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TECHNOLOGICAL DEVELOPMENTS AND INNOVATION REGARDING DOMESTIC WASTE MANAGEMENT: A CASE STUDY ON NARNAUL CITY

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ABSTRACT
Technology has transformed the way waste management works with automated sensors that trigger instant alerts every time a container is full and needs service. Other innovative tools that are making the sorting process fast and easy include optical sorters, magnets and advanced disk screens. This paper tries to identify technological developments and innovation in waste management systems which are already present and which can still be applied in case of Narnaul city. To fulfil this objective researcher use Secondary data from journal, books, periodicals and other relevant published literature were collected. . To enhance the efficiency of waste management in India, citizen participation should be promoted, especially in source segregation and treatment processes. The policy agenda for sustainable waste management must drive behavioural change amongst citizens, elected representatives and decision-makers, Secondary data to minimise wastage and littering, and increase reuse and recycling. Community awareness and a change in people's attitudes towards solid waste and their disposal can go a long way in improving India's waste management system.

Keywords: Technology, Waste Management, Narnaul city, Reuse and Recycling, innovation

1. INTRODUCTION

Waste not, want not: this old saying rings so true today, as global leaders and local communities alike increasingly call for a fix for the so-called "throwaway culture." But beyond individuals and households, waste also represents a broader challenge that affects human health and livelihoods, the environment, and prosperity (Marquardt & Berger, 2012).

Solid waste management is a universal issue that matters to every single person in the world. And with over 90% of waste openly dumped or burned in low-income countries, it is the poor and most vulnerable, who are disproportionately affected (Kaza et al., 2018).

In recent years, landslides of waste dumps have buried homes and people under piles of waste. And it is the poorest who often live near waste dumps and power their city's recycling system through waste picking, leaving them susceptible to serious health repercussions (Merry et al., 2005).

"Poorly managed waste is contaminating the world's oceans, clogging drains and causing flooding, transmitting diseases, increasing respiratory problems from burning, harming animals that consume waste unknowingly, and affecting economic development, such as through tourism," said Sameh Wahba, World Bank Director for Urban and Territorial Development, Disaster Risk Management and Resilience (Merry et al., 2005).

Greenhouse gasses from waste are also a key contributor to climate change. In 2016, 5% of global emissions were generated from solid waste management, excluding transportation.

"Solid waste management is everyone's business. Ensuring effective and proper solid waste management is critical to the achievement of the Sustainable Development Goals," said Ede Ijjasz-Vasquez, Senior Director of the World Bank's Social, Urban, Rural and Resilience Global Practice. "Left unmanaged, dumped or burned, waste harms human health, hurts the environment and climate, and hinders economic growth in poor and rich countries alike." (Merry et al., 2005).

Several studies and contemporary issues motivate us to look at the solid waste management, in our case, in Narnaul city. After investigating the prevailing process of collection and disposal of the waste at the household level, the dhalao worker's, waste collector's and the segregator's level and examining the role of the authorities, this paper tries to identify technological developments and innovation in waste management systems which are already present and which can still be applied in case of Narnaul city.

2. LITERATURE REVIEW

Pacey, J., Augenstein, D., Morck, R., Reinhart, D., & Yazdani, R. (1999) in their study stated that sanitary landfilling in the United States has made monumental strides in the last 20 years, moving from open dumps with little or no control to "state of the art" controlled facilities with sophisticated containment systems,

environmental monitoring, improved operational practices, and increased regulation. The modern sanitary landfill is truly an important component of today's integrated solid waste management system. However, in order to advance the field of solid waste management, new and innovative ways of managing solid waste disposal need to be continually evaluated. One idea that has gained significant attention in the last several years is the "bioreactor landfill." The concept is seen as a way to significantly increase the extent of waste decomposition, conversion rates and process effectiveness over what would otherwise occur within the landfill. Other benefits include maximization of landfill gas (LFG) capture for environmental recovery projects; increased landfill capacity; improved opportunities for leachate treatment and storage; reduction of post-closure activities; and abatement of greenhouse gases. This paper presented an overview of the bioreactor landfill concept, including existing relevant regulations, benefits to be derived, design and operational issues and possible solutions to many of these issues. In addition, the paper addressed the numerous non-technical and non-environmental barriers to acceptance of the bioreactor landfill concept. This paper was intended to raise reader awareness that the bioreactor landfill is an emerging viable option for solid waste management. It is hoped that landfill owners and operators, policy makers, regulators, others concerned with the environment, and the public at large will use this paper as a focal point for future discussion.

Osokina, I. V., Afanasyev, I. V., Kurbanov, S. A., Lustina, T. N., & Stepanova, D. I. (2019) stated in their study that the rate of waste accumulation in Russia increases every year. The scientific community is constantly looking for new methods of waste management and is forced to solve the emerging environmental and economic problems in this area. The purpose of the article was to analyse the relationship between tax regulation and investment in the waste management industry. The article substantiated the relevance of the introduction of innovative technologies in the field of waste management in the conditions ensuring environmental safety and economic feasibility. The features of tax and investment relations are considered and the application of the investment criterion in determining the environmental tax rate is demonstrated. The priority of an investment project's investment requirements is presented based on the example of the construction of a new municipal solid waste landfill. The experience of investing in waste management in the EU countries is considered. Based on an expert survey, the factors of investment and innovation attractiveness of investing in the waste management industry, as well as the existing innovative waste management technologies in Russia and other countries, are determined.

Gaeta, G. L., Ghinoi, S., Silvestri, F., & Tassinari, M. (2021) in their study stated that often considered a traditional labour intensive activity, in recent years, the solid waste management (SWM) industry has been largely interested in innovation. Nonetheless, the analysis of innovations in the SW industry is frequently confined to process innovation in the disposal segment, neglecting other kinds of innovation – such as product innovation and organizational innovation – in other segments. While several economic theoretical frameworks have been developed for interpreting eco-innovation in general, a specific analysis of innovation in each segment of SWM is still missing, despite the specificities of this sector. To fill this gap, this paper shows how complexity theory can be profitably used to integrate the more traditional neoclassical approach, offering a comprehensive theoretical framework to analyse innovation in the SWM industry from both a market and firm perspective (the neoclassical approach) and from a social perspective (the complexity theory framework). Four main typologies of the SW market system, exhibiting different kinds of innovation, are outlined: (i) a "traditional" landfill-oriented system; (ii) a modern "waste-to-energy" incinerator-oriented system; (iii) a "light recycling" system with integrated solutions and a selection performance that is lower than 50%; and (iv) a "hard recycling" system.

Hara, K., & Yabar, H. (2012) comprehensively analysed the historical evolution of waste treatment and recycling practices in Japan since 1950s when the rapid economic development started, particularly looking into societal background conditions, policy responses, and technological aspects in an integrated manner. Based on statistical data related to waste management and relevant documents, authors discussed that Japanese waste management and policies evolved from reactive and end-of-pipe approaches that primarily focused on safe disposal and incineration to more integral and proactive policies with recycling practices. The most recent trend after the year 2000 is best characterized in the integration of two different governmental policies: i.e., realizing a sound material-cycle and low-carbon society. From the overall analyses, three key characteristics associated with waste management system are particularly highlighted: (1) reliance on incineration as a means to reduce waste volume, (2) material recycling with ambitious recycling targets for specific wastes, and (3) an integral resource management approach that stresses not only improvement in energy and material recovery but also an increase in resource productivity. Authors also discussed technological and system innovations related to waste management by exploring two specific cases of incineration system and polyethylene terephthalate (PET) bottle recycling. Regulations and incentives by governmental policies are found to have been effective in that they triggered the technological and system innovations necessary to achieve recycling targets. Japan's experiences on historical waste management and policy designs for technology and system innovations shall provide

important lessons for other rapidly developing countries just facing increasing wastes volumes and a critical challenge of building sustainable waste management systems. It is indispensable to enhance international cooperation to share essential knowledge about waste management and recycling schemes.

3. TECHNOLOGICAL DEVELOPMENTS AND INNOVATION IN DOMESTIC WASTE MANAGEMENT

There exist certain technologies for solid waste management and treatment. As is well known, the most effective way to handle waste is by building an integrated system that consists of high tech, the waste management industry, and the public sector. The integration of related businesses can develop new motivations to boost the value generated as well as lead the growth of markets for recovered products. Speaking of technology, it is crucial to penetrate the contribution of waste management innovations. Brand new solutions and improved methods reform the processes in the right direction.

3.1 Waste-to-Energy

Generating actual power from waste is one of the major innovations in the waste management industry. This technique aims to convert waste into energy in place of the accumulation of waste in the landfills. Digesters produce the biogas from different sorts of waste such as food, agriculture, etc. and transform that into the energy utilized on-site. Within the waste-to-energy innovation concept, it is super important to mention thermal energy conversion. Broadly speaking, this technology is based on the change in heat and pressure and works well to turn waste into chemicals, fertilizers, oils, etc. Aside from that, the microturbines, burning waste gas to create power and heat, already became a substitute for traditional methods for landfill processes.

3.2 Software for Waste Management Companies

Today, a great number of prominent firms reap the benefits of SaaS (Software-as-a-Service) offering advanced digitized platforms for the most efficient waste management process. These platforms refer to facilitating solutions to cope with industrial challenges and amplify the performance. Though several solutions are provided by waste management software, the most crucial ones are as follows:

- Central management & control
- Operational efficiency & improved service quality
- Immediate intervention capability through real-time alerts
- Increased employee productivity
- Increased customer and citizen satisfaction

3.3 Robot Recyclers

While talking about innovation, we cannot skip the robotic technology that has become the top trend in the last decades. After the import of recycling waste products was restricted by China in 2018, western companies expedited their innovative steps to integrate robotic technology in a better processing capability. Furthermore, researchers in numerous companies and universities highlight a more than $6 billion environmental service gap in the recycling industry and indicate robotic technology is a potential solution to fill this gap. All these institutions strive to develop more AI-enabled robotics that can assist in controlling quality, sorting recyclables, and minimizing the health risks to human work teams. Currently, several companies produce robotic solutions for recycling efforts. As stated by the producer firms, the investments are mainly focused on improving the quality of shipped secondary commodities and reducing labour costs on the sorting line (Rotman, 2005).

3.4 Internet of Things (IoT)

The leverage of the Internet of Things (IoT) and cloud computing technology provide high-tech sensors and enable waste management companies to optimize hauling routes and timing data. Throughout the process, haulers identify where full waste containers are located and when should they be collected. This technology lets customers collect waste from full containers. In fact, IoT aims to boost efficiency and save money by reducing unnecessary pickups. The GPS monitoring system is a great innovation as well as sensors. As data is the key in today's world, waste companies utilize the computer algorithms collecting information associated with the most efficient routes based on the distance and traffic patterns. All areas including residential routes, industrial waste pickup, construction containers, and smart bins can seize the opportunity of merging with such an innovative tool (Xu et al., 2016).

3.5 Waste-to-Raw Material

The search to reuse waste in a productive manner and innovations in that regard has been markedly increasing. Companies turn waste products into a source of raw material by extracting plastics and cellulose fiber. Autoclave sterilization technology is essential within this operation. Autoclaves are used as heat treatment processing units to destroy microorganisms before disposal (Maye et al., 2019).

3.6 Self-Driving Trucks

Despite the fact that it's still in the development phase, autonomous waste pickup is close to being implemented. As known, Volvo has been working on this technology for 3 years. Uber became its partner and participated in the research and development process. This system targets a truck maneuvering itself whilst the operator gets

out for collecting the garbage. Gear changing, steering, and speed are also optimized for low fuel consumption and emissions.

3.7 Robotic Trash Cans

Robotic wheeled trash containers that roll out on their own at the push of a button are an example of the greatest innovations. This innovation is especially helpful for those with limited mobility and motor skills. Another invention in this category is motorized garbage bins with wheels which take themselves to the curb. They were programmed to travel from a docking station at a person's residence to a second docking station at the curb. The innovators also add a function in this invention to be scheduled for the time and day of the neighborhood's trash pickup (Sarc et al., 2019).

4. DOMESTIC WASTE MANAGEMENT IN NARNAUL CITY

Narnaul town extends from 28°2'29" North latitude and 76°6'25" East longitude in the south-western part of Haryana state. It is one of the sub division and district headquarters of Mahendergarh district. The town is connected by road from Delhi at a distance of 161km, 43 km from Khetri, 125 km from Rohtak city and 23 km south of Mahendergarh town. It is almost plain area on an elevation of 100 feet (30.5 meters) above mean sea level. It has population of 62,091 persons inhabited in 12899 houses in 15 wards of the city, spread over an area of 9.67 sq. km. The literacy rate and the sex ratio recorded 78.56% and 878 respectively (Khanna, 2019).

In Narnaul, 29 tonnes of garbage comes out of these houses and shops. Source wise distribution of generation of solid waste in Narnaul town reveals that maximum amount of domestic solid waste generated from the residential houses in wards 11, 12, 13, 15 & 21 dominated by economically weaker section of the society and the Scheduled caste population, followed by other wards 4, 8, 10, 14, 15, 16, 18, 19, 20, and 23 in which solid waste generates from non-domestic works like market waste, commercial activities etc. The lowest quantity of waste generates from the hospital (Khanna, 2019).

Narnaul municipal committee look after the affairs of the water supply, cleaning of the roads and the streets, collection of the solid waste materials, supply of dustbins and the disposed off the same at designated places by appointing employees, supply of essential materials, equipments, and the transport. The municipality has sanctioned post 171 and employed 107 sweepers. They have engaged in cleaning, sweeping, collecting and disposed off the solid waste in the town. To assess the requirement of the employees and their optimum use, and the available limited infrastructure and resources, the municipal committee is divided into two wings (i) private contractor and (ii) the municipality committee. The private contractor controlled two regions, viz., II and III including 5 wards viz., 13, 17, 18, 19 as well as 8 wards viz., 8, 9, 10, 11, 12, 14, 15, 16 respectively while the municipal committee controlled the region- I and IV which took care of 5 wards viz., 1,20,21,22,23 and four wards viz., 2,3, 5, 6 respectively. Presently, there are 107 sweepers' posted in the Municipality. The private contractor has controlled 38 (44%) sweepers to take care of region-Il and III and the Municipal committee has engaged 69 (56%) sweepers to see the affairs of cleaning of the road and the street of the region I and IV. It indicates uneven distribution and the paucity of the employees (Khanna, 2019).

Narnaul Municipal Committee has 22 containers, 263 dustbin and waste storage installed at identified points. There is uneven distribution of containers and dustbin in the municipality. There are 4 tractors and two tempo trolleys in the municipality which took three rounds in a week or two for collecting and transporting garbage. In some cases they took round in four week or very irregular in the wards 11, 12 and 13. The municipal committee had been transporting waste through open tractor trolley and tempo, which were being aided manually. The system of manual loading of waste is unhygienic, time consuming and injurious of the health. There is no treatment plant established in the town for proper utilization of solid waste till date (Khanna, 2019).

High amount of solid waste collection is done in the wards 1, 3, 14, 15, 17 and 21 and the low amount collected in the wards 5, 6, 7, 8, 9, 10, 11, 12, 13, 18, 22 and 23 It is done weekly in the wards (1, 2, 3, 5, 7, 9, 17, and 22) where officers, highly educated, and economically sound people inhabited. Where as in the wards 11, 12, and 13 it is done after a gap of four week or irregular occupied by economically week persons and the Scheduled Caste. It should be collected daily otherwise it will be unhygienic for dwellers. The solid waste disposal is high in five wards, viz., 1, 3, 5, 14 and 17 and the lowest amount in 14 wards viz., 4, 5, 6, 7, 8, 9,10, 11, 12, 13, 18,20,22, and 23. There are 6 wards viz., 1, 5, 14, 16, 17 and 19 where high amount of solid waste remained for disposal every day in the area under study. It reflects that Municipality is not in a position to dispose off total collected solid waste every day. The remaining waste / garbage accumulated and produced various types of diseases in the town (Khanna, 2019).

In order to dispose off the garbage, municipal committee of Narnaul have five land-fill sites, namely, Taliya Wali Johad near Telephone exchange, Near Ravidas Mandir, Mohalia Bas Ka Johad, Near Stadium, and Sobha Sager tank. These sites were originally pond, low lying area and swampy areas which are getting reclaimed and fill up through continuous dumping of town waste. These dumping areas are not fenced and very poorly maintained. If these maintained properly, the content of waste (largely biodegradable matter) through which fertilizers may be generated that contribute to a larger source of income to the municipal committee. But now

the waste has a large proportion of plastic. It cannot be useful if it is not used properly. An amount of 26 tones solid waste including 8 tones (30.77%) from domestic area and 18 tonnes (69.23%) from non-domestic area generates per day from many sources. Out of which 20 tones (77%) waste collected and 18 tones disposed off and the remaining waste left out at the collected sites, which create environmental pollution. Out of total 20 tones collected waste materials, only 5 tones (28%) wastes are disposed off from domestic area. There are some places where dustbins are installed but they are not use properly where as some places are badly required but they are not installed. Hence, the usual way of disposing the waste wrapped in coloured poly bags by the people used to throw their waste from long distance toward the dustbins. This had led to gathering of waste around the bins. As the lifting of waste is irregular, it keeps accumulating, and keeping one away from utilizing the dustbins. However, it is observed that garbage is scattered everywhere other than the dustbins. There is no regular maintenance of dustbins in terms of lifting of garbage and cleaning the surrounding area. Due to weak financial position, the committee is not in a position to provide sufficient number of dustbins to store at all localities that is why people throw solid waste on the street. Sweepers clean the allotted beats one time a day and dispose the waste in the municipal containers. The overflowing dustbins invite stray cattle's leading to more messing up of the waste (Khanna, 2019).

The municipal employees go from house to house and bring the garbage, but they throw the garbage in the open. This pollutes the air and also eclipses the beauty of the city. The municipality has no place for dumping. The employees dump garbage in the open forest. This garbage is scattered when the storm comes. There is so much smell in the garbage that people have to pass by with their hands on their mouths (Khanna, 2019).

Due to the absence of solid waste management plants in the city, municipal employees are dumping garbage in the open, which is causing damage to the environment. The national green tribunal had ordered the setting up of a solid waste management plant two years ago. Though, work on the plant at Narnaul has already started (Khanna, 2019).

After the solid waste management plant is installed, this garbage will become gold. This will earn the municipality lakhs of rupees per year. After disposal, plastic, iron, rode and other wastes can be sold separately. Garbage lying around the city today will become a source of income for the municipality (Khanna, 2019).

In the annual sanitation survey of solid waste management plant, there are different marks. These numbers have a considerable impact in the hygiene rankings. Due to the absence of solid waste management plant, the city lagged behind in the cleanliness rankings. In 2020-21, the cleanliness ranking of Mahendragarh had been declining at the state and zonal levels (Khanna, 2019).

5. PROPOSED DOMESTIC WASTE MANAGEMENT SYSTEM IN NARNAUL CITY

Municipal Committee should have a comprehensive plan for solid waste management. It should be well equipped to collect waste, transport at disposal points on regular basis. In addition, let's take a closer look at some of the ways that technology is innovating in the waste management sector (Srivastava et al., 2005).

- New sensors can let Narnaul Municipal Corporation know that public waste bins are full and need to be serviced. New types of screening technology can sort through recyclables quickly and efficiently, which takes the work out of the hands of consumers and encourage higher recycling rates.
- It is observed that present tractor trolley vehicles are used for collecting and transporting of waste from various bins. The dumper container can also be used for collection of waste. This would reduce cost of collection and faster's transportation of waste besides reducing environment hazards.
- Some technology can help Narnaul Municipal Corporation to optimize routes and improve efficiency of their waste collection vehicles. Advanced software has made it easier to plan out routes that can efficiently guide waste collecting trucks. This not only makes it easier to collect the waste and recycling materials that need to be collected. It also makes collection more fuel-efficient and reduces energy usage.
- To maintain the environment hygiene around the waste collection bins, container and disposal sites should be maintained by using modem methods of disposal; such as sanitary land filling, preparation of compost pulverization etc.
- There should be proper maintenance and supervision of landfills sites.
- There is an urgent need for encouraging NGOs, local representative and private participants to educate the people of various aspects of health diseases from solid waste. However, sufficient care should also be exercised in identifying and awarding the contract to genuine NGOs / Contractors.
- The waste recycle is not popular in this area. A recycling sector in the city can be very well functioned from the starting point - door to door waste collector, rag pickers and middlemen - to the manufacturers of the consumer products and citizen without much support from the Municipal body or the State Government. It should be promoted through establishing formal and informal waste collection and processing sectors in the city.
- So many products and industries require the use of precious metals. Because these minerals are so useful, they can be rather expensive. These materials, which include platinum, palladium, and iridium, can be used

as catalysts in a wide variety of industries, including the automotive and chemical sectors. New methodologies like plasma arc recycling can help Narnaul city meet rising demands for these materials. This tech can recover a vast majority of the platinum metal found in a vehicle or other object by using a super-hot plasma torch. Instead of mining for new ore, we can just reuse these materials and give them a second life.

- One of the biggest innovations coming to the waste management industry is the ability to turn waste into actual power. Instead of sitting in a landfill, certain types of waste can simply be converted into energy. New machinery known as "digesters" can take the waste and the biogas it produces and turn it into energy that can be used on site. This kind of technology can be used on a variety of waste, including food, animal waste, agricultural leftovers, and more. Thermal conversion is another new technology that can be used to convert waste into specialty products. This process takes some cues from natural geothermal processes that use heat and pressure to turn useless materials into useful products. It could be used to turn waste into chemicals, fertilizes, oils, and other things that could give your waste another life. Some landfill gas can even be converted into energy. This kind of gas would normally be released or flared, but now it can be turned into energy with the aid of some new technology. Bioreactors, microturbine technology, and even fuel cells can now be used to do something useful with waste.

6. CONCLUSION

The waste management system in Narnaul, or even the entire India for that matter, is in a critical state, as local bodies have largely failed to manage solid waste efficiently. Being heavily dependent on the state governments for funding, these local bodies lack the resources to acquire new land or obtain the technologies required for waste management. Moreover, waster pickers, who are key workers in the industry, lack legal status and protection, and are hardly effective or capable of enforcing systems in the collection and segregation of waste. For the situation to improve, institutional and financial issues must be addressed on priority. While the 2016 SWM Rules do address a significant number of issues, compliance remains weak. A policy paper or action plan must be prepared to promote the decentralisation of the waste management system. To enhance the efficiency of waste management in India, citizen participation should be promoted, especially in source segregation and treatment processes. The policy agenda for sustainable waste management must drive behavioural change amongst citizens, elected representatives and decision-makers, Secondary data to minimise wastage and littering, and increase reuse and recycling. Community awareness and a change in people's attitudes towards solid waste and their disposal can go a long way in improving India's waste management system.

In an era of rapid urbanization and population growth, solid waste management is critical for sustainable, healthy, and inclusive cities and communities. If no action is taken, the world will be on a dangerous path to more waste and overwhelming pollution. Lives, livelihoods, and the environment would pay an even higher price than they are today. Many solutions already exist to reverse that trend. What is needed is urgent action at all levels of society. The time for action is now.

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