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Article

An assessment of household solid waste management in Mainpuri, Uttar Pradesh, India

Mohini Saran[1,*], Salahuddin Mohd[1], Venkat Choubey[2], Atul Kumar[3], Abhishek Rajak[4], Manoj Kumar[5,*]

[1] Department of Geography, School of Earth Sciences, Banasthali Vidyapith, Rajasthan 304022, India
[2] Graduate School of Public and International Affairs (GSPIA), University of Pittsburgh, Pittsburgh 15232, PA, USA
[3] Department of Geography, N.R.E.C. College, Chaudhary Charan Singh University Meerut, Khurja 203131, India
[4] International Institute of Population Studies, Mumbai 400088, India
[5] Center for Economic Studies and Planning, Jawaharlal Nehru University, New Delhi 110067, India
*** Corresponding authors:** Mohini Saran, mohini.saran31@gmail.com; Manoj Kumar, manojkumar@jnu.ac.in

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Abstract: Rapid industrialization, urbanization, population growth, and migration from rural areas have resulted in increased solid waste generation in developing cities, which is commonly regarded as the most significant urban issue. The improper disposal of waste and inefficient collection methods is a significant problem in most of the municipalities in Indian cities. This challenge is further compounded by unscientific waste treatment practices, lack of modern technology, and limited resources. This study aims to assess the status of solid waste generation and disposal across different household income groups and to evaluate how Mainpuri manage and handles the solid waste management system. The study is based on primary data collected through a household survey in Mainpuri city, covering a sample of 1,836 households from various income groups. The data used in this assessment was collected from household surveys and government records. Although there is a recycling plant in operation, its capacity is inadequate to address the increasing waste generation and demands of the community. This shortfall underscores the need for enhanced waste management strategies and infrastructure to effectively cope with the rising volumes of solid waste. As a result, large quantities of solid waste accumulate in low-lying areas near the Isan River and the proximity of the plant. Without a comprehensive solid waste management plan in the municipality, the situation is likely to deteriorate further. Mainpuri City urgently needs a sustainable strategy to effectively manage its solid waste, addressing both current challenges and future demands. Implementing such a strategy is essential for improving public health, environmental conditions, and overall quality of life in the city.

Keywords: solid waste; solid waste management; recycling; household

1. Introduction

Waste generation is an inevitable byproduct of human activities and has been present since the dawn of mankind [1,2]. As civilisations have progressed, the complexity and volume of waste generation have increased significantly [3]), and the late 19th century marked the rise of a consumer society driven by the Industrial Revolution, which further escalated waste production [4]. The rise of industries and changes in lifestyle have profoundly transformed the natural environment.

Waste is any substance or object which the holder discards or intends or is required to discard (UNEP) To the average person, anything unwanted, useless, or lacking economic value is typically regarded as “garbage” or “waste [5,6]. The term “solid waste” specifically refers to unwanted or discarded materials originating from households, street cleaning, commercial, industrial, and agricultural activities [6].

Through the lens of science, there is no such thing as absolute waste; nearly all components of solid waste can be repurposed if managed or treated properly. Solid waste can thus be described as organic or inorganic materials produced from household or commercial activities, which may have lost value to their original owner but still hold potential worth to others [7].

The rising population, swift economic growth, and improving community living standards are driving an increase in municipal solid waste generation in developing cities. As economies grow and living standards rise, the demand for goods and services is escalating rapidly, resulting in higher per capita solid waste generation [8]. In nature and society, the recycling and decomposition process always continues. Hence, one type of solid waste may prove useful to others [1]. Recycling old iron, plastic, glass, paper, etc. items come in a new form in front of us, and the bio-degradable substance in a fixed amount is decomposed by the micro-organisms[9]. Yet, there is an excessive amount of waste currently being generated in this era, so it is not possible to recycle and decompose, and the excessive amount of solid waste becomes a serious problem.

In the current assessment, the various aspects of solid waste management have been evaluated and discussed in Manipuri City, located in the Gangatic Plains of India. The primary source of municipal solid waste is generated from households, and the rest comes from commercial, medical, and other activities. The type and quantity of solid waste varies with the time and season. At the same time, household solid waste is generally biodegradable. Population growth and urbanisation, key drivers of economic progress, lead to a rising demand for resources. As a result, the amount of biodegradable solid waste is decreasing, while non-biodegradable solid waste continues to increase daily [10].

Approximately 5 billion of the world's population, roughly 8 billion, will reside in cities by 2025 [11]. Currently, about 4 billion tons/day of solid waste (municipal, industrial, hazardous) is produced annually worldwide. Municipal solid waste is between 1.6 to 2 billion tons/day [12].

Solid waste is taking a serious challenge, not only for environmental experts but also for the public. The facts of the 2011 census of India show that 31.2% (3771.06 lakhs) of the present total population, and in 1901, 12.26% (258.55 lakhs) of the total population lived in urban centres. In the last few years, the population is continuously migrating from the rural, semi-urban areas to the cities. Due to this, the population and number of towns are increasing. The total number of cities in 2001 was 5161, which increased to 7935 in 2011[13,14].

CPCB report data has shown India's solid waste generation status in **Table 1**. It is clear from the appropriate table the amount of solid waste has decreased from the year 2013–2014 to 2017–2018; this decrease is not due to a reduction in solid waste generation; rather, it is attributed to a decline in the submission of annual reports by states each year. This report shows the negligence of the state, due to which it is difficult to estimate solid waste production in India correctly.

Table 1. Status of solid waste generation and annual report (2013–2018).

Year	Solid waste generation status			Status of annual report received
	Solid waste generation (TPD)	Collected (TPD)	Treated (TPD)	
2013–2014	142,566	117,645	33,665	35
2014–2015	141,064	127,531	34,752	30
2015–2016	135,198.27	111,027.55	25,572.25	24
2016–2017	119,140.9	116,685.9	24,045.05	26
2017–2018	43,298.385	45,082.15	15,386.81	16

Source: CPCB reports from the year 2013 to 2018

According to the recent report of the Central PollutionControl Board, 43,298.385 TPD (tons per day) of MSW was generated in India from 2017 to 2018. Of the total waste generated, approximately 45,082.15 TPD of MSW was collected, and only 15,386.81 TPD was processed or treated. This data is only received from 16 states out of 35. **Figure 1** shows which state submitted their report in 2017–2018, and states like Uttar Pradesh, Rajasthan, Maharashtra, Haryana, Himachal Pradesh, Punjab, Kerala, Delhi etc. didn't submit their report. In India, solid waste management is the most neglected sector by government and local authorities [15].

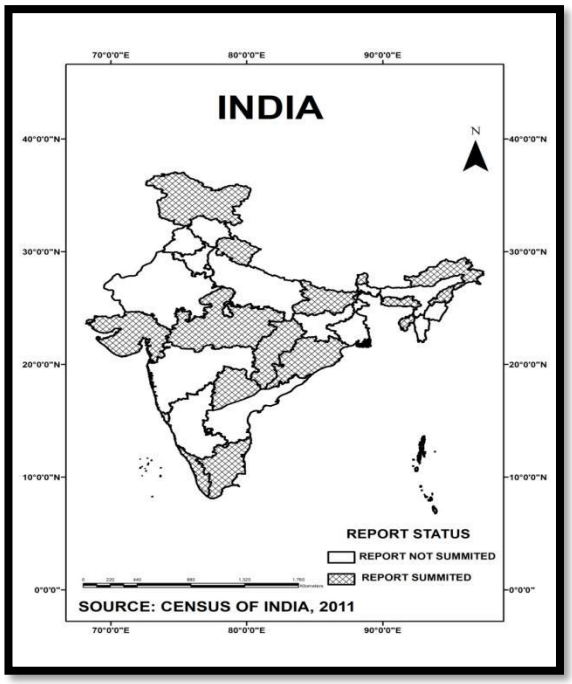

Figure 1. Status of an annual report received in 2017–2018.
Sourse: Censes of India (2011) and CPCB annual report (2017–2018).

2. Objectives

This paper aims to achieve two primary objectives. The first is to identify the key challenges associated with the city's solid waste management system. The second objective is to evaluate the effectiveness of solid waste management and disposal systems at both the municipal and household levels. These objectives will

provide a comprehensive understanding of the current issues and the efficiency of existing waste management practices.

3. Database and Methodology

The primary sources of data for this study include household surveys and questionnaire-based interviews, which were conducted to gather information from respondents. In addition, the study also utilised secondary data from relevant sources to complement the findings. The sampling method employed was a stratified random sampling approach to ensure diverse and representative data collection across different segments of the population. In the first strata, 16 wards (representing approximately 50% of the total 32 wards) were selected from Mainpuri City based on population size and geographic location within the city. In the second strata, 10% of households (a total of 1836) were chosen from each of the selected wards, stratified by income groups to ensure representation across different socio-economic levels. The income groups in the questionnaire shown in **Table 2** were developed based on data and methodologies from similar studies [16–19]. This approach ensures that the research instruments are grounded in established research practices and tailored to effectively capture relevant information for this study. Secondary data was gathered from several sources, including the Mainpuri Municipal Council (2019), the District Census Handbook of Mainpuri City (2011), and the Central Pollution Control Board (CPCB) Report (2013–2014 to 2017–2018), among others. These sources provide valuable insights and contextual information that support the analysis conducted in this study.

Table 2. Indicating the various income groups and their proportion in the respondents.

Category	Income	Households n (%)
High-Income Group	> ₹35,000/month	474 (25.81)
Middle Income Group	₹10,000–35,000/month	626 (34.10)
Low-Income Group	< ₹10,000/month	736 (40.09)
Total		1836

Sourse: City field survey, 2018–2019.

4. Study area

Mainpuri, the administrative headquarters of the eponymous district in Uttar Pradesh, India, is a city situated to the northeast of Agra. Geographically, the city is located at an elevation of approximately 153 meters (502 feet) above sea level, with latitude and longitude coordinates ranging from 27°12′8″ N to 27°15′53.98″ N and 78°58′42″ E to 79°04′52.11″ E. Surrounding Mainpuri are the towns of Sultanganj to the north, Ghiror to the west, Jagri to the south, and the Kuravali development block to the east (**Figure 2**).

The district of Mainpuri is characterised by a vast, level plain punctuated by sand ridges along the western border, rolling sand hills and undulations near the Kali and Isan Rivers, and ravines along the Yamuna to the southwest. The Kali Nadi forms the northern and northeastern boundary of the plain, while the Yamuna

encloses it to the southwest.

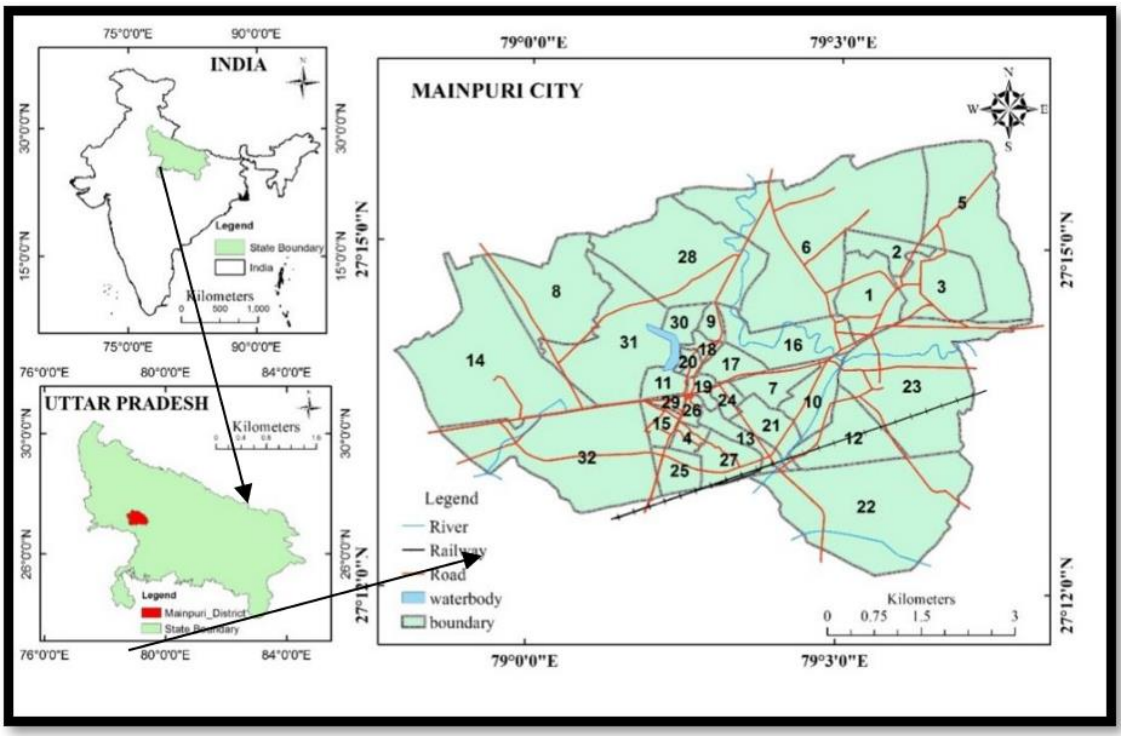

Figure 2. Location Map of the Mainpuri City.
Source: Census of India (2011) and Municipal Council, Mainpuri city (2018).

In terms of infrastructure, Mainpuri has a well-established transportation network. The Mainpuri railway station, established in 1905, provides essential rail connectivity to the city and surrounding regions. Additionally, the national highway NH 91 passes through the district, connecting it to nearby cities such as Etah and Kannauj. Although NH 91 does not directly pass through Mainpuri city, the major road from the city provides access to this vital transportation artery. Furthermore, two state highways, UP SH 83 and UP SH 84 pass through Mainpuri, enhancing its connectivity to other parts of the region.

Mainpuri's economy is primarily driven by industrial activities, including cotton ginning, oilseed milling, and the manufacture of lamps and glass products. These sectors have played a significant role in contributing to the city's economic development and providing employment opportunities for its residents. Moreover, Mainpuri has a rich cultural heritage, exemplified by its traditional crafts, such as tobacco cultivation and wooden sculpture [20,21].

5. Status of household solid waste in Mainpuri city

The Mainpuri Council is responsible for solid waste management services in Mainpuri City. As per the 2011 Census, the total population of Mainpuri City was estimated to be 120,400. According to the Municipal Council of Mainpuri present 2019 population of the city is 179,288.

Figure 3 reveals that the city's population is unevenly distributed across its wards. Nearly one-third (35.06%) of the residents live in wards with a high population density (5501 to 6000 people), while a slightly smaller number reside

inwards with a very high population density (over 6000 people). A smaller proportion of the population lives in wards with moderate (5001 to 5500 people) or low population levels (under 5000 people).

It is observed that about seven wards came under the category of the very high density of population (> 25,225 persons per sq. km), five wards came under the category of high density (15,655–25,000 persons per sq. km), and nine wards came under the category of moderate density (5268–15,000 persons per sq. km), while eleven wards came under the category of low population density (< 5000 persons per sq. km). The classification shows that most of the high-density wards lie in the core of the city.

The Municipal Council of Mainpuri estimates that City produces 40 tons of solid waste daily. However, a recent survey suggests that the actual amount of waste generated is significantly higher, ranging from 80 to 100 tons per day. Additionally, the city's recycling plant can only process 40 tons of biodegradable waste daily, indicating a significant gap between waste generation and recycling capacity.

This data shows that 50 % of the solid waste of the city is dumped on the empty spot located near the Ishan River, Shamsan Ghat Road, and Jail Road. Every day, 10 to 12 trucks of Solid waste are being dumped on the banks of River Ishan. (Reported in Dainik Jagran Newspaper, 21 March 2018). A cleanliness drive named "Rejuvenation" was undertaken for Rs. 11.86 crore for the cleaning of the river Ishan (Reported in Amar Ujala Newspaper, 13 June 2018).

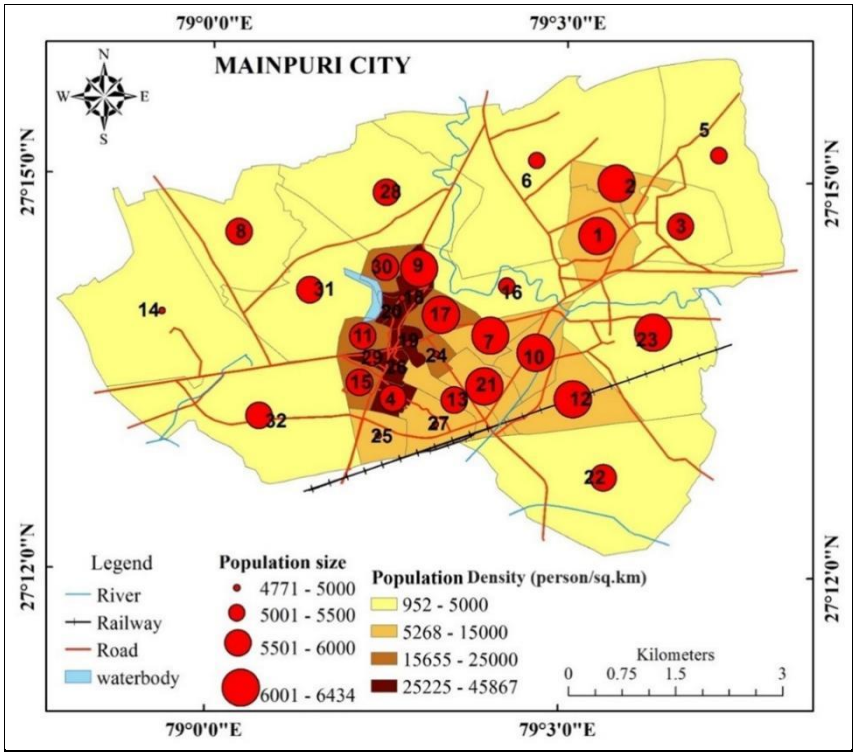

Figure 3. Population size and density of Mainpuri City.
Source: District census handbook of Mainpuri city (2011) and Municipal Council, Mainpuri city (2019).

5.1. Amount of solid waste generation by households

The quantity and quality of waste vary according to residential, commercial, and

industrial areas, as well as economic, occupational, educational, and population status. It was observed from **Table 3** that approximately 42% of the total sampled households generated less than 1 kg of solid waste per day.

It is clear from income group distribution that 53 per cent of the high-income group generated 2–3 kg of solid waste per day, 46 per cent of the medium group generated 1–2 kg of solid waste per day and 78 per cent of the lower-income group generated less than 1 kg solid waste per day. The higher-income households are generating more solid waste than the lower and medium-income households.

Table 3. Income-wise distribution of sampled households from Mainpuri City according to the amount of solid waste generation (In percentage).

Income Group	Amount of solid waste generated by households (%)			
	<1 kg/day	1–2 kg/day	2–3kg/day	> 3 kg/day
High	3.16	18.57	53.59	24.68
Medium	28.43	46.01	16.29	9.27
Low	77.85	18.62	3.53	-
Total	41.72	27.94	20.81	9.53

Source: Field survey, 2018–2019.

5.2. Solid waste disposal at the household level

According to Municipal Solid Waste (Management and Handling) Rules, 2000 [22], every urban local authority has door-to-door waste collection service, but due to a lack of labour and financial crises, authorities are not able to give their services properly. Household solid waste disposal habits are very important to clean their neighbourhood environment.

Table 4. Income-wise distribution of sampled households (in percentages) from Mainpuri City according to place of disposal.

Income group	Unauthorized sites				Authorized site
	Into drain	Open spaces	Waste dumps	In hole of house	Municipal waste bins/ collation van
High	1.48	10.13	22.57	6.32	59.5
Medium	5.27	38.82	32.43	0.79	22.69
Low	15.64	43.88	32.88	-	13.6
Total	7.46	28.95	29.29	2.37	31.93

Source: Field survey, 2018–2019.

As shown in **Table 4**, approximately 66 per cent of the sampled households dispose of their solid waste at unauthorised sites, which includes drains (7.46%), open plots or fields (28.95%), and waste dumps (29.29%). In contrast, around 34 percent of the total sampled households properly dispose of their waste at authorised sites. Additionally, a small percentage of households (2.37%) engage in composting their waste, which is a commendable practice for reducing and reusing solid waste. This approach not only minimises waste but also contributes to sustainable waste management efforts.

It is clear from the income-wise distribution that approximately 60 percent of

the high-income group, 23 percent of the medium-income group, and 14 percent of the low-income group dump their waste on authorised sites. It is seen that unauthorised waste disposal practice is very common in most households of the lower-income group, the reason for this is that the dustbins are not placed at a great distance from their households.

5.3. Collection of solid waste by municipality

The collection of waste from the city is the responsibility of Mainpuri Municipal council. It was observed from **Table 5** that approximately 46 percent of the total sampled household solid waste was not collected for more than 15 days. This action of the municipality is harmful to both human health and the environment.

It is clear from the income-wise distribution that the frequency of waste collection services is good in the higher-income groups as compared to the low-income groups. Approximately 55 percent of high-income group solid waste is collected daily, approximately 30 percent of medium-income group waste is collected weekly and approximately 56 percent of low-income group waste is collected monthly. Low-income people are highly affected by municipal service and live in an unhygienic and messy environment, which is very dangerous in the current situation for their health.

Table 5. Solid waste collection frequency by municipality (in percentages).

Income group	Daily	Alternative days	Twice a week	Weekly	Fortnightly	Monthly
High	55.49	17.09	16.03	7.17	1.27	2.95
Medium	8.47	10.7	8.95	30.51	25.08	16.29
Low	3.53	2.04	3.8	13.59	21.07	55.97
Total	18.63	8.88	8.71	17.7	17.32	28.76

Source: Field survey, 2018–2019.

6. Challenges in Solid Waste Management in Mainpuri City

Based on the assessment associated with the solid waste management practices in Mainpuri city, it can be derived that the management of solid waste is very poor, and it is worsening day by day due to a lack of people's awareness and lethargic behaviour of agencies involved in this. Not only the behaviours responsible but also the resources, funds, and infrastructure played an important role in this manuscript. With the interaction of various departments of the city and respondents, we can identify some problems.

A comprehensive assessment of solid waste management in Mainpuri city revealed several significant challenges. The absence of an efficient door-to-door collection system, coupled with inadequate numbers of bins in wards and public areas, has contributed to the accumulation of waste. Moreover, the lack of source segregation practices and public awareness regarding proper waste disposal has exacerbated the problem.

Other notable issues include the prevalence of open burning of solid waste by local residents, the illegal disposal of waste in open dumps, drains, and low-lying areas, and the widespread littering of streets, footpaths, and public spaces.

Additionally, financial constraints faced by the municipality have hindered effective solid waste management initiatives.

Furthermore, the study found that the level of awareness regarding solid waste management among households, irrespective of income group, is generally low. This lack of understanding and engagement has hindered the implementation of solid waste management rules at the ground level.

7. Recommendations for improving solid waste management in Mainpuri city

To address the challenges identified in solid waste management in Mainpuri City, several recommendations can be implemented. Firstly, the municipality should adopt a comprehensive and organised Solid Waste Management (SWM) plan that ensures efficient and regular collection of waste from households and public bins. Secondly, the installation of sufficient bins at key disposal sites within the city is essential to facilitate proper waste disposal.

Promoting waste segregation and encouraging recycling and reuse practices are crucial components of a sustainable SWM system. The municipality should actively implement guidelines outlined in SWM rules to ensure compliance and effectiveness. Additionally, the establishment of a landfill site for the final disposal of solid waste is necessary to prevent environmental contamination.

To enhance the implementation of SWM initiatives, increased funding from the Government of India is essential. The government's ongoing awareness campaigns through print and electronic media should be expanded to reach a wider audience. Moreover, involving the private sector in the collection, transportation, and treatment of Municipal Solid Waste (MSW) can leverage their expertise and resources to improve the overall efficiency and sustainability of the system.

8. Results and discussion

From **Table 1,** we can see the current condition of solid waste management in India. From the help of **Tables 3**–**5** this study shows that the low-income group household solid waste management condition is very pathetic and municipal conical does not give proper service in these areas. About 78 percent of low-income group houses generated less than 1 kg of solid waste per day this amount of solid waste is negligible as compared to medium and high-income groups on the other hand, and they don't have public bins in their area this is one reason why about 86 percent of low-income group household dump their household waste on unauthorised site. Apart from this, the frequency of collection of waste by the municipality is very low all over the city; the municipality must collect the waste daily. However, only about 19 per cent of sampled households get the municipality service daily. Out of these, the high-income group, about 55 percent, the medium-income group, about 8 percent and 3 percent of low income get municipal service daily. Rather than this, about 56 per cent of low-income groups get the municipal service monthly.

The condition of solid waste in Mainpuri City is influenced by factors such as location, socioeconomic conditions, and weather patterns. During the rainy season, certain wards, including Agravaal, Sansarpur, Sheetala Dhaam, Dhaarau,

Dariba-Mahmud Nagar, Nagla Niranjan, Nagariya, Ram Lila Maidaan, and Nagla Rate, experience particularly severe waste management issues (**Figure 4**). The open dumping of waste in these areas leads to the production of leachate, which contaminates local water bodies, posing a serious environmental threat to Mainpuri City.

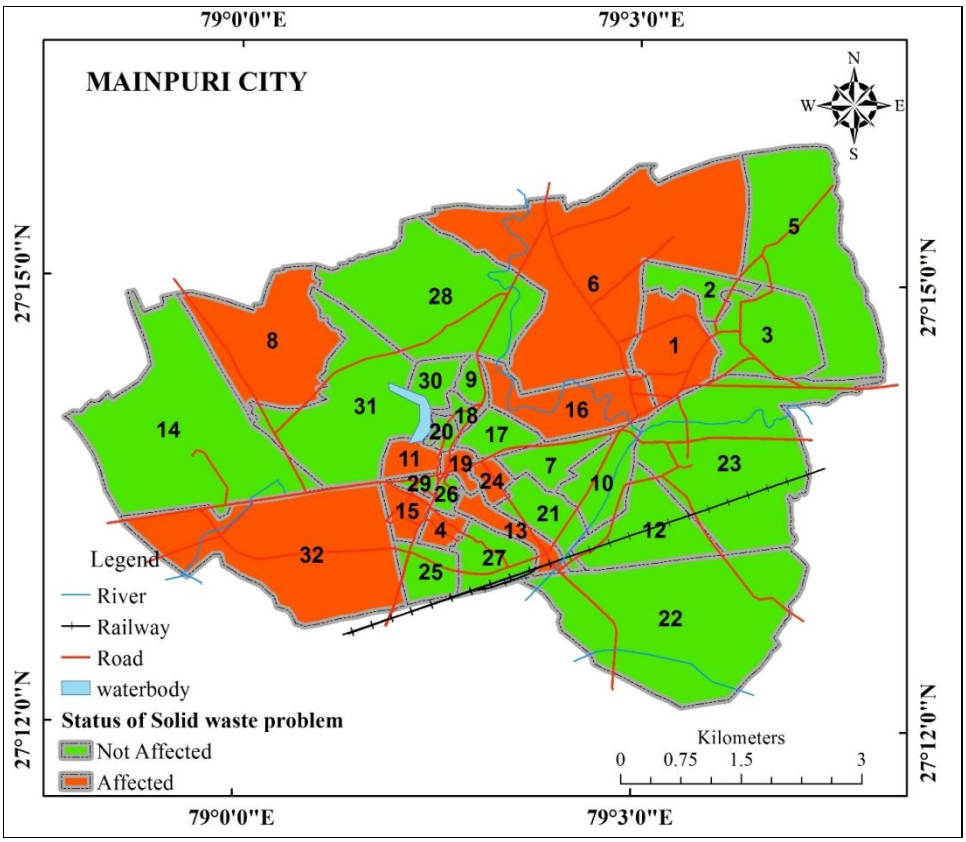

Figure 4. Map of Mainpuri City Affected with Solid Waste Management Service.
Sourse : City field survey 2018-19 and Municipal council, Mainpuri city 2018.

The wards experiencing the most severe solid waste problems are situated in low-lying areas of the city, close to the Raaja Ka Taal Pond and the Insan River. This geographic location exacerbates the issue. Due to the garbage lying in this unauthorised place, the people of the city are facing many problems like garbage blocking the drain and waterlogging problems immerged Flies arise in this stagnant water which becomes the cause of many diseases and health burden, Foul surrounding environment, the uncollected waste attract the animal-like cow, dog, pig etc., the open dump on rode site also creating the traffic problems.

9. Conclusion of the study

The analysis of solid waste management in Mainpuri City reveals several critical challenges, including inadequate infrastructure, improper waste disposal practices and limited public awareness. These factors have contributed to the accumulation of waste, environmental pollution, and public health concerns.

Key findings from the study include:

- Uneven Distribution of Waste: The population density across wards varies significantly, with certain areas experiencing higher levels of waste generation.
- Inadequate Infrastructure: The city lacks a comprehensive and efficient solid waste collection system, leading to improper disposal practices and accumulation of waste.
- Lack of Awareness: Public awareness regarding proper waste disposal and segregation is low, contributing to the problem.
- Environmental Impact: Open dumping of waste has resulted in the contamination of water bodies, posing a serious threat to the environment.
- To address these challenges, it is imperative to implement a comprehensive solid waste management plan that includes:
- Improved Infrastructure: Investing in a robust collection system, sufficient bins, and a well-maintained landfill site.
- Public Awareness Campaigns: Educating residents about proper waste disposal, segregation, and recycling practices.
- Enforcement of Regulations: Strict enforcement of solid waste management rules to ensure compliance.
- Private Sector Involvement: Leveraging the expertise and resources of the private sector to enhance efficiency and sustainability.

By addressing these issues, Mainpuri City can significantly improve its solid waste management practices, protect the environment, and enhance the overall quality of life for its residents.

Author contributions: Conceptualization, MS and SM; methodology, MS and SM; software, MS, SM and MK; validation, MS, SM, AK, VC and MK; formal analysis, MS, VC, AK and AR; investigation, MS; resources, MS; data curation, XX; writing—original draft preparation, MS and SM; writing—review and editing, MS, SM, VC, AK, AR and MK; visualisation, MK; supervision, SM; project administration, MS; funding acquisition, MS and SM. All authors have read and agreed to the published version of the manuscript.

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