

Article

Review of Municipal Organic Waste Management in Uttar Pradesh State, India

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Abstract: Organic waste is the main fraction of municipal solid waste in most developing countries. Despite various efforts, municipalities often fail to properly handle generated waste due to poor source segregation, inefficient collection system, insufficient financial resources, and a lack of proper treatment and disposal facilities. In India, organic waste mainly ends up in open dumpsites. The Government of India launched the Swachh Bharat Mission and enacted legislation to improve solid waste management. This notwithstanding, the most populous state of the country, Uttar Pradesh (UP), faces serious challenges in terms of achieving the national environmental policy goals. This study attempts to assess organic management practices in UP by analyzing the existing situation. The study reviewed the legal and financial frameworks governing the waste sector, the responsibility of stakeholders, waste segregation and collection mechanisms in place, and treatment and disposal methods. The identified gaps were analyzed to provide recommendations for the local conditions. The study recommends the control of incoming materials in centralized facilities compost facilities to enhance compost quality and enhance the management of organic waste via source segregation, animal feeding, and treatment in a decentralized manner.

Keywords: organic waste management; source segregation; decentralized treatment; composting; animal feeding



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1. Introduction

India generates 160,038 tonnes of municipal solid waste (MSW) per day. Approximately 95% of this waste is collected, but only 50% is processed or treated, with the remaining amount ending up in uncontrolled disposal sites [1]. There are about 3159 dumpsites operational in India. Among these, a few are designated by the authorities for the disposal of mixed waste, while others have been unintentionally created by the accumulation of waste dumped outside city peripheries. In 2019, India dumped 23.35 million metric tonnes of waste at dumpsites [1].

It is estimated that waste generation in India will increase to 735 million tonnes/year of waste generation by 2051 [2,3]. Thus, the estimated level of waste generation increases by ~5% every year [4]. The major fraction of waste in India, like in all developing nations, is biodegradable [5]. Organic waste has a high moisture content, which increases the density of MSW when collected mixed and contaminates recyclable materials. It decomposes naturally, either aerobically or anaerobically [6]. However, the uncontrolled decomposition

of organic waste in dumpsites results in leachate generation, which contaminates ground-water, and the emission of methane, which contributes to climate change [7]. To address these issues, in 2014, the Government of India launched Swachh Bharat Mission 1.0 (SBM 1.0), its flagship program, intending to enhance solid waste management both in rural and urban areas [4,8,9].

The program's initial phase concentrated on open defecation prevention, solid waste management, including source segregation, and the promotion of municipal organic waste composting. The program's second phase concentrated on establishing decentralized systems for the management of organic waste, on-site waste management by bulk waste generators, organic waste bio-methanation, and legacy waste remediation. Additionally, the announcement of Solid Waste Management (SWM) Rules in 2016 reinforced this vision by imposing requirements on stakeholders, including Urban Local Bodies (ULBs), waste generators, and waste processing facilities, among others, to govern the waste management system at the national level [8,10].

The SWM Rules imposed several requirements on various stakeholders concerning the management of organic waste, including source segregation, management of organic waste at the household and community levels, transportation of segregated organic waste, the establishment of decentralized and centralized organic waste processing facilities, and a ban on the dumping of organic waste at landfills [11,12].

With the largest population and fourth largest by geographical area, the state of Uttar Pradesh (UP) faces serious challenges in the area of solid waste management. It features one of the largest number of temples and many religious activities along the three major rivers (Ganga, Yamuna, and Saraswati), while also serving as a prominent center for tourism. The mismanagement of MSW in UP has impacted the environment and human health through the creation of numerous open dumpsites across the province. Notably, the Ghazipur dumpsite, one of the largest in India, standing at a height of 65 m, is located in UP [7]. Many of these dumpsites are situated near human settlements, a consequence of urban expansion over time. Residents in proximity to these locations often suffer from smoke, heat, odors, pests, contaminated water, and other related issues [7,13]. UP has also been reported to have lower literacy rates than the other states of India [3]. These factors hinder the proper implementation of solid waste management with respect to the national environmental policy [14].

This study seeks to review and evaluate organic waste management in the UP state. To this end, comprehensive desk research including a review of the current policies, laws, existing technologies, management options, and programs related to organic waste management was conducted. Additionally, data were retrieved from technical discussions with local officials and experts. The review resulted in the identification of gaps in the existing systems. Practical and implementable recommendations to promote organic waste management were provided.

2. Overview of the Study Area and Existing Waste Management Situation

Uttar Pradesh is located in the northeast of India (Figure 1), with a surface area of 243,286 km² and a total population of 235 million inhabitants [2,3]. The state consists of 75 districts which are further divided into 18 divisions, namely, Agra, Aligarh, Azamgarh, Allahabad, Kanpur, Gorakhpur, Chitrakoot, Dham, Jhansi, Devi Patan, Faizabad, Bareilly, Basti, Vindhyachal (Mirzapur), Moradabad, Meerut, Lucknow, Varanasi, and Saharanpur [2,3]. UP has 734 ULBs, including 17 Nagar Nigams (NN) in large cities with populations of more than a million, 200 Nagar Palika Parishads (NPPs) in cities and towns with moderate populations, and 517 Nagar Panchayats (NPs) in small towns and peri-urban areas.

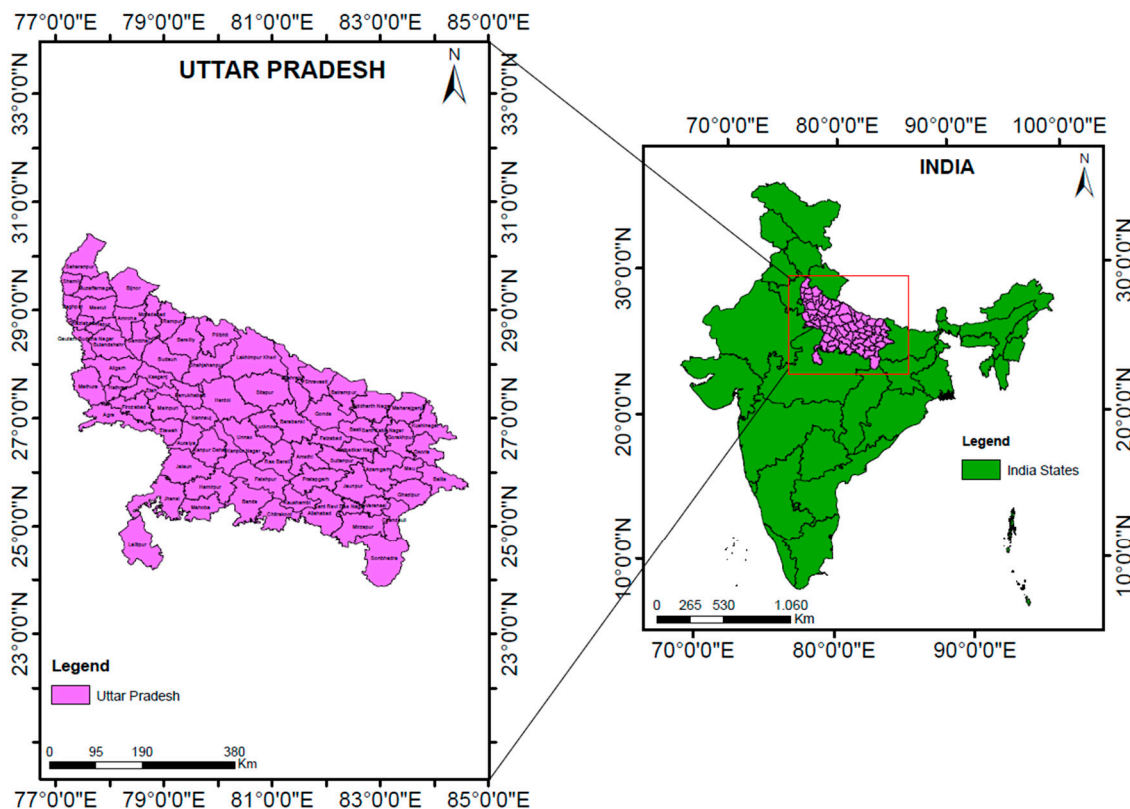


Figure 1. Map of the state of Uttar Pradesh.

The major economic activity in UP is agriculture. The commonly cultivated crops are wheat, pulses, oilseeds, rice, sugarcane, and potatoes. The tropical monsoon climate of the state creates suitable conditions for the cultivation of sugarcane as a cash crop. The state experiences mild winters with temperatures 12.5–17.5 °C in January and hot summers with a maximum of 45 °C. Precipitation differs from 1000–2000 mm in the east to 600–1000 mm in the west. Moreover, along the two major rivers of the Ganga and the Yamuna, there are several religious and cultural hotspots throughout the state of UP. Cities such as Varanasi, Mathura, and Prayagraj have hosted thousands of visitors annually for religious and spiritual purposes [1,2].

The general overview of solid waste management in UP is shown in Figure 2. About 14,468 tonnes of waste per day is produced by 762 ULBs [2]. Home composting is infrequent, and in the decentralized composting facilities, 10–20% of organic waste is treated using a static aerobic method called NADEP (named after its founder Narayan Deotao Pandharipande) and compost pits. In the NADEP model, the composting structure is typically constructed from readily available materials, such as bricks. The primary advantage is the enhanced air supply provided by perforated walls, which reduces the need for frequent turning. Pit composting is typically practiced at the community level and by bulk waste generators. Each waste generator usually has two pits of equal size operating through the year. Food waste is fed to animals directly in smaller ULBs; in bigger ones, it is collected and delivered to animal husbandry (e.g., Gaushala). About 50% of wards have access to collection services. Thus, open burning and dumping are severe issues because the uncollected waste streams are usually burned in an uncontrolled manner. Even when the organic waste is collected, transporting the waste to a dumpsite typically involves mixing or becoming mixed with collected waste at secondary locations. Most ULBs treat a part of collected mixed waste in a Mechanical Biological Treatment Facility (MBT) to recover recyclable items, and they use the fine fraction for windrow composting. The final product is of low quality due to the presence of foreign materials [1,2,14].

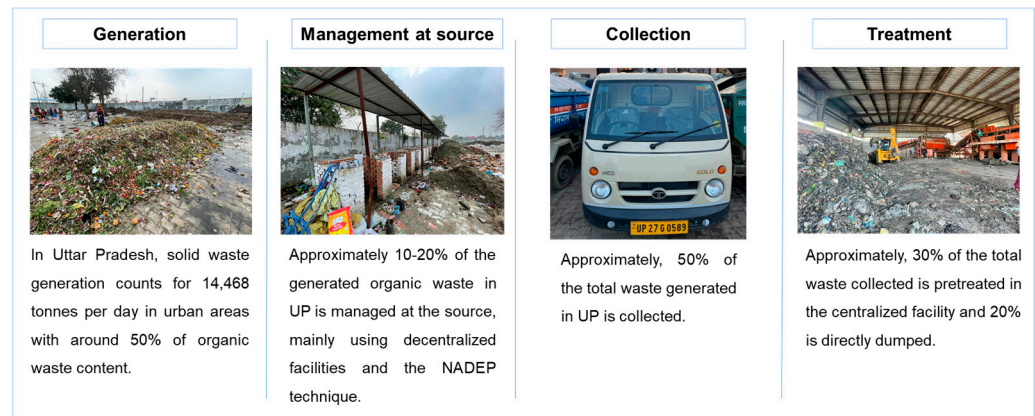


Figure 2. The existing frameworks of organic waste management in UP.

3. Legal, Institutional, and Financial Frameworks

The institutional framework of waste management in India is shown in Figure 3. ULBs are responsible for providing MSW management services in urban areas, while central and state governments have an important role in defining the policies and planning. To this end, a Central Monitoring Committee (CMC) comprising representatives from all levels is formed to fulfill the solid waste management law and link the planning and implementation levels.



Figure 3. Institutional Framework of Solid Waste Management in India.

The UP government updated the solid waste (management and handling) and sanitation rules on 20 October 2021 [2]. The SWM Rules require the segregation of waste at source and the collection, transportation, and storage of each fraction separately at the secondary collection points, while prioritizing the decentralized treatment of biowaste [1]. However, the state SWM strategy plan determines different schemes for handling solid waste based on the population size of the ULBs [2]. In large ULBs with >1,000,000 inhabitants, the waste should be separated into three bins at the source (organic, recyclable, and residual), and in less populated areas, two-way segregation (recyclable, and mixed residual) should be practiced. In all ULBs, the collected waste should be stored in two fractions at the secondary collection point, and in populated ULBs, the mixed waste should be transferred to a centralized composting facility.

At the state level, the divisional program officer, followed by the district program officer, is responsible for controlling, monitoring, and reporting all operations carried out. The ULBs are in charge of the implementation of technical actions such as collection, transportation, processing, treatment, and disposal, as well as monitoring. They can fulfill their responsibility either on their own or by tendering to a third party, e.g., the private sector and Non-Governmental Organizations (NGOs) [4,10]. However, currently, in UP, most ULBs do not have an appointed sanitary inspector.

Usually, municipal SWM activities are funded through a combination of government grants and internal revenues. These include property tax, non-tax revenues, such as rents, license fees, etc., user charges, penalties, public–private partnerships (PPPs), grants from state and central government, namely, Swachh Bharat Mission, and an insignificant amount of revenue from the sale of products, such as compost and vermicompost [10]. Yet, the financial aspects of the planning of Municipal SWM projects are not assessed thoroughly, and there is a lack of data on the adequacy of existing funds and an absence of a monitoring system on the procurements.

4. Waste Generation and Composition

The average per capita waste generation in UP is 0.350 kg per day as a result of the lower urbanization rate of the state and the large number of medium-sized cities [1,2]. Based on the field observation, the generation of waste varies among different-sized ULBs. In pre-urban areas and smaller ULBs, waste generation can vary from 0.250 kg/capita/day to 0.350 kg/capita/day, whereas in medium-sized ULBs it varies from 0.300 kg/capita/day to 0.400 kg/capita/day. In populated ULBs and municipal corporations, comparatively higher waste generation of 0.45 kg/capita/day has been reported. Thus, the trend of waste generation clearly shows the low- to middle-income level of the citizens, as UP inhabitants are mainly engaged in agricultural activities. Further, the main component of the waste stream is organic (on average 47%) with less than 10% being plastic and paper content (Figure 4) [1,2,14].

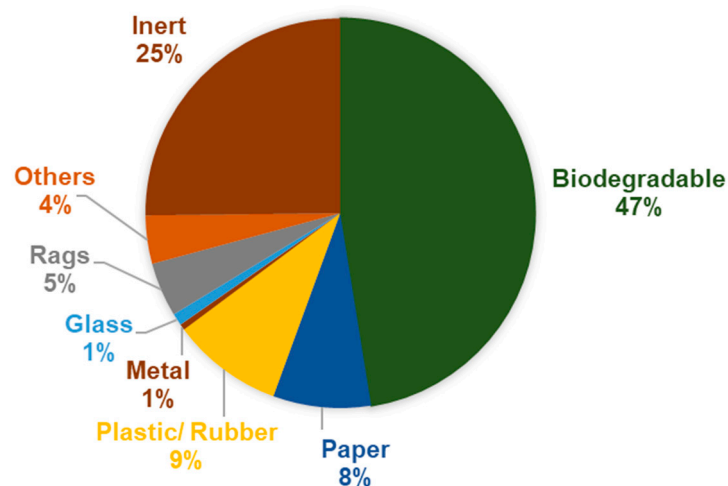


Figure 4. Average of municipal waste composition in the UP state.

Overall, by assuming an annual population growth rate of approximately 1% and constant per capita waste generation, the total waste generation by the year 2050 will increase by more than 33% in UP [3]. This could put serious constraints on the waste management system [15].

5. Waste Collection and Transportation

Waste collection services are offered daily to households and businesses [10]. In most ULBs, collection services do not cover 100% of the wards, resulting in the illegal dumping of the waste and the creation of so-called garbage-vulnerable points [2]. The door-to-door

collection of MSW is usually carried out by pushcarts with containers, tricycles, or small machinery such as rickshaws in respect to the population of the ward, the width of streets, and the type of urban building [16]. Depending on the size of the ULB municipal, solid waste is collected in different fractions (recyclables, organic, and residual). The waste received from the households is either stored in a secondary collection point or directly transferred to secondary collection vehicles. The choice between secondary storage or direct transfer to secondary collection vehicles will depend on the availability of secondary collection vehicles, the area of collection, and the timing of collection. However, in large cities, the waste is either collected mixed or gets mixed at the secondary collection point [5]. Further, the low environmental awareness of citizens leads to a lack of intrinsic motivation to contribute to the waste management and collection system, e.g., unwillingness to pay collection fees and using waste containers provided by ULB for the segregation of waste to store other products.

6. Treatment and Final Disposal of Municipal Organic Waste

The UP state attempts to follow the standards of the National SWM Rules to plan and implement the treatment systems at the city level and final management in the centralized/decentralized systems at the ULB level. This scheme primarily works well in smaller ULBs to handle smaller volumes of MSW at lower costs of storage, collection, and transportation. Generally, the treatment and processing of biodegradable waste at the household and community level is low. Despite many efforts, a negligible number of households opt for composting. Decentralized composting is practiced, yet malfunction or dysfunction of these plants is typical. A major reason for this is poor system design. The composting system is not designed in a way that ensures moisture control, air circulation, and heating of the pile. In this regard, the construction of a roof, drainage system, airflow inlet, and/or turning is neglected in many cases.

The capacity of each composting unit is not estimated based on receiving materials. This leads to a non-homogenous mixture and hinders effective process control [17]. Further, throughout the decomposition process, temperature measurement, squeeze tests for moisture control, and/or turning are not frequently implemented [18]. For almost all systems, a leachate collection system is not considered for collecting the extra moisture, especially in the rainy season.

In some ULBs, food waste is collected separately and transported to animal shelters also known as Gaushalas. The provision of a Gaushala is common in UP; these Gaushalas, with a decent number of cattle, are fed with fresh organic waste [2]. Further, in some cases, these Gaushalas are integrated with biogas plants for biogas production and generation of electricity using animal waste (cattle dung).

As the state has a high value of religious interest because of the presence of a large number of Hindu temples, there is a noticeable generation of flower waste on a day-to-day basis. This flower waste is separately collected by a private company weekly from limited cities including Kanpur, Varanasi, and Mathura. The collected waste is used in the production of colors and incense sticks.

In larger ULBs, collected waste from household and business units is transported to the processing facilities that are at high risk of failure due to poor segregation either at the point of generation or at the secondary collection point. There are unreliable data available in UP concerning the amount of waste managed at the treatment facilities.

Table 1 shows the designed capacity of the processing facilities in UP [1]. Considering a waste generation rate of 14,468 tonnes per day and 5395 tonnes of mixed waste delivered to these facilities, it is estimated that nearly 9100 tonnes of waste are collected daily but dumped, openly burned, or drained.

Table 1. Capacity of the MBT Facilities in UP.

Processing Facility	Capacity (Tonnes per Day)
Prayagraj	600
Barabanki	30
Etawah	75
Kannauj	25
Mainpuri	30
Pilkhua	45
Muzaffar Nagar	120
Raebareli	70
Aligarh	220
Lucknow	1300
Varanasi	600
Kanpur	1500
Agra	300
Moradabad	300
Mathura	180

On top of that, most of the MBTs receive volumes of waste higher than their capacity or are non/functional. Mixed waste is dumped daily at the facility. The MBTs are located near the dumpsite and usually comprise a centralized composting plant. Windrow composting is the most common technique used to treat organic waste. The collected materials are sorted manually before composting.

7. Bridging the Gaps in Existing Organic Waste Management

Sustainable management of organic waste can reduce pollution, improve public health status, create local jobs, and mitigate climate change. The current MSW system in UP does not fully comply with national legislation. Solid waste is collected mainly mixed, processed in the centralized facility, or end up in dump sites. In the absence of a sanitary inspector position, most ULBs do not have the power to enforce the rules in terms of user fee collection and imposing penalties. Furthermore, there are no effective monitoring and evaluation indicators in place.

The main concerns for improving the organic waste value chain are the poor level of management at the source of generation, inefficient waste collection, lack of skilled workers, low public awareness, technological barriers, and market-related aspects for final products. The government claims that out of 14,468 tonnes of generated waste per day, 96.5% is collected and transported to the 15 MBT facilities with a total capacity of 5395 tonnes across the state. This means that around 9100 tonnes of waste per day end up in dump sites in UP. Based on these gaps, the following sections provide recommendations for improving various aspects of SWM in UP.

7.1. Administrative Aspects

To initiate a concrete base for the futuristic application of policies at all levels, it is vital to strengthen data creation strategies [17]. One of the first steps the state government can take to better understand a densely populated state like UP is to lay down political boundaries in the form of digitalized maps. This database of maps must include all levels of information, i.e., land use patterns, roads for collection and transport points, and jurisdiction areas and their developments over time. The database must be updated at regular intervals for the understanding of newly formed bulk generators, waste-producing and -processing industries, commercial spaces, hotels, or any catering units. This information is

not only helpful for the ULBs but also for the ward, community, and state in the formation and circulation of new regulations.

7.2. Regulation Aspects

Before implementing any plan or treatment technology, state government should revise SWM rules to ensure proper management of the various waste stream types. In an integrated waste management approach, waste prevention, minimization, food donation, and feeding animals are prioritized over recycling, treatment, and disposal. The updated state legislative frameworks must meet the national policy goals and include robust assessment and monitoring methods for evaluating treatment technologies and their output quality [19].

7.3. Institutional Aspects

All the ULBs need to redefine their organizational structure for the management of solid waste in the city. This must include the capacity of sanitary workers, health officers, waste engineers, and sanitary inspectors to track developments and close loopholes. To achieve full-scale efficiency in waste collection from every corner of the ULBs, the deployment of sanitary workers is essential. Proper planning is necessary to determine the demand for sanitary workers required for street cleaning, drainage network maintenance, waste transportation, pre-processing (segregation), processing, and proper disposal of waste. Additionally, protecting sanitary workers from infectious diseases and chemical hazards is crucial. Therefore, providing them with adequate personal protective equipment (gloves, safety shoes, and masks) and access to toilets is a must. If any of this infrastructure is lacking, ULBs can consider partnering with third parties for solid waste management on a partial or full scale. The collected waste can also be outsourced directly for treatment. ULBs should maintain a list of NGOs, voluntary groups, or Self-Help Groups (SHGs) involved in solid waste management within their area.

7.4. Financial Aspects

The most challenging step in achieving financial viability for the MSW system is implementing an effective cost recovery mechanism. The standard approach for many ULBs involves periodically collecting user fees, such as monthly collections in NNs and NPPs. These fees can be fixed or variable, encouraging waste reduction or making waste disposal more affordable for low-income households. For instance, within a single city, poorer communities might be charged minimal or no fees, while wealthier communities, commercial operators, non-governmental organizations, and institutions might be required to pay the regular user fee.

In areas where residents are unwilling to pay for solid waste management services, alternative schemes can be practical. The enforcement of user fees should be introduced gradually. ULBs (NPPs and NPs) can initially incorporate MSW fees as a fraction of property tax or utility charges, then increase these fees annually. However, achieving full cost recovery through these schemes can be challenging. ULBs should raise public awareness about the importance of a clean environment and convince residents to pay the user fee regularly.

Additionally, senior authorities at the ULB level, such as district officers and sanitary inspectors, should be trained to understand that proper and sustainable waste management can generate revenue for the ULB. They should be responsible for deciding the allocation of funds in each ward and monitoring the implementation of funded projects through quarterly financial reports.

7.5. Technical Aspects

7.5.1. Utilizing Organic Waste to Feed Animals

In Uttar Pradesh state, apart from feeding animals at the household level, an effective organic waste management program is diverting food waste to Gaushala. The government

pays each Gaushala 27,000 INR per cow/cattle per month for providing food, shelter and taking care of them. The food that is left after every meal is used to feed the animals. To facilitate the success of this initiative, ULBs should collaborate closely with Gaushalas to ensure the efficient collection of surplus food and establish robust monitoring mechanisms. This includes addressing biosecurity concerns related to potential pathogens and prions, a task that could be overseen by sanitary inspectors.

Further, with the availability of cattle manure in the Gaushala, there is a huge potential for constructing a biogas plant with the possibility to add additional value to cattle manure through the production of biogas, electricity, and using the digestate as fertilizer. To integrate the biogas into Gaushala, the capacity of each unit should be assessed. Assuming that each cow produces on average 12 kg of manure per day [20], a Gaushala with 200 cows would produce 876 tonnes of manure per year. This available amount of fresh biomass has the potential for generating 48,180 m³ methane per year and the installation of a 23 kW power plant [21] (methane generation and power plant size were calculated by assuming 7000 h of operation per year, 0.36 electricity efficiency, and 0.42 thermal efficiency). Under these conditions, the Ghoshal can generate net electricity of 147,853 kWh/a [21]. A feasibility study is required to better understand how the plant will be designed and developed, as well as how to use the power that will be produced.

7.5.2. Management at the Source and Decentralized Composting Plants

To enhance the recycling of organic waste in UP, treatment at a lower level of the waste management system, namely household-level, community-based, and decentralized units should be given higher priority [22]. At the household level (possibly in households having the area to manage waste), buckets, baskets, and tri-bins/pots are effective methods for the management of kitchen waste in 45 days with low investment requirements (Table 2). Successful implementation of this scheme requires awareness-raising and capacity-building to avoid the NIMBY effect (Not In My Back Yard), wherein people usually retaliate against the processing of waste in their house premises [6].

Table 2. Locally adaptable organic waste treatment methods [18].

	Method	Feedstock	Capacity	Area	Time	Investment
Household	Bucket	Kitchen waste	1 kg	1 m ²	45 days	Low
	Basket					
	Tri-pot					
	Tri-bin					
Community-based	Pit	Kitchen waste	8–10 kg	85 m ² . Tonnes per day	45 days	Moderate
	Ring	Animal manure				
	HDPE container	Garden trimming				
Decentralized	NADEP	Kitchen waste	100 kg	85 m ² . Tonnes per day	8 weeks	Moderate to high
	Vermicompost	Market waste Animal manure Garden trimming	50,000 kg	300–580 m ² . Tonnes per day		

In communities, a circular or ring-shaped compost enclosure (pit) and plastic containers are appropriate systems with moderate investment and capacity to handle up to 10 kg of organic waste per day. Kitchen and garden waste are used as raw input materials. However,

meat, bones, oil, and dairy products should not be added to the system. The small-volume containers are ideal for treating fruits, vegetables, food, and garden leaves. To control the moisture in the container, fruits like watermelon should be squeezed before addition, and if possible, the leachate should be collected. In containers where air circulation is restricted, materials should be mixed regularly and bulking agents such as sawdust or dry leaves should be added. To accelerate composting, soil or cow dung can be added between layers. This would help to control moisture, reduce odor, increase porosity, and speed up the process.

NADEP is a common decentralized composting method in UP. Vermicomposting, a cost-effective technology that relies on the activity of earthworms, is less common. Decentralized composting, especially in NPPs and NNs, reduces the additional expenses of collecting and transporting waste over long distances. These facilities have lower operating expenses, have less operational complexity, and create jobs for the locals.

For the effective development of composting facilities, several aspects should be considered. The proper choice of technology based on feedstock, process control, in situ measurement, and effective marketing ensures the successful implementation of the composting method [17,23]. In this regard, the capacity building of facility operators is a decisive parameter. They should be trained in composing methods and how the microbiological process is affected by temperature, moisture, and oxygen concentration. These parameters are fundamental in the design of all composting systems. To operate the system successfully, they require knowledge about the quality of received material, sorting, mixing, piling, turning, temperature, moisture control, maturation, screening of the waste, and bagging of the final product [18].

The know-how on the physical and chemical properties of incoming materials is the key to sorting and mixing appropriate ratios of the raw feedstock. The plant manager should be enabled to run some trials to find out what the best mixture is under local conditions. The agricultural department and agriculture universities should examine the application of the final products on different plants in experimental farms. In this respect and to have tangible data, the existing labs should be improved. The obtained results can be used to develop the market linkage and build trust among farmers.

Community aspects play a vital role in promoting and implementing source separation, home composting, and the utilization of the final product in agriculture. To this end, any nuisance such as odor problems for residents living nearby should be avoided. Furthermore, the local stakeholders including farmers should be involved in developing treatment options and developing a market for the final products.

The funding mechanism includes supporting the establishment of composting plants by allocating funds to implement the proper technology and developing marketing strategy from the planning phase by promoting labeling and standardization. In order to reduce transportation expenses, compost producers and fertilizer firms should offer compost bulk to farmers or as near to the production region as possible. Manufacturers are motivated by the release of a subsidy (70:30 ratio) to assure quality and ownership.

From the regulation aspect, the involvement of the Swachh Bharat Mission (SBM) office, State Pollution Control Board, and ULBs is crucial. The SBM office should be involved in all actions connected to the city's compost policy. In the event of non-compliance with the SWM Rules, 2016, and fertilizer control order requirements, pollution control boards could take strict enforcement action against ULBs or compost producers.

The senior authority on the ULB level should be trained to plan effective source separation schemes, plant monitoring, and product quantity and quality certification. They should have clear responsibilities in implementing these measures. Further, the agricultural department must take the lead in testing and the use of municipal compost for land regeneration, quality control of the compost through their laboratories, and suitable fertilizer certification mechanisms.

7.5.3. Improving Processing and Treatment of Residual Municipal Organic Waste

The first step in improving the existing situation is to control the incoming materials in centralized MBT facilities. The transported waste should be received by the processing facilities in a timely and efficient manner. The payloads of the vehicles should be evaluated using a weighbridge or at least a visual estimation. To minimize local disruption and environmental impacts, the received waste should be processed daily, followed by facility cleaning and leachate management, among others. Integration of the informal sector would ease the pre-sorting process [17]. The capacity building and training of all manpower in the facility is another important aspect to be considered [18]. In the midterm, the establishment of controlled processing facilities should be planned (Figure 5). A digitalized map for active and inactive waste treatment and disposal in all the ULBs should be created. This digitalized map can have information on the availability of land space (equal distribution in a location), centralized or decentralized types of processing units, and located landfill areas or a dumpsite, etc. Further, this can be detailed by adding more information for each of these locations. Each processing unit can be described by the technique of waste processing, the percentage amount of waste treated from the total waste collected, the capacity, and the nearby end disposal facility.



Figure 5. Considerations for the development of a centralized biological treatment facility.

An environmental impact assessment should be performed at the state level to evaluate the locations for the establishment of new facilities [24,25]. In this aspect, the amount of waste projected, the development of urban areas in the future, and the protection of natural resources, especially water bodies, etc., should be carefully assessed [26].

The design and designation of a MBT facility should be decided by a committee, chaired by the sanitary inspector on certain factors such as the amount of waste that can be processed daily, robustness and quality of the material chosen for building the facility (for a longer lifespan), type of technology adapted with its efficiency, closest available storage facility, and any certifications needed following the standards [27]. The upkeep and maintenance of any MBT facility should be delegated by a trained worker and important criteria in the establishment of centralized biological treatment facilities should be considered. Land ownership, waste collection, transportation route, location, waste sorting, processing, and storage facility are key factors [28].

The financial viability of the centralized biological treatment facility is an obstacle to the proper organic waste management (OWM) of these facilities. An effective approach for evaluating the cost-benefit of material flow is by conducting waste characterization to estimate the generated revenue per tonne of processed waste [29]. Based on the the estimated revenue, the MBT facility operations should be tendered to a third party, e.g.,

PPPs or NGOs. This mechanism enables the ULB to use the stabilized fine fraction for the landfill covering and not invest in producing compost from mixed waste [30]. In the long term, the current uncontrolled centralized MBT facilities should be phased out. This requires promoting home composting and animal feeding. Improving decentralized composting would also decrease the burden on centralized facilities. Accordingly, the ULB has the opportunity to generate revenue from mixed waste by outsourcing instead of seeing it as a burden/challenge to be taken care of. The ULB acts as a project supervisor and checks on health, safety, and environmental measures through monitoring tours. Sanitary inspectors should strictly monitor and control the process to ensure quality products that are fertilizer control order compliant.

8. Conclusions

In UP, the most populous state of India, approximately 14,468 tonnes of waste are generated every day. Of this, only 38% undergoes processing, while at least 9100 tonnes are indiscriminately dumped in open low-lying areas, contributing significantly to methane emissions and groundwater contamination. Mismanagement of MSW in the state along the three major rivers (Ganga, Yamuna, and Saraswati) poses serious environmental and human health threats. Therefore, this study reviewed the organic waste management system and investigated gaps in the current practices.

Adhering to the principles of the food recovery hierarchy, we advocate for strategic interventions. A main fraction of the generated organic waste can be diverted to animal husbandries, e.g., Gaushalas. What remains can be effectively treated using different composting approaches. At the household level, buckets, baskets, and tri-bins are effective methods for managing kitchen waste. At the community level, pits, rings, and HDPE containers are suitable systems. NADEP and vermicomposting are the most common decentralized composting methods. Finally, in the absence of all other options, mixed waste should be safely pre-treated through MBT facilities. This trend creates value from waste at different levels.

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