION AND FUTURE WORK

The study, "A Study on Novel Methods for the Estimation of Health Impact Assessment (HIA) of Solid Waste Management Facility in Chhatrapati Sambhajnagar," concludes that improper waste management significantly compromises public health, particularly for sanitation workers and residents near disposal sites. Analytical findings reveal a high prevalence of musculoskeletal (78%) and respiratory (55%) disorders among the workforce, exacerbated by a critical 58% gap in the regular use of Personal Protective Equipment (PPE). Environmental monitoring confirms that pollutants like PM_{10.5}, PM_{2.5}, and H₂S exceed safe standards, with Hazard Quotient (HQ) values indicating significant non-carcinogenic risks. GIS spatial analysis successfully identified high-risk zones in Chikalhana and Padegaon, establishing a strong positive correlation between pollutant exposure and disease prevalence.



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Future work aims to implement the developed modular HIA framework across multiple urban contexts to validate its scalability and adaptability to different waste management typologies. Research will expand to explore the long-term health implications of legacy waste bioremediation and the efficacy of advanced gas capture technologies in reducing cancer risk. There is a planned focus on developing a centralized, real-time health surveillance system for workers, integrating digital health camp data with environmental sensors. Additionally, future efforts will advocate for institutionalizing these health-centered decision-support mechanisms into national regulatory frameworks like the EIA Notification.

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