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RESEARCH ARTICLE

Enhancing Municipal Solid Waste Management in Rapidly Urbanizing Areas: A Case Study of Rudrapur City, India

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Abstract

Urban solid waste management is a crucial challenge, involving treatment, recycling, and energy conversion for environmental and public health protection. This research explores the management of municipal solid waste in the city of Rudrapur, located in the Himalayan foothills, in the midst of rapid urbanization and industrial development. Rudrapur is confronted with an increasing waste production as a consequence of its expanding population. The study examines waste distribution, evaluates current practices, and proposes effective waste management solutions for local governance. Using secondary data, interviews, and fieldwork, the study assesses waste generation, collection, transportation, processing, and disposal. The waste, comprising biodegradables, recyclables, and non-recyclables, presents challenges like inadequate equipment, unregulated dumping, and inefficiencies. Composite scores reveal disparities in waste management among city wards, uncovering infrastructure and practice gaps. Recommendations include source segregation, expanded composting, improved waste processing, and public awareness. Modern techniques like Geographic Information Systems (GIS) and remote sensing can enhance waste management strategies. The study underscores the urgency of addressing improper waste disposal's environmental and health impacts. By tackling deficiencies and embracing innovation, Rudrapur can transition to a sustainable solid waste management system, fostering a cleaner and healthier urban environment.

Keywords: Municipal Solid Waste; Urbanization; Environmental issue; Rudrapur City

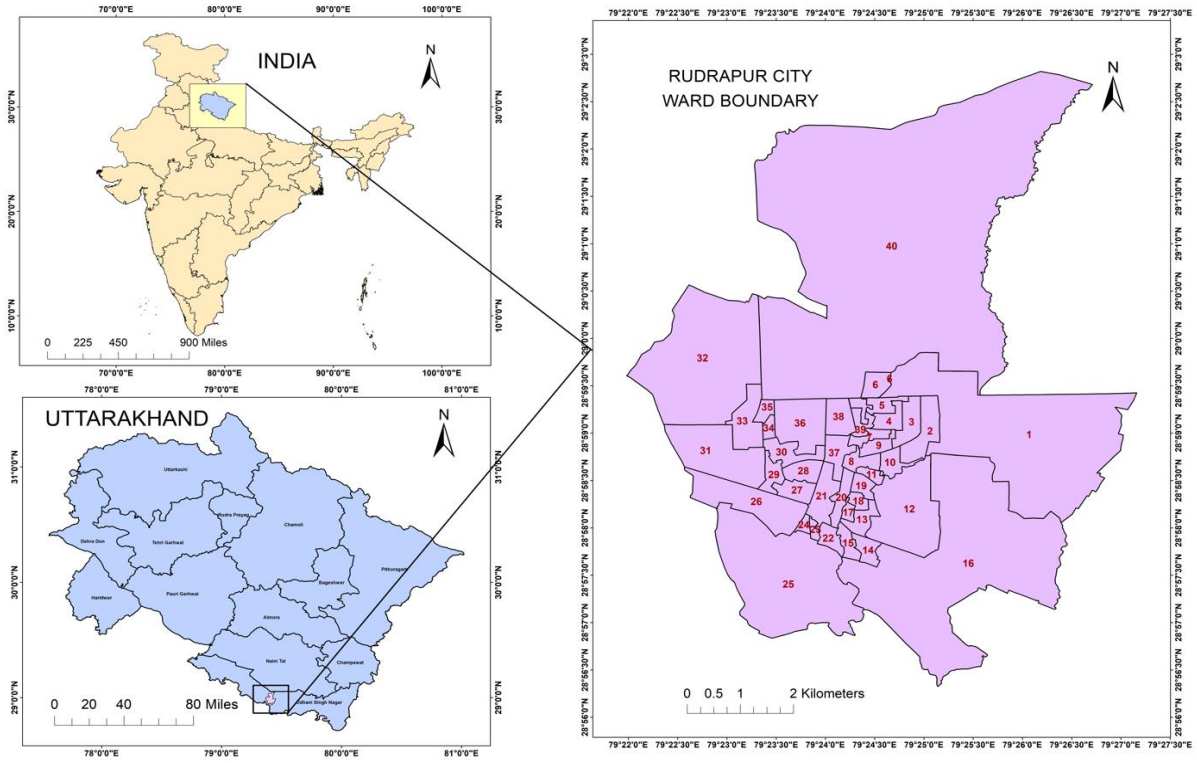
Introduction

Solid waste management means managing the operation of processes to treat, dispose, reuse, recycle and convert solid waste into energy without adversely affecting the environment and public health. Solid waste means those hard things used in our homes, industries, offices, schools etc., which we simply throw away after a single use, which are neither fault nor rot with time. Municipal solid waste is defined as any waste generated by households, commercial and institutional activities and is not hazardous. There are thousands of such products, such as glass, plastic items, electronic items, medical series and medicine vials, etc., which once used remain in the same state for years. Vegetables, fruits, plant leaves, cow dung etc. used in our homes are converted into manure after some

time. Whereas there is no clear system of disposal of solid goods waste. Due to this they not only make many acres of land barren but also increase the pollution in the land and air. The main objective of solid waste management is to make the maximum amount of waste capable of being reused or converted into manure through the plant. Using this waste properly, electricity can be generated. Also, the acquisition of large amount of land can be stopped. In this race of urbanization, industrialization and economic development, we have made such instruments and means, which have given us immediate happiness, but there is no clear action plan for its disposal. In recent years, there has been a rapid increase in the generation of solid waste in India. According to the "Swachhata Sandesh Newsletter" released by the Ministry of Housing and Urban Affairs (MoHUA), as of January 2020, a daily amount of 147,613 metric tonnes (MT) of solid waste is produced, spread across 84,475 wards. Projections indicate that urban areas in India will produce 2,76,342 tonnes per day (TPD) of waste by 2021, 4,50,132 TPD by 2031, and a substantial 11,95,000 TPD by 2050, as outlined in the planning commission report of 2014. Among the states, Maharashtra exhibits the highest generation rate, reaching 22,080 MT per day from 7,322 wards, while Sikkim has the lowest rate, generating 89 MT per day from 53 wards. In Uttarakhand, the daily generation stands at 1589 MT across 1170 wards, according to MoHUA's data in 2020. Main objectives of this paper are as follows:

- To study the distribution of generated and processed solid waste in the city.
- To assess the current scenario of existing process of municipal solid waste management in Rudrapur city.
- To suggest the effective framework for waste management to the local government.

Fig.1: Location Map of Rudrapur City



Source: drawn by authors

Research has been conducted within the Rudrapur city. It is situated in the foothill region of Uttarakhand, a Himalayan state in India. Currently, the city spans a total area of 55.22 square kilometers, positioned between 28°55' to 29°4' north latitude and 79°22' to 79°27' east longitude. It lies in the fertile Terai region, with Uttar Pradesh to its south and the Pantnagar Technology region to its north. Rudrapur is the second most populous city in Kumaun, with its population increasing from 88,815 in 2001 to 1,54,554 in 2011. On February 28th, 2013, it was elevated from a Nagar Palika Parishad to a Nagar Nigam. In 2011, the city covered a total area of 27.65 square kilometers, and in 2018, both its area and population saw growth due to the inclusion of 11 additional villages within its boundaries. As of 2018, the Municipal Corporation Rudrapur is divided into 40 wards, with a population of 175,723 following the delimitation process.

Literature Review

Banerjee, P. et al. (2019) provide an overview of the solid waste management challenges in India. It discusses the various types of solid waste generated, including municipal solid waste, e-waste, radioactive waste, agriculture waste, and hospital waste. The paper highlights the environmental and health concerns associated with improper waste management, such as groundwater contamination, pollution, and the spread of infectious diseases. It emphasizes the need for effective waste management methods, ranging from conventional techniques to modern approaches like refuse-derived fuel, pyrolysis, and incineration, while also discussing their advantages and limitations. Overall, the paper underscores the significance of addressing solid waste management issues in India for environmental safety and public health. Khan, M.H (2018) emphasizes the need for an integrated solid waste management approach in Dehradun, employing public-private partnerships. It highlights the growth in urban population, industrialization, and the challenges faced by the municipal corporation. He also mentions existing rules and provisions, the role of the government, and various studies that recommend sustainable waste management practices. It proposes a strategy involving door-to-door collection, recycling, composting, energy generation, and more, with a focus on evaluation and sustainability. Ultimately, it stresses the importance of improving solid waste management in India for public health and environmental well-being.

Methodology

The data of this paper were collected through secondary sources: the secondary data were available in the Rudrapur Muncipal Corporation, government documents, books, research papers as well as in the websites. A detailed investigation was done regarding the methods of collection, generation, transportation, disposal of solid waste by personal interview session with sanitary inspector of Rudrapur Municipality. The personal observation of the city environment has also done by authors. In order to examine disparities in the levels of solid waste management in wards of the city some variables were considered and analyzed by using Z-score technique (Gallardo et al., 2012 & Miezah, K. et.al, 2015…..). The value of different indicators according to our need were standardized with the help of the following formula:

$$Zi = \frac{Xi - X}{SD}$$

Where,
Zi= Standard score for the ith observation,
Xi=Original value of the observation,
X=Mean for all the values of X, and
SD=Standard deviation of X

The Z-Scores of all the variables were summed ward-by-ward in the second stage, and the average was then calculated for these indicators, resulting in the Composite Score (CS) for each ward, which can be mathematically stated as:

$$CS = \sum Zij/N$$

Where, CS stands for composite score.

N refers to the number of variables.

$\sum Zij$ indicates Z-Scores of all variables i in ward j.

The analysis of collected data were processed in the computer with the help of EXCEL & MS Word softwares. Open-source software (QGIS) is used for diagrammatic representation of data.

Results and Discussion

The city of Rudrapur is grappling with inadequate solid waste management challenges attributed to swift industrial growth, urban expansion, and insufficient financial resources. As the table 1 shows that in 2041 the population would be three times of the 2011 and in upcoming years municipal waste will generate at very high rate.

Table:1 Projected population and MSW status in the city

city	**population**		***MSW status**	
Rudrapur	2011	2041	2017 (@300gcpd*)	2041 (@400gcpd*)
	154514	404705	46.35	161.88

Source: SWM action plan, final draft (Govt. of uttarakhand)2017.

*MSW- Municipal solid waste *gcpd- generation capita per day.

Within Rudrapur City, the tasks linked to the handling of municipal solid waste, spanning from its creation to ultimate disposal, can be categorized into four distinct operational components:

- Generation of municipal solid waste
- Collection of waste
- Transportation of solid waste
- Processing and Disposal of solid waste

Generation of Municipal Solid Waste: According to the 12th Schedule of the 74th Constitution Amendment Act of 1992, urban local bodies (ULBs) are responsible for keeping cities and towns clean. Daily door to door garbage is collected from all the wards covering individual household, bulk waste generator, residential welfare association, hotels and other commercial organizations. On an average, daily approximately 65-70 MT of waste is generated in the city.

Table: 2 Category wise waste generation in Rudrapur City, 2021

Waste category	**Quantity (MT/day)**	**Percentage of waste**
Bio-degradable waste (collected from households, bulk waste generators, parks etc.)	26.00	40
Recyclable waste	19.50	30
Construction/demotion waste	6.50	10
Drain silt	9.75	15
Street sweeping	3.25	05
Total	65 MT/day	100

Source: Municipal corporation, rudrapur.2021

Fig.2 Category wise waste Generation in the city ,2021

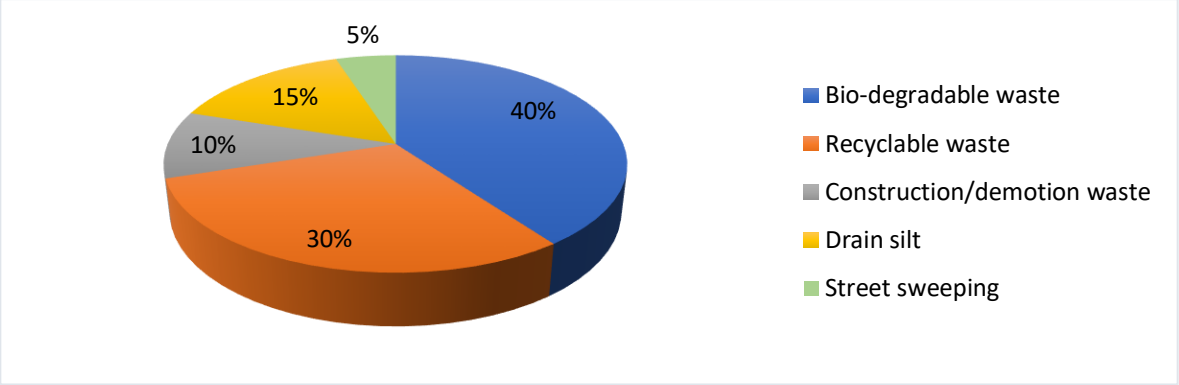


Table 3 indicates that there are only two wards vivek nagar and khera southern that comes under very low category of waste generation . The four wards of the city which fall under the very high category of waste generation/month named as Gandhi colony, aadarsh colony SRA, Alliance colony, Aadarsh Indira colony.(fig.3). This difference of solid waste generation between the wards depends on the lifestyle of the people living there.

Collection of Waste: At present, each city has a different system for the collection of waste. A city has its own municipality which performs this function through community dustbins placed at various places along the roads for the collection of garbage in the city. For the purpose of solid waste collection, necessary number of sweepers have been appointed in the Municipal Corporation Rudrapur and they have been provided with rickshaw tractors and others which can help in garbage collection.

Street sweeping is done by the sweepers from 6:00 to 10:00 a.m. daily with the help of hand rikshaw. They collect garbage from street sides and roads and dump it in nearby the dumping sites and then transport it is picked up by tempos, tractor , trolleys and dumped in open sites outside the city.

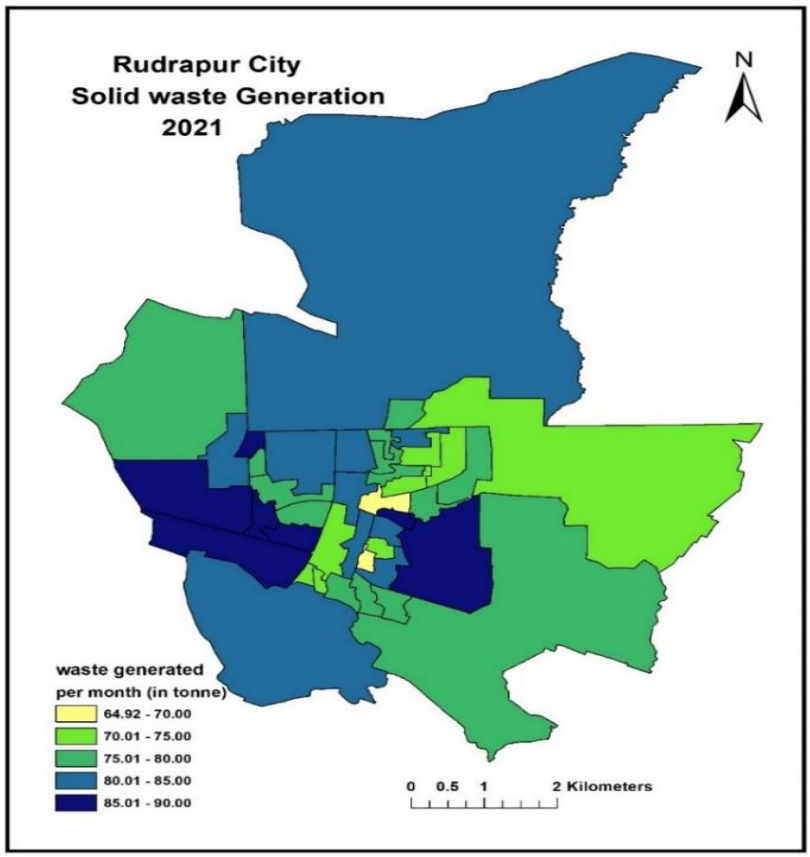
For collection of garbage ,10 tempos run according to their specific routes daily within the city. These tempos collect door to door garbage into two shifts. First shift from 7:00 to 12:00 noon and second shift from 3:00 to 6:00 p.m. with this arrangement, all shopkeepers of the market and houses are requested not to dump garbage on road side or in the drains, but to dump it directly in municipal owned tempos. And finally all collected garbage dumped in open dumpsite which is situated on NH-74 , mohalla pahadganj in Rudrapur.

Table:3 Rudrapur City: Level of waste Generation/month (tonne)

Category	Waste generated/month (tonne)	No. of wards	Name of wards
Very low	64.92-70.00	2	Vivek nagar, khera southern
Low	70.01-75.00	8	Funlsungi, transit camp central and western, shiv nagar, khera middle, bhutbangla west south, Rampura middle, Rampura western
Moderate	75.01-80.00	13	Transit camp east, jagatpura, ajad nagar, raja colony, bhadaipura, paharganj, bigwarha, Rampura east, main market, D1 D2, bhurarani, Indira colony, awas vikas east
High	80.01-85.00	13	Mukerjeenagar, Sanjay nagar, industrial area, dudia nagar, khera north, bhutbangla northeast, fajalpur mahraula, seergotia, singh colony, aadarsh colony ghas mandi, Kalyani view, awas vikas west
Very high	85.01-90.00	04	Gandhi colony, aadarsh colony SRA, Alliance colony, Aadarsh Indira colony

Source: data compiled on the basis on Nagar Nigam Rudrapur,2021

Fig.3 ward wise waste generation,2021



Transportation of Solid waste: The transportation of waste is done through Trucks tripper, Compactors, drain cleaning machine and Tractor, Dumper placer , Rickshaws, J.C.B and plastic compactor. Table:2 reveals the machinery and functional unit which are currently using for the transportation for solid waste in the city. The city also needs few more new equipment's for the collection of waste.

Table:4 Municipal Functional unit for lifting and transportation of solid waste in Rudrapur City, 2021

Equipment	Total numbers
Truck tripper	04
Small tripper	40
Compactor vehicle	03
Refuse collector bins	150
Dumper placer	01
Dumper placer bins	10
Drain cleaning machine	01(under maintenance)
Rickshaws	100
Tractors	07
J.C.B.	05
Plastic compactor	01

Source: Municipal Corporation, Rudrapur.2021

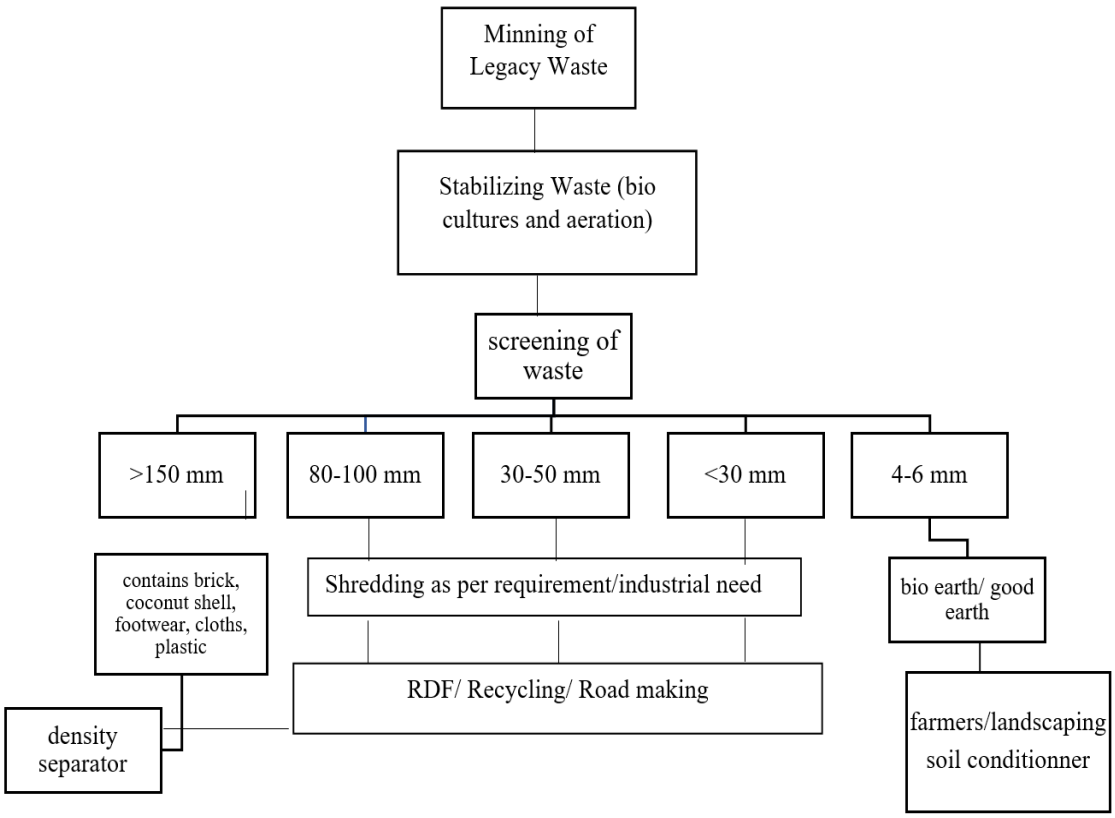
Processing and Disposal of Solid waste: Municipal solid waste dumpsite in rudrapur is located in NH-74 mohalla paharganj at the distance of 1 km from the Nagar Nigam Rudrapur office and it covered 4.04 hectares area. The whole municipal waste is dumped at this place without any segregation. In the absence of landfill or other protected places, the entire MSW is transported to the Rudrapur dumpsite since last 2 years. Existing dumpsite is having Trommel Machine for processing of Municipal waste at dumping site. This trommel plant was inaugurated on 17 july 2020.

Fig.4 Existing Trommel machine installed in Rudrapur city

The treatment and disposal of solid waste is done by bio-minning process. The biodegradable waste is processed into compost. MSW dumpsite at Rudrapur waste is a mix waste dumpsite. In existing technologies only two models are suitable for waste i.e. Bio Mining/ Landfill Mining. Bio mining remediation is most suitable and opted after detailed analysis of waste. Silent features of Bio-Mining are-

- Attain a complete 100% retrieval and recycling of waste
- Employ an alternative source of fuel from rejected waste
- Enhance the available space for post-closure utilization, whether for a new scientifically managed landfill or for alternate purposes
- Achieve minimal emissions of methane and leachate, nearly reaching zero levels
- Clear out old waste sites at a fraction of the cost compared to traditional capping methods, thereby significantly reducing annual expenses related to landfill management, leachate treatment, and gas monitoring
- Considerably decrease the volume of old waste requiring permanent burial and the corresponding land requirement
- Promote the recycling of both organic and previously buried recyclable materials
- Avoid incurring insurance costs and potential legal obligations linked to capped sites susceptible to explosions
- Eliminate any issues of pollution or potential environmental hazards for future generations.

Fig.5 Flow chart to Bio- remediation process of Municipal waste



Source: CPCB, Feb,2019

Fig.6 Waste dumpsite near NH-74 mohalla paharganj in Rudrapur. picture dated 13/may/2022.

Fig.7 burning waste near dumpsite, picture dated 13/may/2022.

Solid waste Management: Level of solid waste management in Rudrapur City was measured on the basis of three variables, number of hand rickshaw per thousand-person, number of dustbins per thousand person and number of garbage truck per thousand people in each ward.

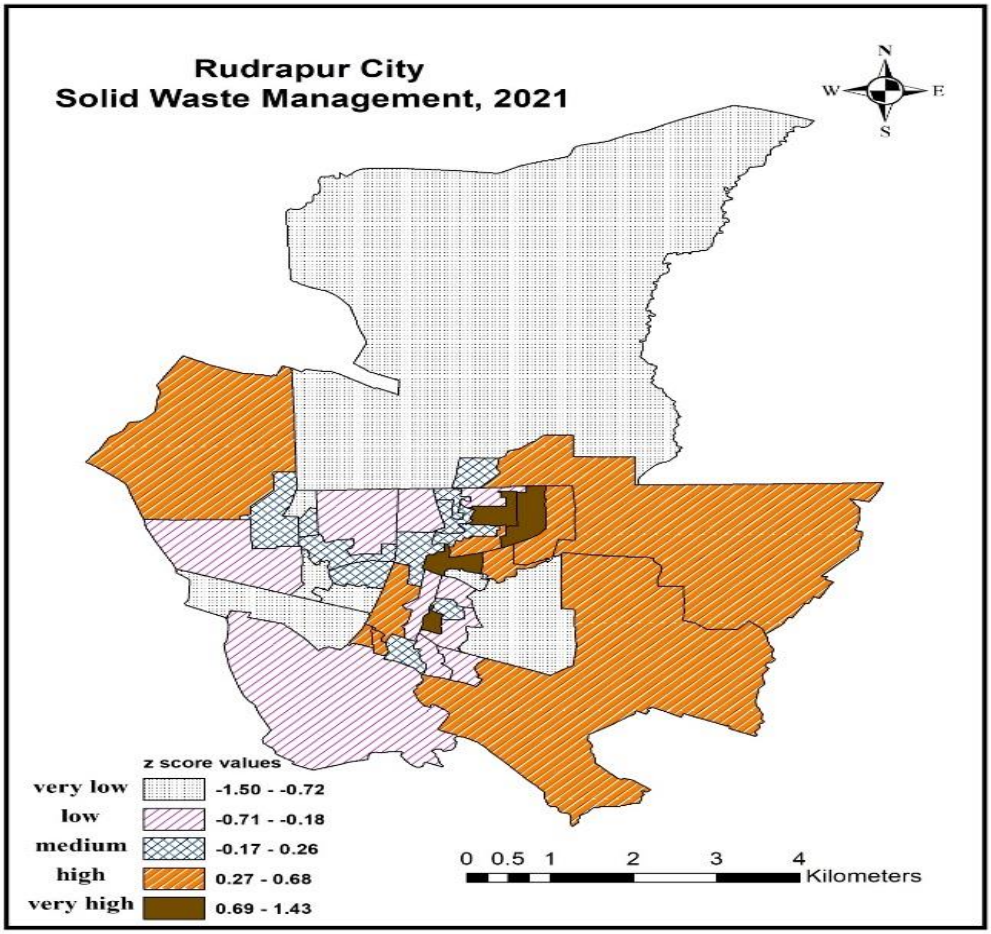
Table:5 Ward wise development of waste management in the city,2021

Level of development	Composite z-score	No. of wards
Very low	-1.50 to -0.72	07
Low	-0.71 to -0.18	10
Medium	-0.17 to 0.26	10
High	0.27 to 0.68	09
Very high	0.69 to 1.43	04

Source: data compiled by author and taken from municipality office of Rudrapur.

Table 5 shows that, the highest value of 1.43 for solid waste management is scored by the khera southern, whereas, the lowest value of -1.5 by SIDCUL ward. 07 wards of the city have inadequate waste management. Several places have large garbage heaps, and dustbins are not kept in the proper locations. Medium level of solid waste management is seen in 10 wards. Small heaps of garbage and filled dust bins are seen almost on every road. Numbers of sweepers are less in number. They are not provided with the needed number of rickshaws and equipment's for the garbage collection. there are 04 wards with very high level of development. Most of them are located in the center of the city, where garbage collection is done on a regular basis.

Fig.8 Ward wise Solid Waste Management in the city,2021



Serious Environmental issues in the study area due to open dumping

Uncontrolled and continuous dumping of solid waste by the Municipal Corporation Rudrapur has created mountains of garbage. After three decades of neglect, it has become a major source of pollution. Waste rotted heaps produces leachate, and dark liquid leaking from the heaps kills surroundings vegetation and irreversibly pollutes groundwater. Garbage dumps also produce methane and a greenhouse gas that causes global warming 21 times more than carbon dioxide. Apart from this, the air quality gets polluted which gets worse due to frequent incidents. It was observed during the field visit that near the dumpsite garbage was being burning. The burning of dumped solid waste is a common practice and creating drastic air pollution as shown in figure 7.

Conclusion

Through the course of the investigation, it has become evident that the efficacy of the solid waste management system in Rudrapur is compromised due to the rapid surge in population, industrial expansion, and deficiencies in administration, legislative enforcement, and financial resources. The unregulated disposal of solid waste alongside roadways is a prevailing issue. These open dumps contribute to the obstruction of drainage systems, the proliferation of flies, and the propagation of contagious diseases. The existing solid waste management framework in Rudrapur proves inadequate due to the absence of proper equipment and funding. The unfavorable ecological consequences stemming from improper waste disposal practices are readily observable. Although Rudrapur possesses a Trommel plant, its capacity of 200MT per day falls short of accommodating the city's entire waste output. Given the current circumstances, it appears unlikely that the plant processes such a substantial volume of waste daily. Moreover, hazardous waste materials from hospitals and other sources are treated as standard waste, a practice that warrants cessation due to its adverse environmental implications arising from open dumping and incineration of waste.

The following recommendations may be incorporated with a view to improve the existing MSW Management:

- To reduce the load on the dumping site, it is necessary to install other composting plant and machine.
- There should be segregation system at source of waste generation point so that Hospitals and other hazardous waste should be process separately.
- Presently, dumpsite is situated along roadside which is environmentally harmful. The garbage should be dumped at an open place away from the city.
- Ongoing surveillance and the systematic accumulation of data are imperative when designing a streamlined solid waste management (SWM) structure.
- The strategic plan aimed at achieving sustainable SWM should spearhead a shift in the behaviours of residents, elected officials, and policymakers to curtail waste generation and elevate recycling and reutilization efforts.
- Embrace contemporary methodologies and technologies such as remote sensing and Geographic Information Systems (GIS) for the comprehensive evaluation of SWM processes.

Declaration statement

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Conflict of Interests: The authors declare no conflicts of interest related to this research.

Authors contribution: Sonu Kaur conducted an extensive review of existing literature, gathered pertinent data through field surveys, and made valuable contributions to the analysis and interpretation of the collected information. Additionally, she was involved in the writing and editing of the manuscript.

Anjali Punera provided comprehensive direction and contributed significantly to shaping the study, playing a pivotal role in crafting the research methodology and analysis.

Data availability: The data utilized in this study were sourced from multiple outlets; including the Rudrapur Municipal Corporation office, government documents, research papers, and various websites. A comprehensive investigation was conducted to understand the methods involved in the collection, generation, transportation, and disposal of solid waste. This investigation included personal interviews with the sanitary inspector of Rudrapur Municipality. Additionally, the authors conducted firsthand observations of the city's environment.

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