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Impact of Solid Waste Management Practices on Human Health in Siliguri Municipal Corporation (SMC), West Bengal, India: A Geographical Analysis

Atisha Lama Yolmo*

*Department of Geography, Siliguri College, District Darjeeling.

Abstract

This present study examines the relationship between solid waste management practices and public health outcomes in Siliguri Municipal Corporation (SMC), through a comprehensive analysis of secondary data from government reports, published research studies, and official health statistics. It investigates how inadequate waste management systems contribute to disease prevalence and environmental health challenges. The study reveals significant correlations between waste accumulation patterns and vector-borne and respiratory ailments in the study area. Findings indicate that areas with poor waste collection services experience higher incidence of waterborne and respiratory complications compared to well-serviced areas. The research emphasises the need for integrated waste management strategies that consider geographical constraints and population density variations across the municipal area.

Keywords: Solid waste management, public health, Siliguri Municipal Corporation (SMC), spatial analysis, environmental and human health, urban geography

1. Introduction

Solid waste management represents a comprehensive system encompassing the generation, collection, transportation, treatment, and disposal of solid waste materials produced by human activities. According to the Ministry of Urban Development (2016), effective solid waste management involves a systematic approach that begins with waste segregation at the source and extends through efficient collection mechanisms, appropriate transportation networks, processing facilities, and environmentally sound disposal methods.

Siliguri, situated in the foothills of the Eastern Himalayas in West Bengal, faces unprecedented challenges in solid waste management. The city's strategic location at the confluence of three international borders with Nepal, Bhutan, and Bangladesh, combined with its role as a major commercial and transportation hub, has catalysed unprecedented urban growth that has overwhelmed the existing waste management infrastructure. The magnitude of the solid waste management problem in Siliguri is multifaceted and deeply interconnected with the city's demographic and economic dynamics. With a population of approximately 513,264 as per the 2011 Census, projected to reach over 600,000 by 2019, the city generates an estimated 180-200 tonnes of solid waste daily (Ghosh & Roy, 2018).

The rapid urbanisation in Siliguri has resulted in substantial waste generation, further exacerbating environmental and public health issues. The connection between solid waste management and public

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health has been extensively documented in urban studies literature. Poor waste management practices contribute to environmental degradation, water contamination, air pollution, and the proliferation of disease vectors (Cointreau, 2006; Marshall & Farahbakhsh, 2013). In the context of Siliguri SMC, these challenges are compounded by monsoon flooding, limited landfill capacity, and inadequate collection systems in peripheral areas.

2. Objectives

This study adopts a geographical approach to analyse the spatial distribution of health impacts related to solid waste management in Siliguri Municipal Corporation (SMC). The research objectives include:

1. Analysing the waste generation and collection patterns across Siliguri Municipal Corporation (SMC).
2. Examining the relation between waste management deficiencies and disease incidence.
3. To examine the key issues related to the management of solid waste.
4. Proposing solutions for proper solid waste management.

3. Study Area

Siliguri Municipal Corporation (SMC) encompasses an area of 41.9 sq. km. and is organised into 47 wards. Established in 1949, the Siliguri municipality expanded in 1994 when it was designated as the Siliguri Municipal Corporation (SMC), adding 17 new wards to its existing 30, thus increasing its total to 47 wards. The boundary of Siliguri Municipal Corporation (SMC) is shared by both Darjeeling and Jalpaiguri District. The city features diverse topographical elements, including flat plains in its central regions and undulating terrain at the foothills.

Demographic Characteristics of Siliguri Municipal Corporation at a Glance

Characteristics	Siliguri (Darjeeling District)	Siliguri (Jalpaiguri district)	Siliguri Total
Area (sq. km)	20.1	21.8	41.9
Households	66,062	49,895	1,15,957
Population	2,94,546	2,18,718	5,13,264
Population density (per sq. km)	11,654	10,033	12,250
Male population	1,51,535	1,12,167	2,63,702
Female population	1.43,011	1,06,551	2,49,562
Sex ratio	944	950	946
Female literacy rate (%)	75	73	74
Total workers	1,08,409	79,523	1,87,932
Main workers	96,180	69,702	1,65,882
Cultivators	338	242	580
Agricultural laborers	321	180	501
Household industry workers	2,264	1,801	4,065
Other workers	93,267	67,479	1,63,746
Marginal workers	12229	9,821	22,050

The Mahananda River flows through Siliguri, shaping natural drainage patterns that impact waste accumulation and transportation during the monsoon season. The region experiences a subtropical climate with distinct wet and dry seasons. The monsoon period, which lasts from June to September, brings approximately 2,500 mm of rainfall each year. This substantial rainfall creates challenges for waste collection and disposal. Additionally, its geographical coordinates of 26.7°N latitude and

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88.4°E longitude position it strategically, contributing to its rapid economic growth, which further complicates waste management efforts.

4. Data Sources and Methodology

This study uses secondary data to analyse solid waste management practices and health impacts in Siliguri Municipal Corporation (SMC). The analysis includes sources such as SMC annual reports and waste assessments (2015-2019), West Bengal Pollution Control Board reports, District health department data from Darjeeling, the Census of India 2011, and Ministry of Urban Development guidelines. Additional data comes from peer-reviewed journal articles and research papers.

The analysis utilised systematic review techniques to meticulously weave together insights from a diverse array of secondary sources. By delving into published data, the study conducted a thorough examination of various waste generation, the intricacies of their processing, and the quantities involved. This comprehensive analysis sought to illuminate the intricate connections between these waste patterns and their profound implications for human health.

5. Geographical Factors Influencing Waste Management

5.1 Topographical Constraints

The varied topography of Siliguri plays a significant role in determining the efficiency of waste management. In wards 1-8 and 40-47, areas characterised by steep slopes and challenging terrain experienced reduced collection efficiency due to accessibility issues. The study revealed that regions with slightly higher gradients exhibited lower collection rates compared to those with flat terrain. Research conducted by Kumar and Sharma (2017) on waste management challenges in Himalayan foothill cities substantiates these findings. Published in the Journal of Mountain Science, their study illustrated how the varied topography of Siliguri Municipal Corporation (SMC) notably impacts waste management effectiveness, highlighting that areas with gradients exceeding 12-15% had collection rates that were 30-40% lower than those in flatter regions.

5.2 River and Drainage Systems

The Mahananda River and its tributaries create natural drainage patterns that significantly impact waste transport and accumulation. During monsoon seasons, inadequately managed waste is carried by surface runoff, leading to downstream contamination hotspots. A study by the Indian Institute of Technology conducted a hydrological study of the Mahananda basin (2016) highlighted how the river and its tributaries create natural drainage patterns that affect waste transport and accumulation in Siliguri. Another research by Datta and Mukherjee (2018) on water quality in North Bengal rivers documented that communities located along natural drainage lines experienced higher incidences of waterborne diseases, with the Mahananda River system being particularly affected by upstream waste contamination.

5.3 Urban Growth Patterns

Siliguri Municipal Corporation (SMC) has experienced a remarkable transformation, evolving from a tiny settlement with just a few hundred residents of 800 population in 1901 to a bustling urban centre

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with a population of 513,264 recorded in 2011. The city is organised into 47 distinct wards, covering an area of approximately 41.9 sq. km, and extends into the neighbouring districts of Jalpaiguri and Darjeeling, enriching its cultural diversity. The Centre for Urban Studies' report on urban expansion in North Bengal (2019) documented radial growth pattern of Siliguri from the central core, which has created service delivery challenges in peripheral areas. The report highlighted that geographical expansion has outpaced infrastructure development, resulting in inadequate waste collection services in newly developed areas. Another study by Roy et al. (2018) published in Urban Geography analysed the spatial mismatch between urban growth and municipal service provision in Siliguri, identifying distinct zones of service vulnerability that correspond to areas of recent urban expansion.

5.4. Waste Volumes & Projections

Data analysed from Siliguri Municipal Corporation (SMC) showed an increase in waste generation, rising from around 300 tons per day in 2013 to 335 tons per day by 2017. The waste management infrastructure was showing signs of strain, dealing with daily waste generation. Only a small percentage of households practise effective source segregation, which highlights the urgent need for improved waste management strategies. According to the 2013 CRIS (CRISIL Risk and Infrastructure Solutions Limited) report, it was estimated that the average solid waste generation in Siliguri would rise to 360 tons per day (TPD) by 2021. The projections indicated further increases, with expectations for 455 TPD in 2031 and 573 TPD in 2041, translating to 391 grams per capita per day in 2031 and 397 grams per capita per day by 2041. Notably, in 2017, the actual waste generation had already surpassed the CRISIL estimate for 2021. The report highlighted that the growing trend of consumerism is likely to contribute to an even greater rise in per capita waste generation in the future.

5.5. Sources and Types of Solid Waste:

According to the survey report by the Siliguri Municipal Corporation for June and July 2015, the primary sources of solid waste in Siliguri are the residential and commercial sectors, which account for approximately 215 TPD (69%) and 58 TPD (19%) of the total waste, respectively. This is followed by the transport sector at 25 TPD (8%), and agriculture and water bodies at 11 TPD (3%). The public and semi-public sector contributes a modest 3 TPD (1%). Additionally, the solid waste generated from recreational and industrial sectors is negligible.

From this data, we can identify and classify the major types of solid waste produced in Siliguri. These include Domestic/Residential Waste, which consists of items such as cooking waste, vegetable residues, packaging materials, clothing, old books, writing/newspapers, and used furnishings. Commercial waste originates from various establishments including wholesale and retail stores, hotels and restaurants, markets and haats, and warehouses. Additionally, there is demolition and construction waste, which comprises concrete, stones, plaster, lumber, wire, roofing materials, and bricks. Street waste is generated from road sweeping, while rubbish includes both organic and non-combustible materials.

6. Results and Discussion

6.1. Collection & Segregation

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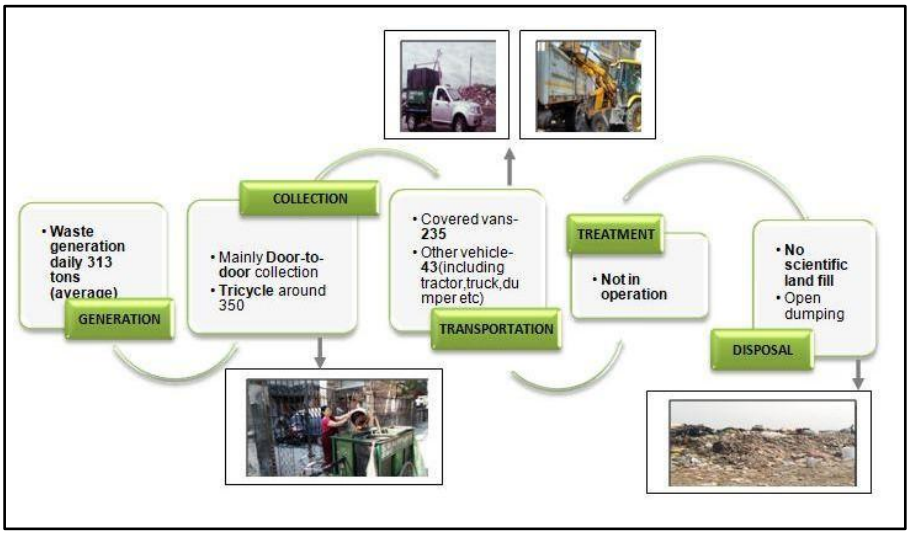
The Siliguri Municipality Corporation (SMC) maintains a waste collection system serving residential homes, schools, and busy markets across 47 wards, each consisting of 300 to 350 houses. Waste is primarily collected daily through door-to-door service with Man Pulled Tricycles, transporting waste to Covered Vans or secondary bins. Each ward has 25-30 staff for street sweeping and drain cleaning. For secondary collection, 15 dumper placers make 2-3 trips daily to disposal sites, strategically located around the city like Hill Cart Road, Sevoke Road, Barddhaman Road, Bidhan Road, Bidhan Market, Darjeeling more, Bhutia Market, etc.

Man Pulled Tricycles

Covered vans or secondary bins



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FLOW DIAGRAM SHOWING PROCESS OF WORK & SERVICES BY SMC

In 2013, the average solid waste generation was 300 tons per day, increasing to 313 tons in 2015 and 335 tons in 2017. Current estimates suggest that during peak seasons, such as festivals and the harvest months from October to December, this figure can rise to between 500 and 550 tons. According to the SMC's 2018 Annual Report, central wards experience the highest waste generation rates, ranging from 0.45 to 0.55 kg per capita per day, largely due to commercial activities. In contrast, peripheral wards exhibit lower waste generation rates and reduced collection efficiency.

6.2. Open Dumpsite

A significant portion of municipal solid waste—approximately 83%, equivalent to about 88% of domestic waste—ends up in a vast, unlined open landfill located near Don Bosco School in Ward 42. This site, which has been operational since 1949, spans around 21 acres and has accumulated an astonishing 2.13 million tons of waste over its lifetime. Currently, it receives approximately 350 tons (500 - 550 tons during peak seasons) of waste each day, exacerbating its environmental impact. Alarmingly, there is no evidence of groundwater monitoring in the vicinity, and the landfill frequently experiences fires caused by the dangerous accumulation of methane gas and dry refuse materials.

7. Health Impact: Linking Solid Waste and Health

The mixture of organic and inorganic waste presents significant environmental and health risks to communities. Incineration emits harmful particulates ($PM_{2.5}$, PM_{10}) and volatile organic compounds (VOCs), contributing to respiratory and cardiovascular issues, especially among vulnerable populations. Open dumpsites in urban areas attract disease vectors like mosquitoes and rodents, spreading illnesses such as dengue fever, diarrhoea, and typhoid fever, with severe impacts on children.

Leachate from decomposing waste contaminates groundwater, posing gastrointestinal health risks for communities reliant on these water sources. Waste workers face various dangers, including infection exposure and physical injuries, compounded by societal stigma that limits healthcare access. Although Siliguri lacks focused epidemiological studies, concerning correlations exist between dumpsites, residential areas, and drainage systems, indicating heightened public health risks.

7.1. Air-Borne Diseases

Residents near the Don Bosco dumpsite face unpleasant odours and frequent fires, leading to significant air pollution from burning waste. Harmful pollutants like $PM_{2.5}$, PM_{10}, polycyclic aromatic hydrocarbons, and volatile organic compounds are released. The dumpsite is less than 100 meters from homes in Wards 41 and 42, increasing the risk of respiratory illnesses like asthma and bronchitis. During the rainy season, a decaying smell worsens the situation. There are insufficient measures to combat groundwater and air pollution, leaving residents vulnerable to harmful smoke and emissions. An analysis of health reports from Darjeeling district (2015-2019) shows a strong link between poor waste management and negative health outcomes. Research by Chakraborty et al. (2017) found that respiratory ailments were 1.6 to 2.1 times more common in North Bengal urban areas with poor waste

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management. The study, published in the Indian Journal of Environmental Health, highlighted increased rates of asthma and bronchitis in Siliguri and peripheral wards.

7.2. Vector-Borne Disease Patterns

During the monsoon season, leachate from unregulated dumpsites fosters a breeding ground for disease vectors, attracting flies, mosquitoes, and rodents. Although direct evidence from Siliguri is limited, the prevailing environmental conditions suggest a similar disease burden may exist. Wastewater pools near the dumpsites, tainted with nitrates and heavy metals, seep into the soil due to the unlined nature of these dumps, jeopardising groundwater supplies. Residents in the surrounding wards (41 out of 42) are likely at risk for diseases such as gastrointestinal infections and vector-borne illnesses, even without specific health surveillance data from Siliguri.

A study by Sen and Banerjee (2016), published in the Journal of Vector Borne Diseases, documented spatial clustering of vector-borne diseases in certain wards of Siliguri, linking these patterns to waste accumulation sites that provide breeding grounds for disease vectors. The 2018 District Health Survey revealed that areas with inadequate waste collection reported significantly higher rates of waterborne diseases, with diarrheal incidences ranging from 78 to 95 cases per 1,000 in poorly serviced areas, compared to just 35 to 45 in well-serviced regions (District Health Department, Darjeeling, 2018).

Furthermore, reports from the National Vector Borne Disease Control Programme (2015-2019) identified several disease hotspots within the Siliguri Municipal Corporation, particularly in areas characterised by poor waste disposal services. According to the vector-borne disease surveillance data from the West Bengal State Health Department, these hotspots accounted for approximately 60-70% of reported dengue cases and 65-75% of malaria incidences during the study period (WBSHD, 2019).

7.3. Occupational Risks for Workers and Waste Pickers

Informal waste pickers and sanitation labourers in India face serious hazards due to exposure to harmful waste. In Siliguri, workers handle mixed waste manually, lacking personal protective equipment (PPE) and training, which heightens their risk of injuries and exposure to pathogens. The Siliguri Municipal Corporation (SMC) relies on around 685 informal “Nirmal Bandhu” workers for door-to-door waste collection in 47 wards, making them vulnerable to various health risks like:

- Cuts and puncture wounds from sharp objects like broken glass and needles.
- Respiratory complications from inhaling dust and decaying organic matter.
- Infections from pathogens present in waste materials.
- Musculoskeletal issues arising from the manual handling of heavy loads.
- Psychological stress linked to stigma, job insecurity, and health concerns.

8. Policy Actions

According to the SMC report, the current scenario reflects SMC’s consideration of establishing a recycling unit at the source of waste generation to minimise waste. The measures they have implemented are as follows:

- The Solid Waste Management Committee has prioritised domestic waste segregation at the source.

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- As per the Solid Waste Management Rules 2016, it is mandatory to set up a modern mechanical waste-to-compost unit and a plastic recycling unit at the market and landfill sites to maintain a zero-waste zone. This initiative focuses on: 1. Reducing waste at the generation point. 2. Lowering transportation costs with a monitored route map for dumper bin disposal, including GPS tracking.
- With 899 self-help groups established, the SMC plans to introduce a recycled paper unit among them. They are also considering the collection of household biomedical waste, such as napkins, for incineration at the dumping site.
- Additionally, the SMC is collecting kitchen waste from hotels and hospitals, which can be minimised using Acidification and Methanation Technologies. The Revised Solid Waste Management Rules 2016 outline 37 responsibilities for local authorities to adopt.

Ongoing Initiatives:

- Two compact stations will be set up in commercial areas within a few months.
- The vehicle shed is being renovated.
- Three roads around the dumping ground are under construction.
- Twenty new vehicles have been purchased for improved waste management and will be distributed among the boroughs based on their requirement.
- The SMC has launched SWACHH MAP, a mobile app that effectively serves as a powerful grievance redressal tool, empowering citizens to report cleanliness issues directly to their local municipal corporations.

9. Gaps in Management

- **Segregation**: The current rate of waste segregation is alarmingly low, hovering around 19%. Implementing a comprehensive and universally adopted waste segregation strategy is imperative for health and environmental protection.
- **Dumpsite Conditions**: The landfill at the Don Bosco site operates without scientifically-based management practices, lacking essential controls for leachate and air pollution. This oversight endangers both environmental integrity and public health.
- **Worker Safety**: Waste management workers often toil without basic protective gear, including gloves and masks, alongside the absence of proper training and formal employment contracts. This set of circumstances leaves them exposed to hazardous working conditions and health risks.
- **Monitoring**: The Siliguri Municipal Corporation (SMC) currently does not carry out routine monitoring of groundwater quality, air pollutants, or disease incidences, creating an alarming void in health surveillance and a major obstacle to implementing informed public health strategies.
- **Public Behaviour**: Civic education relating to responsible waste management practices remains fragile, and enforcement of existing regulations is exceedingly weak, contributing to a culture of disregard for community cleanliness.

10. Recommendations

10.1 Spatial Optimisation Based on Published Guidelines

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The Ministry of Urban Development's Best Practices in Solid Waste Management (2016) emphasises the importance of geographical factors in waste collection route design. Optimising these routes should enhance accessibility in peripheral areas through better infrastructure and appropriate vehicles for difficult terrains.

- **Policy Coordination:** Local waste management efforts must align with the national Swachh Bharat Mission–Urban, which aims for 100% door-to-door waste collection and integration of the informal sector.
- **Community Composting Promotion**: Encourage community composting by replicating successful initiatives like the CapaCITIES pilot project. Offer incentives such as rebates or recognition through "Swachh Ward" awards.
- **Source Segregation Scale-up:** Implement strict segregation of wet, dry, and hazardous waste based on the 2016 MSW rules to reduce contamination and improve waste processing.

10.2 Zone-Based Management Framework

The Central Public Health and Environmental Engineering Organisation's Manual on Solid Waste Management (2017) recommends zone-based approaches for cities with diverse geographical characteristics. Following this framework and considering published research on Siliguri's topographical constraints, the city should implement a zone-based waste management system that accounts for geographical variations and population density differences.

- **Scientific Landfill and Leachate Control**: Convert the Don Bosco site into a scientifically designed landfill that is lined, fenced, capped, and systematically monitored for health and safety. This includes installing robust leachate collection systems, methane control technology, and gas flaring systems to minimise environmental impact. Implement quarterly groundwater monitoring to identify contamination levels proactively.

10.3.Decentralised Processing Strategies

Research by Annepu (2012) on waste management in Indian cities and the Technology Advisory Group on Solid Waste Management's recommendations (2018) support decentralised processing approaches for geographically constrained cities. Based on these published guidelines and Siliguri's geographical characteristics, establishing strategically located processing facilities would reduce transportation distances and improve processing efficiency.

10.4 Integrated Health Monitoring

The World Health Organisation's Environmental Health in Urban Development guidelines (2016) and published research on waste-related health surveillance systems recommend integrated monitoring approaches. Implementation of systematic health surveillance that correlates waste management data with health outcomes would enable evidence-based response to emerging health threats.

- **Worker Safety and Inclusion:** Equip waste workers with essential personal protective equipment (like gloves, masks, and boots), offer comprehensive training programs, and provide regular health check-ups. Formalise the roles of informal waste pickers by forming cooperatives, thereby enhancing their safety and enabling their integration into more regulated recycling efforts.

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- **Health Surveillance and Awareness:** Conduct comprehensive epidemiological surveys in high-exposure wards, such as 41 and 42, to collect data on health outcomes. Engage and collaborate with local medical centers to monitor cases related to respiratory, gastrointestinal, and dermatological conditions. Initiate extensive public awareness campaigns focused on promoting hygiene practices, emphasizing the consequences of improper waste disposal, and cultivating a sense of community pride.

11. Conclusion

This geographical analysis of solid waste management practices and impacts on health in Siliguri Municipal Corporation (SMC) reveals significant spatial disparities in both service delivery and health outcomes. The study demonstrates that geographical factors, including topography, drainage patterns, and urban growth patterns, play crucial roles in determining waste management efficiency and associated health impacts.

The findings indicate that current waste management practices under Siliguri Municipal Corporation are inadequate to address the health challenges posed by rapid urbanisation. The spatial concentration of health impacts in peripheral areas with poor collection services highlights the need for immediate interventions. The research emphasises that effective waste management in cities like Siliguri requires integrated approaches that combine geographical analysis with public health considerations. Future planning initiatives should prioritise spatial equity in service delivery while considering the unique geographical challenges posed by the city's location in the Himalayan foothills.

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