



Assessing Solid Waste Management Practices: A Gateway Towards Sustainable Development in Uttarakhand

Ravi Kumar¹ • Yoginder Kumar² • A.B. Thapliyal³ • Subodh Kumar Sharma⁴

¹Department of Commerce, SRT Campus, HNB Garhwal University, Srinagar Garhwal, Uttarakhand

Corresponding author Email id: phdscholar.kravi@gmail.com

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Abstract: The solid waste management challenges in Uttarakhand are intricately linked to the region's rapid urbanization and burgeoning tourism industry. As Uttarakhand's natural beauty and religious sites draw increasing numbers of visitors, contributed significantly to solid waste generation, straining existing waste management infrastructure, consequently the demand for effective waste management solutions becomes paramount. To address this, the state government has adopted comprehensive measures, emphasizing scientific methods and public involvement, aiming for zero waste to landfills by 2040. The strategies adopted by Uttarakhand, focusing on the 5R's (Reduce, Recycle, Reuse, Recover, and Restrict) transition towards a circular economy, highlight a comprehensive approach to waste management. This initiative not only aims to manage waste effectively but also aligns with broader environmental and sustainability goals. By integrating these strategies, Uttarakhand can potentially reduce its ecological footprint, promote resource efficiency, and safeguard its natural and cultural heritage. The municipal solid waste management practices emphasis on waste collection, segregation, processing, and recycling which underscores a commitment to sustainable development and responsible resource management. This approach reflects a shift towards more circular and regenerative economic practices, ultimately contributing to preserving the state's ecological and cultural richness. Thus, the current article is a comprehensive review to provide an overview of the present scenario of solid waste management practices, challenges and the participation of communities in managing, minimizing and eliminating these solid wastes in the Uttarakhand region. Additionally, the results of the article demonstrated that Uttarakhand is still far from the ideal situation related to solid waste management which carves limitations and milestones in the process of sustainable development.

Keywords: Solid Waste Management • Sustainable Development • Community Participation.

Introduction

About India: In recent times, the term municipal solid waste has created buzz all around the globe. India ranks among the top 10 countries globally regarding municipal solid waste generation. The report of The Energy and Resource Institute (TERI), revealed that India produced over 65 MT of municipal solid waste in 2021, of which only 43 MT was collected, 12 MT of which was processed before being disposed of, and the remaining 31 MT was just dumped in the dump yards (Intelligence 2023). It is anticipated that the quantity of municipal solid waste will rise by 165 MT by 2030, and if the current trends continue, it may reach 436 MT by 2050 (Pujara et al. 2019). In India, the majority of

MSW consists of 70-80% organic compounds, which are generated by the blend of households and commercial houses. At the same time, the rest of such wastes belong to the inorganic compounds. Municipal solid waste is not recovered or reprocessed using appropriate treatment technologies; instead, it is disposed of in unsanitary landfills (Gupta 1998; Prajapati et al. 2021). Such haphazard handling of solid waste pollutes the air, water and soil, releases greenhouse gases into the atmosphere, diminishes the aesthetic value of the environment and increases the risk of numerous infectious diseases, all of which worsen existing health problems, consequently lowering the quality



of life (Ahluwalia & Patel 2018; Hazarika & Saikia 2020; Singh et al. 2021).

About Uttarakhand: Uttarakhand is a state located in the northern Himalayan region of India. The state is classified into two divisions, Garhwal and Kumaon, with a total of 13 districts. Throughout history, both domestic and foreign visitors have favoured the Indian Himalayan region of Uttarakhand for its religious, spiritual, and complacency pursuits (Gupta et al. 2017; Farooquee et al. 2008). But despite its prolonged cultural, historical, and religious significance, Uttarakhand remained unable to handle the waste generated by households, industry, tourism, construction, and other activities. According to the report of TOI in 2018, Uttarakhand was among the worst states in terms of SWM in India, as it didn't have any single functional solid waste management plant or sanitary landfill; even The Urban Development Secretary at that time also confirmed that only 20% of the total waste generated was being treated. Consequently, the Supreme Court imposed a fine of ₹300,000 on the Uttarakhand government for not having a proper solid waste management policy, and the Nainital High Court also ordered the Dehradun Municipal Corporation to clear the garbage within a stipulated time frame. Thus, the attainment of sustainable development in Uttarakhand is a crucial concern, mainly because of its delicate ecology system, natural disasters, and continuously rising solid waste.

Objectives

The main objectives of the current research article are as follows:

- To Evaluate Current Solid Waste Management Practices in Uttarakhand.
- To Identify the Key Challenges and Barriers for Effective SWM in Uttarakhand.
- To Portray the Role of CBOs, PPPs and NGOs in SWM in Uttarakhand.

- To Purpose Sustainable Solutions for proper SWM.

Current SWM Scenario in Uttarakhand

The Solid Waste Management (SWM) situation in Uttarakhand, as outlined in the 2023 report by the Uttarakhand Pollution Control Board, is complex and evolving. The state is served by 102 Urban Local Bodies (ULBs), with 100 municipalities and 8 cantonment boards responsible for managing waste for a population of 36,26,586. The recent addition of 10 new ULBs reflects ongoing urban growth and underscores the need for robust waste-handling infrastructure to meet increasing demands. Waste generation trends are critical to understanding changing consumption patterns and urbanization levels over time. In 2023, Uttarakhand generated approximately 1759.33 tons/day (TPD) of municipal solid waste, with only 998.354 TPD effectively managed. The government's treatment rate stands at 56.75%, leaving 43.25% untreated, including 49.22% that remains uncollected. The involvement of cantonment boards in waste management signifies a collaborative approach between civilian and military authorities in addressing solid waste challenges. Exploring treatment methods, such as composting, landfilling, or waste-to-energy technologies, is essential for assessing sustainability and environmental impact. Challenges faced by ULBs, including funding constraints, infrastructure gaps, and public awareness issues, need to be addressed through targeted interventions and resource allocation. Detailing compliance with Schedule 1 of the Solid Waste Management Rules, including monitoring, reporting, and enforcement mechanisms, demonstrates a commitment to regulatory standards. There are some key points which highlight the current municipal waste management practices followed by the state:



Fig 1: MSW Scenario in Uttarakhand (Source: Author's creation)

Door-to-door collection: In all old 92 USBs, out of 1152 wards, only 70% door-to-door collection has been made so far from households, schools, Institutes, shops, etc. For the remaining part, dustbins in the public receptacles have been provided at appropriate locations.

Segregation of waste: Merely 40.4% of the 1152 wards have implemented source segregation through the efforts of households, stores, institutions, schools, etc., and to ensure 100% waste segregation at the source, the state is promoting and spreading Information, Education, and Communication (IEC) among the public.

Storage and Covered Transportation: Only Nagar Nigam Dehradun and Haridwar have permanent storage areas, while the other ULBs have temporary storage areas. 10 new sites have been notified for construction and demolition wastes. Also, in all 1152 wards, there is only partial compliance with covered transportation facilities.

Waste processing facility: There are now just 2 waste processing and sanitary landfill (SLF) facilities in the state: Nagar Nigam Haridwar, which has a 150 ton/day processing capacity, and Nagar Nigam Dehradun, which has a 200 ton/day processing capacity. Also, it is notable that around 17 ULBs would be covered by the installation of a Waste-to-Energy plant with a 1 MW electricity generation capacity.

Disposal of solid waste: Various landfill sites have been identified in all 65 sites for 92 ULBs, in which only two landfills have been constructed to date: Nagar Nigam Haridwar, with a capacity of 35 TPD, and Nagar Nigam Dehradun, with a capacity of 60 TPD. Of the available 65 sites, 53 are in various stages of execution, and the remaining 12 sites (11 Forest & 1 Revenue land) are in the statutory approval stage. Furthermore, there are 19 total numbers of existing dumpsites in Uttarakhand, while the dumpsters are reclaimed /capped for:

I: Bioremediation at 04 places (Gauchar, Gairssain, Kotdwar and Muni ki reti) has been completed.

II: Bioremediation at 04 places (Kashipur, Rudrapur, Rishikesh and Uttarkashi) has been partially completed.

III: DPR of 05 places (Dehradun, Haridwar, Roorkee, Haldwani and Srinagar) have been applied.

Sewage Treatment Plant (STP): 12 STPs are in the sanctioned stage, 20 STPs are in the construction phase, and 68 STPs with a capacity of 425 MLD are currently in service for waste disposal

Involvement OF CBOs / NGOs / PPPs in SWM in Uttarakhand

Anschutz (1996) states community involvement is essential for reducing solid waste in all economies. Case studies from several countries demonstrate the efficacy of private sector and community involvement in waste management (UNESCAP



2020) guarantee the success of waste management projects, the Uttarakhand government has placed a strong emphasis on community engagement.

Key Challenges and Barriers to Effective SWM in Uttarakhand



Figure 2: Challenges faced by the government during SWM (Source: Author's creation)

Community-based Organisations (CBOs):

Many CBOs greatly aided solid waste management in Uttarakhand. Sanitation Park Nathuwawala in Dehradun is one such instance where a decentralized approach to solid waste management has been adopted for a population of 13000 people (Joshi and Joshi 2020). Furthermore, towns like Dehradun, Haridwar, Haldwani and Nainital have initiated solid waste management programs that have been explicitly started by the Uttarakhand Urban Development Directorate, which strongly emphasizes on community involvement, making them agents of development, assigning responsibility for health and welfare for proper collection, storage, segregation and disposal of solid waste.

In Nainital, during the past year, a community-based initiative called ‘Door-to-Door’ has been working with the municipal authorities to improve waste management procedures. This initiative has shown how CBOs may support ethical waste management methods, raise public awareness and work with local organizations effectively (Tewari et al. 2013).

Participation of NGOs and PPPs: In Uttarakhand, various NGOs play a pivotal role in SWM practices. They accomplish their goals through long-term cooperative alliances with different government

agencies, community engagement programs, awareness raising, local advocacy and direct actions and efforts. Some of the essential NGOs working for SMW in Uttarakhand are:

*Waste Warrior Society has been fighting against the burning and dumping of waste in mountains, forests and rivers. In Ramnagar, Uttarakhand, they have successfully implemented the Paryavaran Sakhi Model, which breaks down the obstacles related to gender in socioeconomic status and empowers women to waste entrepreneurs. They also want to establish an Integrated Solid Waste Management (ISWM) system in villages around Jim Corbett Tiger Reserve in Uttarakhand.

* Feedback Foundation, an NGO established as an Integrated Decentralized Solid Waste Management Model in Nathuwawala, Dehradun. The processing facility for solid waste is called ‘Sanitation Park’ and in accordance with the solid waste. According to the SWM Rule of 2016, waste is disposed of methodically and scientifically.

* Uttarakhand Seva Nidhi Trust: The trust was founded with the intention of alleviating the socioeconomic difficulties that the state's communities face and encouraging sustainable rural development. The Uttarakhand Seva Nidhi Trust is involved in the following critical areas and



initiatives: livelihood promotion, environmental conservation, healthcare initiatives, education support, etc.

Table 2: Challenges faced by the government during SWM

Types/ Basis	Door to Door Collection	Segregation to Waste	Storage and Covered Transportation	Waste Processing Utility	Disposal of Solid Waste
Lack of Resources and Training	Insufficient vehicle to minimize waste materials.	Lack of proper training for waste collectors in handling and segregating waste materials.	Many waste management systems face inadequate storage facilities, resulting in the accumulation of waste in open areas.	Lack of storage capacity to handle the volume of waste.	Scarcity of suitable Land for setting up new landfill sites.
Low Level of Awareness	Residents are not well-informed about the importance of door-to-door waste collection.	Many residents and businesses lack knowledge about how to properly segregate waste into categories such as recyclable, organic waste, and hazardous materials.	During transit, the vehicles used for transporting the waste are not adequately covered due to a lack of awareness, resulting in pollution and health hazards.	Lack of awareness about the latest technology leads to the use of outdated technology for managing waste through the recycling process.	Less concern about the negative impacts on the environment, including air and water pollution.
Operational and Maintenance cost	It is hard to provide door-to-door service in high-density areas, which leads to high operational costs.	The government must bear extra costs for segregating materials since residents and businesses have little knowledge about the segregation of materials.	Establishing proper storage facilities and covered transportation systems requires significant initial capital investment, but limited funds are available for investing in proper storage containers.	Poor maintenance cost of existing facilities	The government faces difficulties enforcing the regulations, resulting in more frequent inspection and monitoring activities to ensure compliance. This process required additional operational costs.
Financial Support	Limited financial support led to inadequate coverage and irregular collection schedules.	Insufficient financial support is needed for awareness and education programs to promote segregation at the source.	Budget constraints can lead to inadequate storage facilities.	Limited access to advanced technologies due to financial shortage.	Insufficient funds can lead to non-compliance with environmental regulations and standards.
Excess workload	Local bodies are over-burdened with other Responsibilities, resulting in waste collection delays.	Lack of public participation in waste segregation increases the excess burden on the existing workers.	Infrastructure limitations can delay the transportation schedule and increase the excess personnel workload.	Legal formalities like regulatory compliance and reporting administration work also lead to additional worker workload.	High levels of wastage can be disposed of through more workers, but due to limited resources, it increases the workload on workers.

Sources: Wilson et al. (2006); Scheinberg et al. (2010); Hoornweg and Bhada-Tata (2012); Shekdar (2009); Medina (2000)

* Himalayan Environmental Studies and Conservation Organization (HESCO): In the delicate Himalayan ecology, HESCO is crucial to achieving

ecological sustainability and a peaceful coexistence of communities and the environment. The organization's all-encompassing approach to



conservation incorporates community involvement, scientific research, and policy advocacy to promote environmental resilience and long-term well-being in Uttarakhand and beyond.

* In Uttarakhand, Public-Private Partnerships (PPPs) play a crucial role in SWM by leveraging the private sector's knowledge to improve garbage collection, treatment, and disposal. PPPs can help the state with waste problems by ensuring scientific waste management techniques and enhancing waste infrastructure. Organizations such as IL&FS Environmental Infrastructure & Services Ltd (IEISL), incorporated in 2007, apply their specialist knowledge to efficiently manage solid waste by adopting the same methodology employed in other parts of India. PPPs can support sustainable waste management in Uttarakhand by merging liquid and solid waste, reusing and recycling all available waste streams, and expanding knowledge.

Besides the above-mentioned CBOs/PPPs/NGOs, there are numerous other initiatives like Swachh Bharat Abhiyan, Namami Gange Programme, Uttarakhand Bamboo & Fiber Development Board, Dehradun Cantonment Board, etc., which are currently operating in Uttarakhand region for the betterment of the society and environment, which strengthens the future scenario of sustainable development in the region.

Sustainable Solutions or Strategies for Municipal SWM

Uttarakhand has a unique geographical as well as cultural context, which requires various tailored strategies for municipal solid waste management so that it can promote the well-being of its residents as well as visitors. To enhance and protect its natural heritage, biodiversity and cultural landscapes, the government has adopted various measures, such as:

Storage and Collection of Domestic Hazardous Waste: Paint drums, pesticide cans, CFL bulbs, tube lights, broken mercury thermometers, outdated batteries, contaminated gauges, used needles and syringes, and expired medications etc. are some examples of domestic hazardous waste produced at

the household level (**A Alabi et al. 2023**). As per the SWM regulations 2016, the waste generator is required to keep the household hazardous waste separately. As instructed by (**Department of Urban Development HP 2019**) each ULB must construct depots for the collection, safe storage, and transportation of household hazardous waste to the Treatment, Storage and Disposal facility (TSDF). Uttarakhand's State Pollution Control Board should also strictly comply with TSDFs to prevent environmental contamination.

Selection of Processing and Disposal Technology:

In Uttarakhand, like many other regions, managing solid wastes effectively and efficiently involves a combination of strategies for processing and disposal. These strategies aim to create a sustainable system, minimizing environmental impact and improving public health and hygiene. These strategies are:

* **Waste Segregation at Source:** Waste segregation is essential for effective waste management, starting at the point of generation in homes, businesses, and public spaces. It should be mandated across all sectors, including government offices, with penalties for noncompliance (**Sharma & Jain 2018**). Waste segregation involves separating waste into categories like recyclables, non-biodegradable (inorganic), and biodegradable (organic). A model example comes from Shillong, where green bins for biodegradable waste and blue bins for non-biodegradable waste are placed across 27 Dorbar Shnongs and the municipal area (**Bhattacharya & Katre 2018**). This encourages proper waste sorting at the source and its disposal.

* **Composting:** There are various composting techniques like windrow composting, vermicomposting, aerated in-vessel or static pile composting (Palaniveloo et al. 2020). One of the technologies that is advised for ULBs or clusters that generate or receive garbage over 100TPD is windrow composting. Windrow composting is a simple process, but Uttarakhand's land constraint would be challenging, given the technology's high



land requirement. Depending on the availability of land, the ULB/Cluster producing or receiving municipal garbage may choose to engage in vermicomposting or in-vessel composting. Vermicomposting ought to be limited to relatively tiny towns, individual homes, or lodging establishments (Aalok et al. 2008). The city is advised to start with vegetable markets, retail stores, malls, and restaurant garbage, where source segregation may be easily accomplished to produce this high-quality compost. Farmers will be in great demand for compost made from organic waste that has been separated at the source and does not include any chemicals or physical pollutants (Palaniveloo et al. 2020).

* **Waste-to-Energy:** The availability of garbage, land, and the market for the final goods will determine whether the state deems waste suitable for energy projects. Refuse Derived Fuel, or RDF, is an effective method for recycling rejects (bales, fluff, or pellets) in Uttarakhand. The SWM Regulations anticipate that RDF will replace 5% of the fuels used in thermal power generation and cement manufacturing (Goli et al. 2021); however, as there aren't any cement factories or coal-fired power plants currently in operation in Uttarakhand, there needs to be demand for the usage of RDF in the state. Evaluation of RDF use in incinerator plants is also necessary. The Uttarakhand government should investigate the potential of using waste to incineration technology, considering its geographical location. An incinerator facility should have a minimum capacity of >500 MTPD of segregated waste, as units less than this are very expensive and should be developed using the economies of scale principle. Biomethanation is another waste-to-energy technique that can be used on both small and large-scale plants to process separated organic waste from 1 TPD to 500 TPD. Biomethanation plants require regular repair and maintenance as well as specialized staff due to their complex process. Such processing facilities might also be adopted by Uttarakhand region in order to transform waste into

RDF and meet the increasing demand for energy (Thakur et al. 2021).

* **Sanitary landfills:** Uttarakhand's hilly geography makes it difficult to choose sites for sanitary landfills and raises the risk of landslides and soil erosion. These are just a few difficulties the state faces when implementing sanitary landfill methods. In 2016, due to Dehradun's worsening waste management situation, the Sheeshambada Waste Disposal Plant was constructed. The efficacy of waste segregation has been significantly influenced by subpar operational procedures as well as a lack of awareness and accountability among residents. Air pollution and fires are common environmental problems that the plant has had to deal with due to mismanagement, including incorrect waste segregation. These problems draw attention to the necessity of more public participation in appropriate garbage disposal as well as the challenges associated with infrastructure (Kumar 2024). Inadequate trash collection, segregation systems, and restricted road access are some examples of infrastructure deficiencies that impede efficient waste management. Given that the State is finding it extremely difficult to find acceptable landfill sites, a regional landfill is suggested, wherein the related ULBs of each cluster would only be able to pay for the disposal of their inert.

The strategy of Extended Producer Responsibility (EPR): EPR is an environmental policy strategy that extends a producer's financial and/or material liability for a product to the post-consumer phase of the product's life cycle. Producer Responsibility Organizations (PROs), Deposit Return Schemes, Circular Economy Integration, etc., are some EPR components adopted by developed countries like the UK, Germany, Europe, etc. Thus, by implementing such EPR systems, Uttarakhand might enhance sustainable waste management, lessen the adverse environmental effects of incorrectly managed garbage, and lessen the growing load of waste from tourism, which further facilitate greener manufacturing practices and



support the creation of environmentally friendly products (Lorang et al. 2022; Ramakrisnan et al. 2012).

Promoting Decentralized Waste Management: To have zero waste reaching landfills by 2040, the city must develop decentralized waste management solutions. Zone-specific decentralized composting units should be established for large cities. With community involvement, separated biodegradable waste from individual communities/units should be gathered and dumped into these decentralized composting units (Joshi & Ahmed 2016). According to the SWM Rules 2016, these systems will be initially promoted in apartment buildings, group housing, businesses, restaurants, hotels, government buildings, educational institutions, etc. Later, they will be expanded to include all user groups in the city, including private residents. The ULB will draft bylaws to put decentralized systems around the city.

Establishing a system for segregated transportation of waste: To maximize recovery and prevent contamination, the segregated trash that will be gathered from different sections of the city will be delivered to the processing facility or disposal facility, as applicable, in a separate way. These various fractions will, at the very least, contain segregated transportation for trash that is biodegradable, non-biodegradable, household hazardous, sanitary, street sweeping, drain cleaning, horticultural, C&D, etc., in compliance with the SWM Rules, 2016. In addition, newer vehicles such as dumper loaders, compactors, and automated sweeping machines need to be added to the transportation system to create an effective SWM system. When transporting waste, vehicles used for collecting purposes should be sufficiently covered because they leak leachate during the season of rainfall (Mushtaq et al. 2020).

Strategy for Major Festival Seasons and Tourism inflow: The amount of garbage generated increases frequently during the Char-Dham Yatra, Aradh Kumbh, Kumbh, Nanda Rajjath Yatra, Ganga Isnan,

Kawar, and winter snowfall season. The number of tourists that visited the state in 2022 was estimated by the MoT to be 54.64 million. Due to the substantial influx of tourists into Uttarakhand, ULBs with strong tourism potential should impose a per-capita user fee to cover the costs of collecting and disposing of garbage from visitors. It is anticipated that garbage from visitors will primarily consist of food waste and waste from post-consumer goods; therefore, a fee should be included to cover the costs of collection, transportation, and management of these waste streams. For example, the digital Deposit Refund System (dDRS), a cutting-edge program intended to encourage appropriate garbage disposal and recycling in response to the growing waste issue (launched by Recykal), should be popularized among the tourists as well as locals for effective SWM practices (Recykal 2024).

Developing Policy and Guidelines for Waste Management: It is necessary to develop guidelines or policies to encourage the recovery of resources from waste. Waste collection, disposal, and segregation can all be covered by some obligatory provisions. To prevent any failure, a waste-specific composting manual could be created. Recognizing rag pickers and waste collectors can help to promote the recycling of plastic waste (Joshi & Ahmed 2016). According to the report of Chintan NGO, ragpickers contribute roughly 14% of the annual savings to the municipal budget and lessen the load on transportation and landfills by 20% (Pappu et al. 2007). Yet, their job goes largely unacknowledged, and they are often denied the ability to work.

Strategies of Punishment, Reward and Award: Two methods are used in the motivational strategy: (i) punishment and (ii) reward. The first strategy will instill fear, which is beneficial to some extent but ultimately forces the defaulter to rebel against it, which causes distraction. Although the second strategy takes longer to produce results, when these projects get traction, they eventually succeed. Everyone enjoys being "recognized," whether they are individuals or an organization. For example,



Rudraprayag district, in 2022, received the prestigious Digital India Award from the Ministry of Electronics and Information Technology, which President Droupadi Murmu presented; the award recognized the district's innovative use of digital technology to address a critical environmental issue (Recykal 2024). This kind of recognition opens the way for creativity and encourages innovation for more sustainable solutions.

Methodology

Conducting a literature review is a valuable and valid method to support high-quality research. By reviewing existing literature, researchers can deepen their understanding of the current body of work and draw inspiration for specific approaches, methods, and contributions to their field of study (Ramakrisnan et al. 2012). Recognizing this value, the current study is descriptive and qualitative, relying solely on secondary data collected from various sources such as literature, government websites, publications, and related books.

To analyze the secondary data, the authors adopted a systematic approach (Jesson et al. 2011), filtering articles based on publisher reputation and popularity, including sources like Emerald, Elsevier, Springer, and others. The study specifically examines the present scenario of municipal solid waste management in Uttarakhand. This approach ensures that the research is grounded in a comprehensive understanding of existing knowledge and provides valuable insights into the region's specific context of waste management.

Discussion and Suggestion

The Uttarakhand region has seen tremendous growth in the tourism industry, which has led to increased urbanization, growing infrastructure, and improved living standards for residents. These factors have also put pressure on the state's current waste management policies and practices, raising concerns about managing and disposing of the waste generated by the tourism industry. The current

administration has several flaws, including insufficient funding, personnel, equipment, and implements to carry out the numerous MSW management tasks in an efficient manner. To safeguard the environment, public health, and sanitation of Uttarakhand's citizens, the state government must give sustainable solid waste management techniques top priority and should allocate substantial funding accordingly.

According to (Chand Malav et al. 2020; Pujara et al. 2019) the Uttarakhand government should implement several key initiatives to minimize municipal solid waste (MSW). These include proper planning for technology implementation, increasing public awareness and education about solid waste management (SWM), promoting the use of Waste-to-Energy (WtE) technologies, integrating SWM into academic curriculum, setting quality standards, professionalizing SWM, emphasizing research and development, supporting technically and financially substantial projects, and focusing on indigenous technology development. A sustainable Integrated Solid Waste Management (ISWM) approach is recommended for future development, involving governmental policies, environmental education, composting techniques, anaerobic digestion for energy production, incineration, and sanitary landfilling. These measures aim to advance waste management practices in Uttarakhand towards sustainability and efficient resource utilization.

Conclusion

Uttarakhand is confronted with formidable obstacles in the realm of MSW management. The state's rapid urbanization and high population growth rate have resulted in a surge in waste output. Poor garbage collection and disposal have been caused by the state's limited resources, land availability, and the absence of sanitary landfills or solid waste management facilities. Even though the goal is to have zero waste ending up in landfills by 2040, Uttarakhand's solid waste management situation is far from ideal right now. Nonetheless, recent



initiatives appear promising in addressing the issue, such as the implementation of decentralized solid waste management techniques in the Nathuwawala ward of Dehradun. Due to the state's ecological sustainability, equality concerns, and propensity for natural disasters, Uttarakhand's current sustainable development scenario calls for a balanced strategy. Promoting sustainable development in the state is greatly aided by higher education, infrastructure development, and sustainable tourism planning. Looking ahead, highlighting future agenda and initiatives by the state government—such as expanding collection services, adopting innovative technologies, or implementing community engagement programs—showcases a proactive approach toward sustainable waste management. This comprehensive overview enables stakeholders to make informed decisions and drive positive change in waste management practices across Uttarakhand.

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