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ORIGINAL ARTICLE

Environmental Governance, Public Health and Solid Waste Crisis: A Case Study of Jammu City with Proposals for Integrated Remediation

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ABSTRACT
Inefficient Solid Waste Management poses significant threats to public health and presents one of the most critical urban environmental sustainability challenges in developing countries, where rapid urbanization and resource constraints have widened the gap between waste generation and management capacities. Jammu City, the winter capital of Jammu and Kashmir, exemplifies this crisis, with nearly zero percent source segregation, inadequate collection infrastructure, lack of synchronization between primary and secondary systems, and complete absence of scientific treatment facilities. Approximately 85–90% of the city's waste is openly dumped at Kot Bhalwal, violating the Solid Waste Management (SWM) Rules, 2016 provisions for sanitary landfilling, resulting in severe environmental degradation and adverse health outcomes, including increased incidences of vector-borne and water-borne diseases. Despite sanctioning waste-to-energy and material recovery projects, operational inefficiencies and institutional bottlenecks have left them non-functional. This paper critically examines the public health and environmental challenges embedded within the existing SWM value chain in Jammu City. It identifies major infrastructural, institutional, and community-level challenges, and proposes comprehensive, bio-remediation-focused interventions aligned with the SWM Rules, 2016 and the Environment (Protection) Act, 1986. These include strengthening door-to -door (D2D) collection and segregation, optimizing transport and transfer systems, adopting Integrated Solid Waste Management principles, fostering public–private partnerships, and promoting community engagement to mitigate health risks. The findings emphasize the need to transition from traditional disposal-oriented practices toward a modern, technologically-enabled system and inclusive system that safeguards human health and the environment, aligning with Sustainable Development Goals (SDGs), particularly SDGs3, 6, 11, 12, and 13.
Keywords: *Waste Management, Public Health, Environmental Degradation, Value Chain, Integrated Interventions, Jammu City, SWM Rules 2016, Urban Governance, Sustainable Development Goals*

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INTRODUCTION

Solid waste management (SWM) has gained global attention recently as a critical determinant of urban public health and environmental quality [1]. Rapid urbanization, rising population, elevated living standards and changing consumption patterns have led to an enormous increase in worldwide waste generation rates [2, 3]. The world currently generates over 2 billion kg of waste; the average person produces 0.74-0.79 kg per day [4]. It is estimated that waste generation rates are expected to increase by 56% to 3.8 billion tons approximately by 2050 [5]. The issue of SWM is more prevalent in developing countries. Although developed countries generate considerable waste, they are well-equipped with better techniques to handle it efficiently [6]. Developing countries, including India, are facing a sharp disparity between increasing waste generation rates on the one hand and limited resources to handle the waste on the other hand [7,8 and 9]. The country is witnessing significant institutional lapses, acute financial

constraints, persistent administrative bottlenecks, and inadequate infrastructural capacity, all of which have severely undermined the efficiency and effectiveness of SWM systems. According to "Taskforce on Waste to Energy (WTE)" Report 2014, Planning Commission, India is expected to generate 4.5 lakh TPD of waste by 2031 and 11.9 lakh TPD by 2050 [10]. Urban India is estimated to produce 130,000 – 1,50,000 MT of waste with a per capita waste generation of 330-550 g per day [11]. Solid waste generation rates, source segregation practices, collection frequencies, transportation systems and disposal methods are demonstrated to be unsustainable in India [12]. The city of Jammu, the largest in the Jammu vicinity and the second largest in the State of Jammu & Kashmir, is confronting a crucial sustainability issue of SWM. In addition, being the winter capital of the State, while owning a prime location and a pilgrimage venue, faces a consequential upsurge in waste generation rates. SWM is a state subject with jurisdiction endowed upon Urban Local Bodies [13]. Jammu City, presently undergoing rapid urbanization under the Smart City initiative, is experiencing severe challenges in managing municipal solid waste. The Municipal Authorities have failed to stand up to the mark in providing efficient services. The National Green Tribunal Report has assigned 31st rank to the State of Jammu & Kashmir based on its SWM policy. JMC produces 342 TPD of solid waste, with the per capita generation being 0.45 Kg/capita/per day [14]. Almost zero percent of waste is currently segregated at the source [15]. Although community storage bins painted in green and blue have been installed across the city, the lack of public awareness has rendered them ineffective as residents frequently dispose of waste in a mixed manner [16]. Even when D2Dcollection is carried out in a segregated form, the waste is ultimately dumped in mixed form at the disposal sites, thereby nullifying the purpose of segregation [17]. Community bins are found in a pathetic condition, often overflowing and poorly maintained. At the same time, collection frequencies are particularly irregular in slum clusters and low-income colonies, creating unsanitary conditions and serious health risks for vulnerable communities [18]. A further problem lies in the absence of synchronization between primary and secondary collection systems, resulting in delays, accumulation of waste, and frequent overflows in public areas [19]. Unlike other modern urban centres, Jammu lacks even basic mechanical transfer stations, and the entire transportation process of solid waste relies on manual handling with little or no automation, contradicting the larger vision of a Smart City. There exist no scientific treatment and disposal of waste in the city. Around 85–90 percent of the municipal waste generated daily is disposed of in an open trenching ground at Kot Bhalwal in an unsanitary manner [20]. While projects such as the 125 TPD Waste-to-Energy plant at Bandurakh and various Material Recovery Facility projects have been signed and sanctioned, they remain inoperative. This heavy reliance on unsanitary landfills has led to extensive air, water, and soil pollution. The environmental degradation is further compounded by its impact on public health. Various studies conducted in Jammu have revealed increased incidences of neurological disorders, skin and eye irritations, vector-borne diseases such as malaria and dengue, as well as water-borne illnesses like cholera and gastrointestinal problems, particularly in areas near dumpsites [21]. It has also come to the fore through several studies and reports that socio-economically disadvantaged groups, particularly those living in the peripheries of Srinagar and Jammu cities are disproportionately affected due to a lack of household toilet facilities, poor waste management, and insufficient drainage services. These slum areas facilitate the growth of rodents, microbes, and insects, which act as carriers for several vector-borne diseases such as tuberculosis, dengue, diarrhoea, cholera, and taenia, as well as viruses like Zika and Ebola. According to a study published in the leading regional newspaper, Greater Kashmir, on 25th October 2023, 36,712 cases of Tuberculosis (TB) and 1,239 TB related mortalities were reported in Jammu & Kashmir in the four years from 2020 to 2023 [22]. Furthermore, a report released by the J&K Department of Health and Medical Education on 29th September 2023 noted an immense surge in dengue cases, with a significant outbreak in the Jammu municipal region registering 1,886 patients [23]. Seven districts of Jammu & Kashmir also witnessed a diarrhoea and cholera outbreak in 2010, with 7,670 registered cases. Such disease outbreaks are a direct result of poor sanitation, ineffective waste management, and defunct drainage networks across the districts of Jammu & Kashmir, predominantly in Srinagar City, Jammu City, and other major towns [24]. The situation is paradoxical because waste, when managed effectively, is a valuable resource that can be harnessed for multiple benefits, including energy generation, composting, recycling, and revenue creation. If made functional, waste-to-energy projects could produce considerable renewable energy that may be used within the city or sold to the government for integration into the power grid. In addition, decentralized models of recycling and composting could reduce dependence on landfills, lower pollution levels, and generate employment opportunities. However, the city has been unable to tap this potential due to lack of awareness, weak institutional frameworks, and poor community participation. Residents and communities have limited knowledge of waste management practices and show minimal involvement, which further weakens the efficiency and sustainability of the system. This scenario underscores the urgent requirement of shifting from a

traditional, disposal-oriented outlook toward a modern, integrated, and sustainable waste management approach. Strengthening the demand and supply chain in SWM requires adopting the principles of Integrated Solid Waste Management (ISWM), where the focus is on minimization, segregation, recycling, energy recovery, and scientific disposal. The effective implementation of ISWM necessitates the clear delegation of responsibilities and accountability at every stage, from households to municipal authorities, with active participation from private partners. Public–Private Partnerships (PPPs) must be encouraged to increase investment, improve efficiency, and ensure the timely operation of planned infrastructure, such as Waste-to-Energy plants and Material Recovery Facilities. Additionally, adopting automation, intelligent monitoring tools, and IoT-enabled processes is indispensable to achieving the objectives of a Smart City. Improving SWM in Jammu is not just a municipal priority but also a developmental imperative. A sustainable and integrated system contributes directly to the achievement of global targets under the SDGs, particularly SDG 3 (Good Health and Well-Being), SDG 6 (Clean Water and Sanitation), while also aligning with SDG 11 (Sustainable Cities and Communities), SDG 12 (Responsible Consumption and Production), and SDG 13 (Climate Action). The paper, therefore, critically examines the existing value chain of SWM in Jammu City, highlights the significant challenges the system is grappling with, and attempts to put forward a set of serious and feasible interventions that can help transform the city's waste management into a more sustainable, efficient, and inclusive model.

MATERIAL AND METHODS

About the Study Area

Jammu is a prominent city and a winter capital of the union territory of Jammu and Kashmir. Situated on the banks of the River Tawi, Jammu lies amidst the picturesque Shivalik hills. It is characterized by a diverse geography that includes uneven ridges and surrounding mountain ranges such as the Shivalik and Trikuta ranges. With an area of around 240 square kilometers and an average elevation of 300 meters, Jammu is a crucial hub connecting different parts of the region. Historically, Jammu is believed to have been founded by Raja Jambulochan in the 14th century BCE, with the city's name evolving from "Jambupura" to Jammu. It has a rich cultural and historical heritage, ruled by various dynasties, including the Dogra rulers who made the city an important center for art and culture. Jammu is renowned as the "City of Temples," featuring ancient temples and shrines densely scattered throughout the city that contribute to its religious and spiritual significance. The city plays a pivotal role as a gateway for pilgrimage, especially to the famous Vaishno Devi shrine located nearby. Major landmarks include the historic Mubarak Mandi Palace, Bahu Fort, Raghunath Temple, and several forts and gardens that reflect Jammu's rich architectural legacy. Jammu is also a key railway terminus and commercial center supporting regional trade and transportation. The population of Jammu is culturally diverse, and the city supports educational institutions such as the University of Jammu. Economically, it benefits from agriculture in surrounding areas producing wheat, rice, maize, and barley, alongside urban economic activities. The climate of Jammu varies distinctly across seasons, with cold winters and hot summers. The urban agglomeration of Jammu has 75 wards. JMC has divided the 75 wards into three zones.

The division of wards is based on the River Tawi, which passes through the center of the corporation area. The upper area comprises Zone 1 and Zone 2, while the lower area falls under Zone 3.

Zone 1: This zone covers the old city area and its fringes. It is densely populated. Due to the narrow lanes, the movement of auto tippers and hand carts is complicated, thus posing a significant challenge for the waste collection and transportation.

Zone 2: This zone extends and covers some peri-urban areas of the old city up to Barnai, Chenora Keran and Shazadpur. The population density is less compared to Zone 1. The wards under this zone have a large area, thus making collection and transportation expensive.

Zone 3: This region is located south of the River Tawi and is commonly known as the Trikuta Region. Zone 3 consists of a group of high-income population and the quality of municipal waste is assumed to be good.

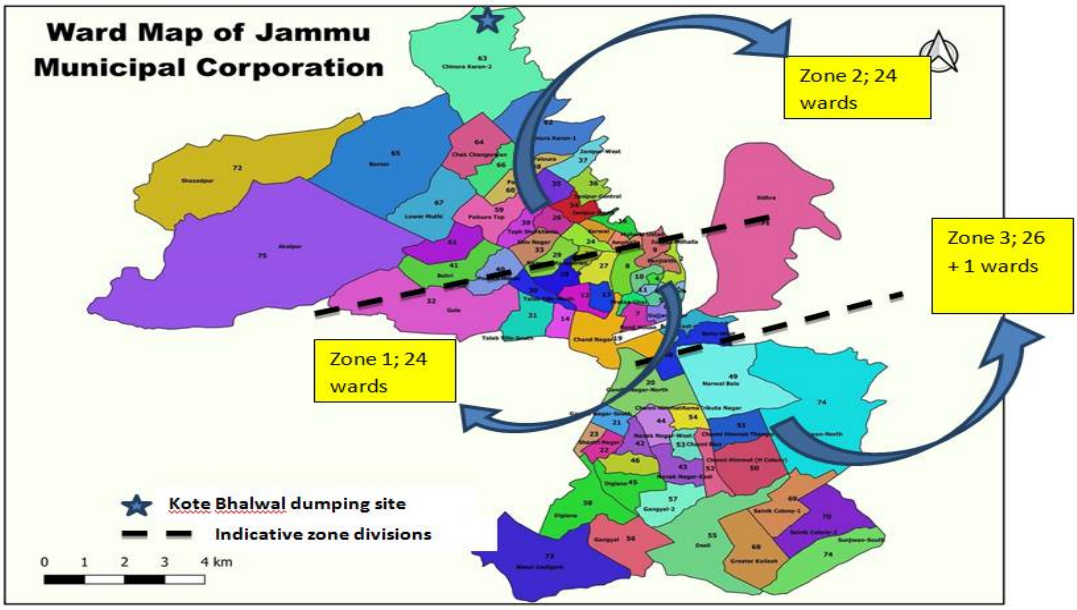

Figure 1: Ward Map of Jammu Municipal Corporation (JMC)

Source: JMC, 2020

Methodology

The study adopted a mixed-methods approach, relying on both primary and secondary data to develop a comprehensive understanding of the SWM system in Jammu City. Secondary data were collected from official and published sources, including Annual Reports of the Central Pollution Control Board (CPCB) and the State Pollution Control Board (SPCB), Action Plans of the JMC, the Techno-Feasibility Report of JMC, Detailed Project Reports (DPRs), and other documents issued by relevant government organizations. These sources provided critical insights into the regulatory framework, institutional arrangements, proposed interventions, and operational aspects of SWM.

Primary data was gathered through unstructured and open-ended qualitative techniques. A total of 30 key informants were interviewed using unstructured interview schedules. The informants represented diverse stakeholder groups, including officials from JMC, representatives of the Jammu and Kashmir Housing and Urban Development Department, SPCB officials, the SWM Nodal Officer, Health Officer, Sanitary Inspectors, Municipal Corporators, and representatives of concerned NGOs. These interviews were conducted face-to-face and designed to capture institutional perspectives, operational challenges, and policy implementation gaps. In addition to the interviews, field observations were carried out at collection points, transfer stations, and landfill sites, allowing for first-hand documentation of waste handling practices, segregation behavior, infrastructure adequacy, and environmental concerns.

Data from interviews, observations, and the FGD were transcribed and thematically analyzed, with codes developed inductively to identify patterns and recurring themes related to governance, infrastructure, community participation, and environmental impacts. Secondary sources were used to triangulate primary findings, thereby strengthening the validity and robustness of the study.

Ethical Considerations

The study adhered to ethical standards in data collection and reporting. Informed consent was obtained from all participants before conducting interviews or engaging in the FGD, and respondents were assured of anonymity, confidentiality, and the voluntary nature of their participation.

RESULTS

Generation of Waste

Residential and non-residential premises, such as commercial places, educational institutions, and public places, generate solid waste in the study area. According to the JMC estimates, the total present waste generated is 342 TPD. Per capita waste generated is approximately 539 grams and is further expected to increase.

Given above, the fractions of dry and wet MSW in JMC are as follows:

Fig 2: Fraction of Dry and Wet Waste in JMC

Source: Author's Tabulation

From the above table, out of the total 342 TPD of waste generated, 60% of the waste accounts for wet, while the remaining 40% accounts for dry waste. Zone 1 produces 108 TPD of waste, with 43 TPD of dry waste and 65TPD of wet waste. Zone 2 produces 134 TPD of waste, with 54 TPD of dry waste and 80 TPD of wet waste. Zone 3 produces 100 TPD of waste with 40 TPD and 60 TPD as dry and wet waste fractions, respectively.

JMC does not carry out a separate estimation of construction and demolition (C &D) waste. As per the C&D Rules, 2017, 25-30% of the total MSW accounts for C&D waste. Thus, the C& D waste is estimated to be approximately 85 TPD. JMC has no separate collection system for C&D waste. The entire fraction is mixed up with MSW for final disposal. Similar to the C&D waste, JMC neither separates the sanitation waste nor quantifies it separately. Due to gaps in the D2Dsolid waste collection, MSW gets mixed with the drain silt and street sweepings. However, JMC approximates the sanitation waste generation rate as 139 grams per capita.

Source Segregation

There is almost 0% source segregation in Jammu. All the mixed waste, including C&D waste and silt from road sweeping, is sent to the same dumping yard. However, JMC reports that 40% of the premises segregate the waste at source, yet it is negligible. This is because the collection of waste is done in an unscientific manner. The D2Dcollection is carried out in non-partitioned vehicles, rendering the source segregation useless. Even if the collection is carried through partitioned vehicles, the collected waste is dumped at a common disposal site, leading to intermixing of different waste streams. However, very few waste fractions are segregated by unorganized rag pickers from secondary storage units.

Collection and Storage

JMC is doing D2Dcollection in all the three zones. Approximately 55 wards have been covered under the D2Dcollection services, accounting for almost 75% of the collection. The D2Dcollection services and storage, transportation, processing and disposal activities have been outsourced to various NGOs. There is a total of 12 NGOs whose manpower is used: Talent club, Swarangan Meditation Charitable Trust, Jagriti Mahila Udyog Kendra, Sain Baba Society, National Council for Urban and Rural Development, National Dev Organization, JK City Sanitation Society, National Youth Child & Empowerment, Association SEED, etc.

Primary collection in Zone 1 is done through open-hand carts instead of auto tippers due to the narrow width of the lanes. Waste from these carts is transferred to the Auto tippers manually. In zones 2 and 3, the use of hand carts/ wheel carts is significantly less due to the dispersed population. Auto tippers collect primarily in these zones from roadside collection points or locality bins. Due to manual transfer, these collection points are subject to waste littering and stray animal invasion. There are 60-80 open storage sites from which collection is done. The secondary storage points are generally the open Dhalaos. Due to insufficient funds and space, Jammu City has no mechanical transfer station.

The total number of bins for primary storage and source segregation is inadequate for the current SWM. However, the total bins required for complete storage and segregation are shown in the table.

Table 2: Total number of Bins required for Primary Storage and Source Segregation

Bin Capacity	Existing Number	Actual Requirement
4.5 cum	220	50
RC Bins 1 Cum	480	100

Source: Author's Tabulation

Transportation of Waste

The secondary storage points' waste is transported and dumped at the Kot-Bhalwal landfill site. The waste gets transferred manually or with the help of JCBs/Front-end loaders to the Refuse Compactors or Dumper Placers. These vehicles manually collect the waste from secondary storage points and dumps it further at an open dump site.

As per the vehicle's availability with JMC, viz-a-viz waste quantities, the carrying capacity is inadequate. Further, no partitions and poor infrastructure maintenance for collection and transportation make achieving Service Level Benchmarks difficult.

Manpower is inadequate in the collection and transportation system of SWM, which leads to inefficiency. The concerned data reveals a shortage of concerned engineers, JCB operators, drivers, helpers, Data Entry operators, etc.

Table 3: Infrastructure requirements for collection and transportation of solid waste

	Type of Vehicle	Additional Requirement
Primary collection Vehicles	Triple Rickshaw	645
	E Rikshaw	68
	Auto Tipper	151
Collection from the commercial area	Twin Bins	250
	Underground Bins (500Ltrs for wet and dry waste)	22
Secondary Collection Point	Shed (Secondary Point)	15
	Skid Steer Loader	09
Secondary Collection Vehicles	Tipper 407	15
	Tipper 609	00
	Refused Compactor	18
	Crane mounted mobile compactor	06
	Dumper	02

Source: Author's Tabulation

Table 4: Manpower requirement for collection and transportation of solid waste

	Man Power type	Actual Requirement
Primary collection	Tricycle operator	54
	Drivers (Auto Tipper)	72
	Helpers (Auto Tipper)	72
	Ward Supervisor	26
Transfer Point & Secondary Collection	Drivers	16
	Helpers	16
	Supervisor (Transfer Point)	06
	Cleaning Crew (Sanitation Crew)	06
	Security Guard (Transfer Point)	06
Workshop	Store Keeper+ Helper	03
	Mechanic Engineer	03
	Helper	06
	Washing Boy	03
	Fitter	01
Operation Command Centre	Data Entry Operators	02
	Total	292

Source: Authors Tabulation

Processing and Treatment of Waste

No wet processing plant/ inert processing plant and Refuse Fuel Derive plant are operating in JMC. Although JMC reports that 60 TPD of MSW is processed daily, it is hardly seen on physical grounds. Despite a high proportion of wet waste in the total fraction, there is no centralized or vermi composting in

the city area. Incineration, gasification, pyrolysis and other WTE technologies remain absent in the Jammu municipal area. JMC reports a bio-methanation plant at Dogra Hall, where only 10TPD of waste is processed. This bio-methanation processing accounts for 2.9 % of the total waste generated.

Further, rag pickers segregate the saleable materials and sell them to itinerant buyers for recycling. However, the commercial waste materials constitute a minor percentage and the material recovery efforts of rag pickers remain unaccountable. JMC has prepared no data on the informal recycling of waste.

Disposal of Waste

MSW is dumped in a trenching ground located in the Kot Bhalwal area, approximately 10-15 km from the city. The total area of trenching ground is 19.5 acres. The dumpsite is fully covered with legacy waste. As per rough estimates of JMC, 470 tons of waste, including bio-medical, hazardous, sanitation, etc., is dumped daily. Approximately 3, 03800 metric tons of waste has been dumped on this ground.

Details of the legacy waste sites

Bhagwati Nagar Dump Site: it is a 25 years old dump site with approximately 12.5 lacs MT dumped to date. The dumping of waste has reached a height of about ten meters.

Kot Bhalwal Dump Site: It is a 7mtr high dumpsite with three lacs MT of dumped waste to date.

The older dump site was at Bhagwati nagar, which had reached its saturation level and therefore new dumpsite was shifted to the Kot Bhalwal area. Soon, due to excessive waste generation, this site will also saturate, requiring more land for dumping. Thus, JMC has taken the initiative of stabilizing legacy waste through bioremediation in both places. The contract has been outsourced to a private enterprise named Akanksha Enterprises Ltd.

DISCUSSION

The following table consolidates the existing challenges in the SWM process of Jammu City:

Table 5: Major Challenges in SWM procedures in Jammu City

Performance Parameters	Identified Issues or Gaps
Planning and Policy related	The J&K State SWM policy lacks effective waste management planning and a mechanism for an incentive-based regulatory approach, such as user charge collection. The existing plan supports cluster-based planning, whereas the absence of buy-back policies from recycling facilities and composting plants is also a concern. JMC has no separate action plan for SWM
Segregation of Waste at Source	Waste segregation at the point of generation is not practiced in JMC because of a lack of awareness among the common people. Also, no proper infrastructure has been developed to collect biodegradable and non-biodegradable waste from the HHs and other premises.
Overflowing Bins/Littering of waste by Animals at the primary collection point	Due to insufficiency in the D2Dcollection of solid waste, JMC is practicing a model for secondary waste storage in open bins/vats and collecting this amount through the secondary vehicles fleet. However, as per CPHEEO Norms for SWM, it is recommended to coordinate primary and secondary collection, thus avoiding the need for secondary storage bins or depots.
Clogging of open drains by solid waste	The Service Level Benchmarks (SLBs) set up by GoI mandate 100 % D2D collection. Without this, much material (waste) becomes street litter and finds its way into open drains, causing clogging and waterlogging.
Frequency of waste collection in Market areas	JMC collects waste only once per day in the majority of commercial areas. However, per MoHUA guidelines, waste collection in market areas is to be done three times daily- 2 times during the day and one at night. Non-adoption of these guidelines leads to open waste littering by the shopkeepers and sometimes disposal of the same in open streets.
Gaps in Respect of Manpower and Vehicle Availability	As per the vehicle's availability with JMC, viz-a-viz waste quantities, the carrying capacity is inadequate. Further, the lack of partitions and poor infrastructure maintenance for collection and transportation make the SLBs' achievement difficult. Similarly, the scientific method needs to be followed for an effective waste

	management system
Design of Waste collection vehicles for primary collection, especially for densely populated areas and narrow alleys	Some densely populated areas in the JMC jurisdiction exist where tricycles cannot even be used for D2D collection. Due to this, waste from these areas is being collected manually and stored at secondary storage points.
Absence of treatment, processing & disposal facilities	All fractions of waste generated within JMC are presently being transported to the dumping ground located at Kot Bhalwal Area without recycling, treatment, or processing.
Large Floating Population	Due to many historical activities, the daily footfall in the JMC area experiences a significant amount of floating population, accounting for approximately 20% of the total population.
Waste management issues with Bulk Waste Generators (BWGs)	As per SWM Rules 2016, these BWGs need to manage their waste entirely on their own or have to pay for it to JMC, but presently only 13 BWGs are managing their waste on their premises; the JMC manages the waste of the remaining 29 BWGs.
Institutionalization of the informal sector - Social Inclusion	Although the Corporation has carried out a few training programs for the Ragpickers community, no system for integrating such ragpickers into the mainstream waste management model has been deployed. Ragpickers and waste collectors work independently from JMC, wherein the ragpickers segregate the recyclable saleable waste in secondary storage bins and sell it off to the waste collectors. These waste collectors' formal registration and participation in SWM are urgently required.
Awareness among city residents and civic authorities - Behavioral Change	The significant concerns flagged in the JMC's SWM program are the lack of awareness amongst the locals, the lack of IEC campaigns and the limited dissemination of knowledge by ULB.
Gaps in Institutional Structure	In the present JMC institutional structure, a Conservancy department and a SWM nodal officers undertake SWM activities. However, the roles and responsibilities of these functionaries are not well defined. Further, the funds allotted in SWM are not categorized as such in the annual budget for the smooth operation of these functionaries.
Capacity Building of ULB	Lack of proper skill training and workshops for the staff and shortage of manpower are the prime issues. This results in a loss of motivation for the workers, further reflecting their work quality. The Corporation needs to develop a scope and plan for the capacity building of conservancy workers. Wastepickers and collectors must also be trained to regularly identify, segregate, and recycle non-biodegradable waste.

Source: Author's Tabulation

PROPOSED INTERVENTION IN THE SWM VALUE CHAIN IN THE CITY

In light of the systemic inefficiencies and environmental challenges associated with the existing waste management framework in Jammu City, there is an urgent need to adopt a set of comprehensive interventions that are both practical and sustainable. These interventions are designed to ensure full compliance with the SWM Rules, 2016 [25] and the overarching Environment Protection Act (EPA), 1986 [26] thereby strengthening the legal mandate for action. The proposed measures must not only address the immediate concerns of collection, transportation, treatment, and disposal but also emphasize governance, financial sustainability, technological innovation, and community participation. By aligning with ISWM principles and national statutory guidelines, the proposed measures seek to create a more efficient, inclusive, and legally compliant system that that minimizes landfill dependency, maximizes resource recovery, and ensures public health protection. The following recommendations are designed to provide a structured pathway for strengthening the municipal SWM value chain in Jammu City while simultaneously contributing to achieving the SDGs**.**

Strengthening Waste Collection and Segregation

- Achieve 100% D2Dcollection in all 75 wards of the city, as mandated under SWM Rules, 2016 (rule 15(b)) [25].
- Provide every household with twin-bin (or multi-bin) system to encourage segregation at source. In this context, Rule 4(1) (a) of SWM, 2016 [25] states that it shall be the duty of all waste generators to segregate and store the solid waste generated by them in three separate streams: biodegradables, non-biodegradables, and domestic hazardous wastes and handover the segregated wastes to authorised waste pickers or waste collectors. While Rule 4 mandates segregation into three streams, a common practice under the Swachh Bharat Mission guidelines, which aligns with and supports the SWM Rules, 2016, is the use of color-coded bins to facilitate this segregation viz., Green bin for biodegradable or wet waste, Blue bin for non-biodegradable or dry waste, and often a third bin- Red or Black – for domestic hazardous waste.
- Promote the habit of segregation at source into wet, dry, and domestic hazardous categories to maximize recovery of recyclables and enhance cost-effective treatment, ensuring compost and bio-manures meet quality standards.
- Conduct D2Dcollection using partitioned vehicles, designed with partitions against the movement axis, so that segregated waste remains separate. Waste from commercial and public areas should also be compacted and transported in segregated form for further treatment and disposal.

Optimizing Collection and Transportation Systems

- Establish a well-synchronized primary and secondary collection system with regular, well-communicated intervals to prevent overflowing bins and roadside littering, which violates the EPA, 1986 [26] provisions against improper waste handling.
- Ensure mechanical and automatic transfer stations for seamless transition from primary to secondary collection.
- Implement route optimization techniques to minimize transportation costs, fuel consumption, and associated emissions, contributing to the environmental objectives of the Air (Prevention and Control of Pollution) Act, 1981 [27] and EPA, 1986 [26].
- All motorized vehicles involved in waste collection and transportation should be GPS-enabled and monitored through a centralized monitoring cell for accountability and real-time supervision.

Waste Processing, Treatment, and Disposal

- Follow the standard waste management hierarchy, prioritizing reduction, reuse, and recycling to minimize landfill dependency, as outlined in the SWM Rules, 2016.
- Promote channelization of recovered products such as compost, biogas, recyclables, and combustibles to open markets, thereby reducing rejects sent to landfills.
- Establish a sanitary landfill at Kot Bhalwal in strict accordance with the SWM Rules, 2016 [25] (Schedule 1) specifications, after proper remediation of the existing dumpsite to allow scientific disposal of inert and residual waste. This action is critical to address the legacy pollution issues and prevent future violations of the Water (Prevention and Control of Pollution) Act, 1974 [28] and the EPA, 1986 [26].
- Strengthen infrastructure capacity at Bandurakh for waste treatment and ensure adequate disposal facilities at Kot Bhalwal for residual rejects.
- Strictly enforce a complete ban on open burning and dumping of waste, with fines and penalties for violators. This is a direct measure to curb air and land pollution under the EPA, 1986 [26].
- Emphasize waste-to-energy technologies that comply with the emission standards of the EPA, 1986 [26] to harness the resource potential of waste, reduce landfill dependency, and mitigate environmental pollution.

Governance, Institutional Strengthening, and PPP Models

- Develop effective legal and institutional arrangements with robust monitoring and evaluation frameworks, as required for Urban Local Bodies specifically under Rule 15 of the SWM Rules, 2016 [25].
- Strengthen operations and financial management by adopting appropriate processes, technologies, and funding mechanisms aligned with the SWM hierarchy.
- Encourage outsourcing of collection and processing services to NGOs and private players to improve efficiency and meet service-level benchmarks.
- Enhance cost recovery mechanisms through user charges, as empowered under Rule 4(3) of the SWM rules, 2016, [25] and other innovative financial models to ensure adequate funding for municipal functions.

- Adopt a centralized approach for land allocation for waste management facilities to avoid the NIMBY (Not in My Backyard) effect, while balancing it with selective decentralized systems where feasible, ensuring long-term viability as per the city's SWM plan under SWM Rules, 2016 [25].

Community Participation and Awareness

- Promote community involvement and citizen participation at every stage of waste management, recognizing the 'duties of every waste generator' as outlined in Rule 4 of SWM Rule, 2016 [25].
- Conduct extensive Information, Education, and Communication (IEC) campaigns, including Nukkad Nataks, symposiums, advertisements, and social media campaigns, to build awareness and in still responsibility among waste generators, fulfilling the mandate for public awareness under the SWM Rules, 2016 (Rule 15(zg)) [25].
- Target significant improvement in the attitude and behavior of local citizens toward waste management through participatory initiatives and regular engagement.

Long-Term Planning and Sustainable Models

- Develop a long-term waste management strategy focusing on sustainability, resilience, and inclusivity, in line with the mandate of the EPA, 1986 [26] and the specific planning requirements under the SWM Rules, 2016 [25].
- Institutionalize incentive-based regulatory mechanisms, such as user charges and reward systems, to promote compliance and improve service delivery.
- Align waste management practices with SDGs to ensure environmental protection, resource efficiency, and improved quality of urban life, thereby upholding the core objective of the EPA, 1986 [26].

CONCLUSION

The foregone discussion succinctly reflects that SWM in Jammu has become both a developmental and environmental imperative, underscored by a robust legal mandate under the EPA, 1986, the SWM Rules, 2016, and other allied pollution control laws. The present system, marked by institutional weaknesses, infrastructural gaps, limited financial capacity, negligible community participation, and limited compliance with the existing legal and policy framework, has failed to keep pace with increasing waste generation. The continued reliance on unsanitary land filling and open dumping has not only led to environmental pollution but also triggered serious public health concerns. Addressing these challenges requires a decisive and legally sound shift from fragmented, disposal-driven practices to a comprehensive ISWM framework. The proposed interventions—from universal D2Dcollection and source segregation to waste-to-energy technologies, PPP models, and community-based awareness initiatives—can provide a roadmap for sustainable transformation. Effective implementation will demand strong governance, adequate financing, the adoption of innovative technologies, and a fundamental behavioral change at the community level. By adopting this long-term, systematic, and legally-compliant approach, Jammu City can transform its waste into a resource, improve the quality of urban life, and make meaningful progress toward national policies and international commitments under the SDGs, thereby fully upholding the core objective of the EPA, 1986, to shield and improve the environment for present and future generations.

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