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Optimizing solid waste management in Bihar: A multi-objective approach

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Abstract
The problem of HRD in handling and effective management of MSW has been compounded by population growth and increasing urbanization in Bihar and especially in cities such as Patna. The increase in waste production has exposed some gaps in the current waste management frameworks such as; inadequate collection networks, fewer processing facilities, and low awareness. However, there has been an improvement in achievement of sustainability goals through people's participation since several quarters have embraced sustainable measures in their communities. Some of these problems have been tackled by measures including education crusades, proper disposal of wastes, as well as methods of dealing with wastes including the composting and recycling techniques. In light of these emerging problems, the better management of the waste issue requires the enhancement of the effective legal frameworks as well as policies, with enhancement of public awareness campaigns. Increasing capacity, enhancing the cooperation between local authorities and residents, and applying successful experience of other areas will become critical in creation of the improved and Sustainable framework of waste management in Bihar.

Keywords: Municipal solid waste, urbanisation, waste disposal, green measures, civil construction

Introduction
For the global waste generation, it is expected to touch 3. 40 billion tonnes by 2050, which would mean that the rate of increase outstrips the population growth from now to the same year. As for now, 33% of the generated wastes are dumped in open dumps, 37% in landfills and only 8% are treated in sanitary landfills. The high and the upper middle income nations have well scientifically managed landfill and efficient waste management while 93% of the low income nations dump their wastes in the open. On average, the world manufactures 0. They produce an average of 74 kilograms of waste per head per day of which 44% is food or green waste and 38% is dry recyclable material. The issue of waste management especially the MSW has become rather pressing for Bihar because of the constantly rising rate of urbanization and population. However, through the generation of ms, length style=1 Constant the state produced 4,200 tons of ms, length style=1 Constant the state produced 4,200 tons of ms, only the portion that is collected and treated is impressive. The position aggravates in rural areas, and most of the wastes remain uncollected, and the waste management is negligible at the village or Panchayat level.
The quantum of waste will increase further as the urban culture in Bihar is on the upswing due to factors such as, urbanization, industrialization and change in life style. It has been projected that the level of MSW generation may touch alarming standards in the future with large cities in Bihar having the potential to contribute 400-600 gm per capita per day waste generation, medium cities 300-400 gm/day and small towns contributing 200-300 gm/day waste generation. But inadequate infrastructural development in waste management is a major set-back that the state will have to address in order to contend with this increasing problem. Like in the rest of India, Bihar also benefited from the employment generation and raise in the disposable income due to the continued phase of economic liberalization in the 1990s. This has promoting urbanization and migration to places like Patna as more people consumed goods and services hence creating more wastes. In this context, Patna, as the state capital of Bihar, is illustrative of this grim tendency, it is unable to cope with the increasingly mounting waste produced by a burgeoning population.

Patna produces about 3000 tonnes of MSW daily including wet waste, dry waste, inert waste and domestic hazardous waste. Most of the cities are under pressure attempting to contain this waste, existing infrastructure and methods failing to match the escalating rates. With Bihar in the process of steady development it is necessary to solve the problem of proper waste disposal, collection, sorting and treatment, especially in the context of the growing urbanization of the state. Further, eradicating the challenges that are related to waste disposal in the rural areas is something that still needs to be done.

Table 1: Indicated composition of waste in Bihar

S. No.	Category	Percentage
1	Vegetable	30
2	Paper	9
3	Plastic	12
4	Cardboard	4
5	Textiles	4
6	Grass/leaves/wood	6
7	Leather	0
8	Electronic item	2
9	Metal	1
10	Organic	23
11	Glass	3
12	Debris	5
13	Biomedical	2

Bihar is the state which is in a process of gradual urbanization and the problem of managing municipal solid waste in Bihar grows with the increase in the urban population of the state. At the moment, the population density in urban areas is increasing steadily, and it is already a significant proportion of the states' population, hence the need for proper waste management. There has been some significant rise to the level of urban populace in the state, therefore this shift from rural to urban areas and changes in live styles. This kind of pace of urbanization brings about lots of pressure on the local leadership in terms of provision of basic public utilities such as garbage disposal. However, today's society has registered tremendous advancement in a society's waste management campaign through community involvement and stakeholders. The citizen has taken up to their responsibilities in disposal of wastes and are coming together to form organizations demanding for better services and proper performance from the local government. Activities on social media, Facebook, WhatsApp, and Twitter have been identified as strategic means through which citizens use to express their concern and report different issues, foster awareness campaigns in different areas of interest including; waste segregation, composting, recycling and reduction of plastics.

These initiatives have found support with non-governmental organisations, self-help groups, green enterprising individuals, and municipal councils. Recently, citizens' networks have started to respond to a number of civic concerns including the disposal of solid wastes; environmental conservation and physical planning. This consciousness of urban environmental management fosters accountability and equally participates the community in governance, hence there is hope for increased customer participation in improving urban administration. Scholars also emphasize the significance of people participation in proper waste management. Researchers have established that citizens' networks and active organisms can provide multi-stakeholder exchange and observation of local environments. Because they are involved in sensitization and promotion of sustainable approaches to the management of wastes which is critical for the ever growing urban area in Bihar.

Citizens' participation in solid waste management remains crucial especially echoed in the research done in other areas, for instance, Bengaluru. In those places, the citizen networks appear to have been able to play a replicative role by taking a watchdog-like role and pointing out problems in local ecosystems. Comparable strategies may be used to improve knowledge and engagement of the public in Bihar in the context of governance in relation to waste management practices of relevant authorities. Some of the issues that are slowing down MSW management in Bihar are; as pointed in Bihar there is a lack of proper waste collection system, less funding and little awareness among the public. The lack of any synergistic action plan for the proper management of solid waste in Bihar call for identification of successful models of other regions in order to adapt a proper formulated framework for solid waste management in Bihar. This framework should involve the use of community and also the use of new techniques in delivery of its services for efficiency and effectiveness. Some of the specific preventive and management measures have categorization based on the options such as legal and policy measures or government programmes. For instance the National Sanitation Policy and the Ecomark Scheme would therefore be useful tools in building on the standards at the national level. Moreover, additional community involvement is important, which means that public awareness campaigns play a very important role concerning proper working waste management systems.

Bihar and all its growth and change processes, including those related to urbanization and exclusion, waste and disposal, will require the unions between citizens and local governments. Dedicating attention to the informal sector worker that participate in waste management and fostering collaboration with private organizations can greatly improve the delivery of service and health of the community. The objective of this paper is to present the various activities that have been carried out in Bihar towards SWM and identify and discuss SWM initiatives and practices that have proved to be effective in Bihar. The discussion will centre on special measures to ensure sustainable management of wastes taking into account the employment opportunities offered by the measures that are being implemented. The proposed structure of the paper will therefore comprise of three sections. The first section will capture different waste management measures with regards to Bihar and the effects on the same. The second section will focus on three more practicable measures that have been demonstrated to be efficient in the promotion of successful waste management. Thus, the last section of the thesis will conclude the major discoveries and conclusion hence recommend on the future attempt in enhancing the solid waste management in Bihar.

Research Methodology

This paper maps and categorises the several activities undertaken at each level of the municipal solid waste (MSW) management hierarchy ie raising awareness about waste, sorting, picking up, transferring, processing, and removing waste. All the data for this study has been

obtained from secondary sources and field research to analyse the status of managing solid wastes in the state and the strategies put in place.

Awareness

A functioning Participatory Solid Waste Management (SWM) programme has been implemented in Bihar due to active engagement between citizens and local governance. Much of these initiatives are focused on education on sustainable practices which in this case include segregation of waste, composting among others in the fight against plastics. These are various campaigns which have being carried out some are educational like the "Trashonomics", a waste management program for school students. Sustaining these educations are the initiation of the eco clubs in schools to change the young generation into environmental conscious individuals. Local authorities have also organized training sessions for the traders, hawks, hotels, and street vendors in an effort to sensitized the traders on the issue of ban on plastics and what substitutes are available on the market. Furthermore, organizing periodical meetings with the sanitation workers is conducted in order explain the necessity of proper waste sorting as well as the requirements regarding the utilization of plastics.

One impressive campaign is known as the Brand-Audit that the SWMRT undertook, which pointed out that 61% of the audited plastic waste was made up of multi-layered laminated packaging. Due to this discovery, there has been calls for setting up of plastic-to-fuel plants so as to deal with this kind of waste. More than 200 numbers of citizens groups are participating in SWM in Bihar of which some groups are using social media for effective communication, scrutiny and involve the citizens in waste management programs.

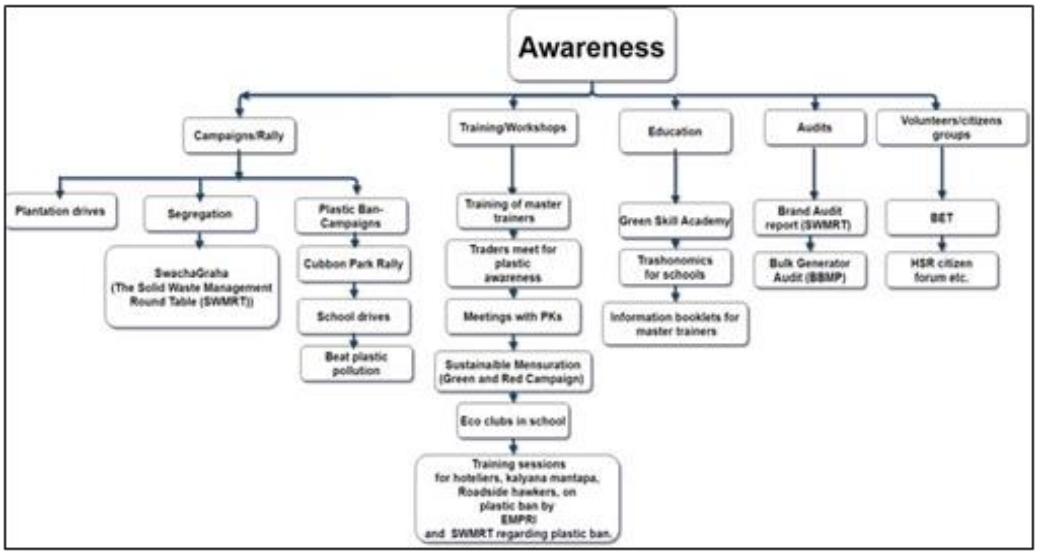

Fig 1: Initiatives for raising awareness in the SWM Process

Segregation: India has benefitted most from the '2bin1bag' system that has been deemed effective in segregation of waste. Introduced after the Karnataka High Court ordered the company to come up with the system on December 17, 2015, the system entails the use of two bins, green for organic waste and red for reject waste, and a bag for recyclable material. More than two lakh families in Bengaluru have adopted this technique. Collection activities focus is presented in Image 2 differentiated under BBMP drives, NGOs and the itinerant buyers. BBMP picks up the wet waste every day in auto tippers and the dry waste is collection bi weekly and then transported to Dry Waste Collection centres for recycling. Some of the major tasks that residents of bulk generators such as large apartments and commercial buildings are required to manage waste directly on site or using BBMP approved vendors. Even the festivals and fairs have specific disposal plans and the technology such as the BinTipper App is used to monitor the daily collection.

In Bangalore, waste management is a responsibility shared by non-governmental organizations and citizen group including Hasirudala, Sahaas and Janaagraha. Recycling, ewaste management and associated support to waste pickers. For example, Sahaas runs a recycling arm and Hasirudala is involved with managing the Allied Waste and Services and assisting rag pickers through issuance of identity cards more than fifteen thousand ugly waste pickers, who without any hesitation have to be addressed as indispensable actors in the waste management process. Transportation entails auto-tippers, compactor & push carts and in efforts to improve tracking implementations of GPS was initiated.

Treatment/Processing: To improve the decentralized waste management in Bihar treatment and processing facilities have been developed. These are bio-methanisation units and several processing centers and sanitary landfills. It supports programmes at the ward level, composting activities in local neighbourhoods, home composting, and composting facilities in public areas. In-situ waste management practices include, barrel digester composting, bio-bin composting, integrated community waste management, eco digester composting and solar composting. Also, the construction of the initial units of top-quality leaf shredders is ongoing in some locations, and the establishment of the processing plants for particular wastes, which include coconut waste and thermocol, is being planned. Even in the case of waste disposal, local composting units are being set up in such places as temples, etc., to skip levels. New retail stores providing upcycled goods and companies using upcycled elements are also being seen. For waste disposal Bihar County makes use of landfill sites. For the purpose of

enhancing landfill management the state government is planning to employ clean-up marshals who are trained personnel and will be in charge of supervising landfill activities and actual waste management

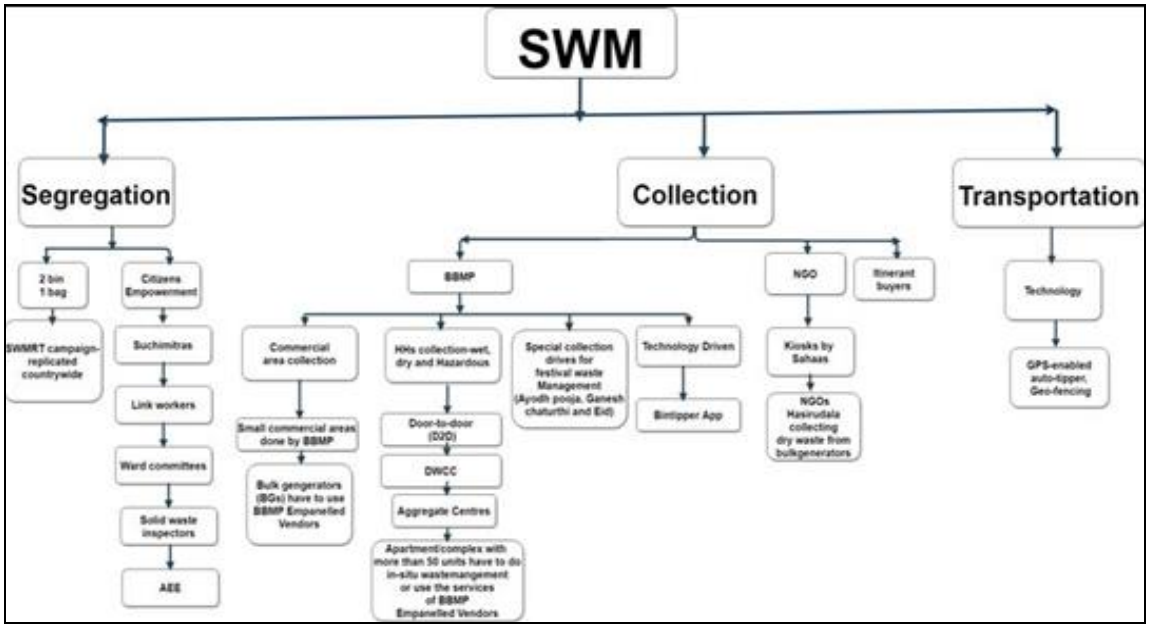

Fig 2: Segregation, collection, and transportation initiatives in Bihar

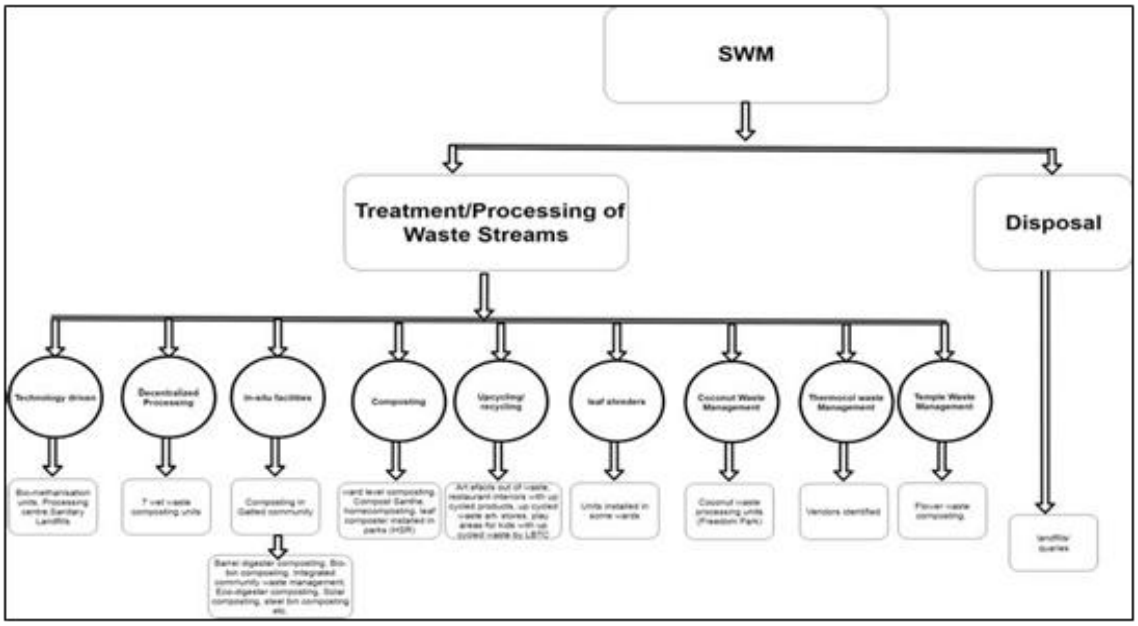

Fig 3: Waste treatment and disposal initiatives in Bihar

Following is a brief discussion of several waste management activities that are clearly depicted in this image. The following initiatives have been facilitated with a view to encouraging zero-waste practices; the speedball events and green weddings and terrace gardening. Speedball events are oriented to increase green cover through distribution of golf ball-sized seed, soil and compost for the growth trees. Eco-friendly weddings ensue that the consumption of disposable cutlery, single plastics or other decorative items is minimized. There is a growing trend in terrace gardening which in turn is increasing the use of home produced compost in one's shamba. Thus, IPL matches, marathons and the like should strive for ending the day with no waste produced; no plastic water bottles, no flex banners. Some eating places have ceased using plastics containers for home deliveries and give customers who come with their own containers a discount. There are what is known as 'cutlery banks' operating with the aim of popularizing steel utensils instead of plastic ones. Muhammad Yunus is popularising sustainable products like bamboo toothbrushes, steel straws, seed papers, and clay and seed Ganesha idols from Green entrepreneurs. Some restaurants have embraced the art of up cycled waste in the interior décor of the restaurants. Some of the food waste bins are placed in commercial centres so that excess food from shops is given out to needy persons. Chai Point and Big Basket are two players that have adopted sustainable practices, with Chai Point upcycling the used tea and coffee ground for farmers regularly, while Big Basket has cut on the use of plastics and cardboard through the help of volunteers.

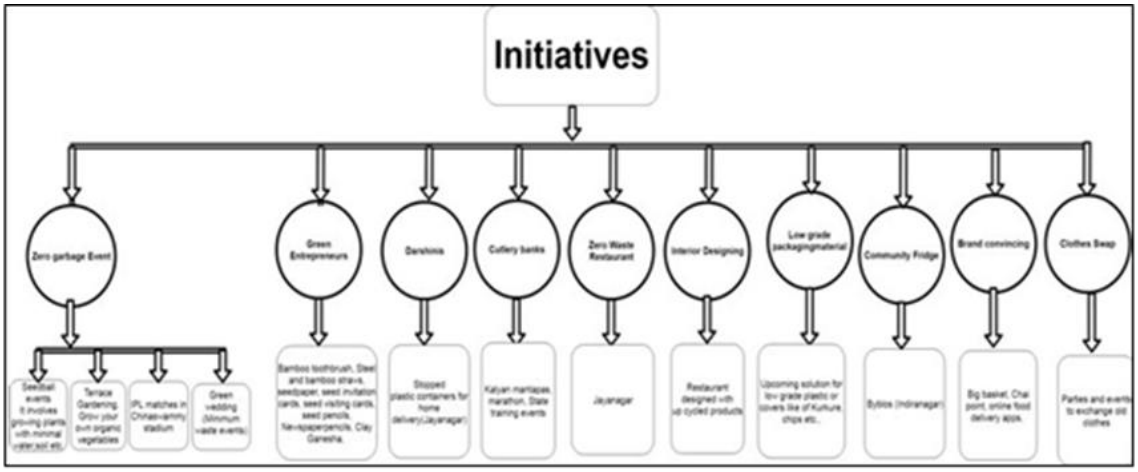

Fig 4: Innovative waste management initiatives in Bihar

Considering the assessment of WMP in Bihar, this study is aimed at analyzing two successful example of practices and one example of eco-innovation which have been systematically implemented and further replicated. Some of them include; provision of community bins for composting and reduction on the use of plastic materials. These practices have triggered more advancement like waste segregation campaigns, local recycling and environmentally friendly processing of wastes. Another example of eco-innovation is the implementation of the use of a technology-based waste management system that improves the operations of managing and disposing waste in the region.

Case Studies

Case Study 1: Compost Santhe

In Bengaluru, the Compost Santhe initiative, a combined effort of BBMP and concerned citizen under a government sponsored campaign has been useful in decentralized composting. To date, 28 Compost Santhe events have been conducted with the aim of teaching people how to properly compost at home for waste disposal. These events are similar to flea markets where composting stalls, information relaying stalls and other activities of community concern occur. The key stakeholders are Corporators at the local level, the local MLAs and farmers who sell the compost directly. The Santhe have heightened people's understanding of composting and supported cause-related agriculture such as the Organic Terrace Gardening (OTG) and Oota from Your Thota (OFYT). The events also include schools and focus on youths and therefore show a good community support on proper disposal of wastes.

Case Study 2: Plastic Ban

Considering that Bengaluru alone produces 350-400 tonnes of plastic waste daily, the Karnataka State Government put into effect the ban of plastic on March 11, 2016. It outlaws a myriad of plastic products such as carry bags and single use plastics, but with exemptions. It is for this reason that the BBMP has resorted to increased enforcement through seizures of plastics and through fines while at the same time conducting training of the vendors. The influence of the ban has been further endorsement by India's World Environment Day 2018 making the public to shift to the use of substitutes such as; cloth bags and bamboo staws. Someday the NGOs and the businesspersons have come up with sustainable products; there are new employment vacancies. In the case that a brand audit was used, there are often multiple layers of laminated packaging to which a company would have to respond.

Case Study 3: Daily Dump

Daily Dump has brought launched new, environment friendly composting systems in India appropriate to conditions there and thus addressing waste to wealth. For food waste, reusable composters by the company come in terracotta material and for different types of wastes giving back to local potters while improving the hygiene standards of the communities. Daily Dump has 26,000 registered users across the key locations managing to recycle approximately 15,000 kg of organic waste per day. The initiative also avails employment to potters and encourage green entrepreneurship therefore cutting on the cost of waste management. Daily Dump does not hold proprietary rights to its designs and business model which in turn are replicate by local franchisees while Trash Trails bring change in people's behaviour to compost their waste.

Challenges for daily dump

One of the major difficulties is to change people's attitudes in the population. Most individuals deem waste management as something that should only be conducted by the government and they do not know that composting is possible at home. Another drawback of composting for urban dwellers is that they don't have available land for it as they do a garden, they also worry that cockroaches or flies will be attracted to the compost pile or that they will begin to smell bad. Another reason is that people have tight schedules which would make them shy away from home composting. Such challenges have to be faced by the Daily Dump's team which strives to change the mind-set concerning waste management. Changing the practices of people means a lot of commitment and not a little effort has to be put in place.

For waste management program to work as planned, there is need to have strong back up systems in place otherwise the programs may collapse. People require confidence that the composters into which they enter their waste products will be taken care of in a way that honours their culture and utility. The team also has the problem of how to find adequate end-user revenues for sustaining the necessary future research and design. Exploratory partnerships with NGOs are currently under way to expand the services

operated by Waste Inovation to other boroughs in the city and further afield. For there to be wider application, Daily Dump has what can be described as a robust and scalable model. This involves altering perceptions of what is waste, and what is not. As entrepreneurs, the informal recyclers, who are regarded as green warriors, take a lot of risks. Indeed, for recycled programmes to work, there has to be careful coordination. For instance, Wipro has recently involved 100 000 of its employees in waste management and underlined the solicitude of recycling into behavioral patterns.

For instance, Poornam, the inventor of Daily Dump, said that the best solutions should go for changing the existing methods and practices. This dispels with using distant dumps or costly technologies and gets to sustainable business practice that gives new life to assets. What is meant here is to awaken and appropriate a new attitude towards waste as a non-threatening concept that is easily recoverable and can be easily utilized.

Solid waste management and challenges ahead

However, even today, there is a range of problems related to waste management even though many attempts have been made to enhance it. Today, the BBMP runs five SWM projects. The SWM projects that the BBMB has been running include the following five: Four of these have a capacity of 1,900 metric tons per day (MTPD); the fifth has a capacity of only 250 MTPD and is still in the pilot stage. Of the four plants currently in operation, only three of them handle the total of 700 MTPD of wet waste. The city generates 5,758. 17 TPD of waste and types of waste collected include the residential, commercial, street Sweeping, and Bulk Generators. This waste consists of 64% of wet waste, 28% of dry waste, 3% of domestic hazardous waste and 6% of reject / inert waste. The current waste management system has the problem of managing this amount of waste and that can explain a great deal of the problem.

Furthermore, there is no figure to compare the waste collected with the one taken to the processing plants or landfills or even the general black spots that are pervading the city. Literature review by Ramachandra *et al*. 2018 shows that the general collection, transportation, and disposal of MSW in India is poor, as out of the total MSW generated, just 60% is disposed of at identified centres, the rest is dumped at unidentified places. The applicability of waste to energy solutions is ambiguous because waste is chiefly wet. The city also has a very weak model of waste segregation at source. Although the feasibility of the ‘’bio-methanisation’’ model has been demonstrated by implementing it in some of the wards, the ability of this system to process wastes decentralised remains somewhat restrained.

Conclusion

Taking into account the findings above, the examined aspects of MSW management in Bihar prove that population growth and the fast pace of urbanization have put a pressure on the capacity to address waste challenges in Bihar’s cities, including Patna. The present situation of waste generation has compelled many deficiencies in the collection system, limited processing facilities, and a lack of public awareness. However, there has been active participation of people in waste management and use of citizens and stakeholders to drive call to sustainable waste management through involvement of the community has been encouraging. Measures like awareness creation, waste disposal, and various ways of processing waste more efficiently; for instance, turning it into compost or using it in some other useful method, have been effective. In response to the emerging problems, the waste management should be strengthened and complemented with legal requirements, policy and publicity programs. Some of the recommendations include; Infrastructure development, increase on decentralization and cooperation with the local governments and identifying best practices from other regions for a better way forward towards a sustainable waste management system in Bihar.

Future Scope

- **Infrastructure Development:** Improve waste management, investing in collection, segregation and processing systems to be able to deal with increased volume of waste.
- **Public Awareness and Education:** Implement large-scale awareness creating and sensitization crusades that target household’s waste disposal methods, including separated pick-up, composting, and recycling among other procedures that will enhance the uptake of the crusade in the different regions of the country but especially the rural tracts of the country.
- **Technology Integration:** Privatize waste management by encouraging the adoption of advanced technologies in dealing with wastes like the waste to energy technologies as well as new age recycling methods. Install optimization techniques in the quantity and disposal of waste in order to enhance its identification and control.
- **Policy and Regulation Strengthening:** To create tough waste management laws and policies for their implementation and enforcement. Partner with national and international agencies to set standards and policies that reduce the entitlement of the landfill and liberal dumping.

Recommendations

- **Upgrade Infrastructure:** Establishment of current waste disposal, sorting, and recycling centres.
- **Boost Public Awareness:** Step up dissemination of information and sensitisation of community for better management of wastes.
- **Adopt Advanced Technologies:** Reduce, reuse, recycle; The adoption of waste to energy opportunities and the conversational optimization of waste.
- **Strengthen Regulations:** Adopt and implement even higher standards of waste management and foster cooperation on the issues concerning the standards.

Suggestions

- **Form Partnerships:** Some of the strategies include; Engaging different stakeholders with a view to coming up with better waste management processes**.**
- **Encourage Innovation:** Promote the funding and development of new methods of waste disposal.
- **Secure Funding:** Finance infrastructure and technology and advance education.

- **Monitor Progress:** Waste should be managed following analytical data that includes evaluating and modifying common waste management regimens.

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