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# Handling Solid Waste using Design Thinking Principle in Bengaluru

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**Abstract:- The issue of waste production and management has taken a toll on municipal corporations around the world. This paper quotes some problems faced, especially in developing countries. The city of Bengaluru in India has been the subject of this study where the application of design thinking for solid waste management is proposed. A step by step procedure has been explicated in order to tackle the production of waste and its mitigation with smart thinking and planning. On a side note, since the solid waste from major developing cities reach into the ocean via a network of rivers, a method of cleaning the oceans (to reverse the damage already done) has also been elucidated. A conclusion is drawn at the end, stating the future scope of this research and ways of extending it to other big and small townships across the globe.**

***Keywords***:- *Design Thinking, Bengaluru, Solid Waste, Management.*

## I. INTRODUCTION

Municipal solid waste is a waste type consisting of everyday items (that may be solid or liquid in nature) which are discarded or rejected on account of being spent, useless, worthless, or in excess. Waste produced needs managed so that it does not create problem for the public. The techniques around the world have changed drastically from manual picking of waste by designated individuals to automatic waste collection using high-tech machines. Solid waste can be of many types based on which the method of its disposal is decided. Solid waste can be characterized based on character and content as organic and inorganic. Then the waste can be homogenous or heterogeneous based on the source of its generation. If the waste is generated in houses and/or industries, it is categorized as heterogeneous. If the waste is generated by farms and mines that are located in urban or rural areas, it is said to be homogenous in nature.

Special care and attention should be given while handling hazardous wastes, which can further be subcategorized into medical and chemical waste. Here hazardous waste refers to the waste that might be harmful for humans and environment in general.

**I.**

➢ *Acronyms Used*

- **BBMP**: Bruhat Bengaluru Mahanagara Palike (Municipal Corporation of Bengaluru)
- **MSW**: Municipal Solid Waste
- **IoT**: Internet of Things
- **SWM**: Solid Waste Management
- **GOI:** Government of India
- **RDF:** Refuse-Derived Fuel
- **USW:** Urban Solid Waste

## II. METHODOLOGY ADOPTED

Design thinking is a solution based approach to solving problems by cognitive, strategic and practical processes. According to Tim Brown, it is a non-linear problem solving method that allows an end-user empathic approach by integrating observation phases, Creativity, prototyping, testing, iteratively [1].

This paper has adopted the following stages in order to implement design thinking procedure: Empathise, Define, Ideate, Prototype and Test. Only the first three stages have been emphasised here.

❖ *Stage 1: Empathise*

In order to empathise, a literature survey of available documentation and publication was done via Internet. The stake holders and authorities involved in the waste management such as BBMP was consulted. Various websites and review papers were also analysed in order to form the following problem statements.

Various loopholes in the existing system of waste disposal and treatment were found [2]. They have been listed as follows:

➢ *Landfilling*

Most of the MSW in locality of major cities and town are being disposed of on common grounds and lands in an improper manner. Also, in major metropolitan cities a common practice is to dump the waste in poorly managed dumping ground that gives rise to serious environmental problems. In coastal regions dumping activity has led to increase in heavy metal concentration in the coastal region. The expanding population and demand for construction of

buildings tends to decrease the isolated/ faraway land available as dumping grounds. In urban centres, MSWs are disposed of by depositing it in low-lying areas in city outskirts with lack of proper principles of sanitary landfilling in place.

➢ *Recycling of Organic Waste*

Organic matter has a tendency to decompose on its own even if it is left unattended. But if left in open to decompose, it gives of foul odour and becomes breeding ground for insects and rodents. These insects and rodents turn out to be carriers of deadly diseases creating severe health problems.

*1. Aerobic composting*

Bacterial conversion of MSW in the presence of air and moist conditions is called compost (humus). This compost has very high value in agriculture and increase the yield of the crops. Such conversion can be done either manually or by mechanical means. By using this technique, the amount of waste can be reduced and it varies from 50-85% reduction in waste. Compost can be used as fertilizer which is odour and pathogen free. Earlier Government of India (GOI) encouraged the initiative for MSWM and focused its implementation in urban areas. Later in 1974, GOI introduced a scheme to implement it in cities with more than 0.3 million populations. Large-scale composting plants were setup in cities all around India with capacity varying from 150-300 tonnes/per day. After 1980, composting is not being used for enrichment of soil properties due to its shortcomings and it proved to be unsuccessful. It has also been found that only 9% MSW can be treated by composting.

*2. Vermicomposting*

It is a joint process using both earthworms and microorganisms for decomposition and stabilisation of organic waste. These microbes initially decompose the biodegradable organic matter by extra cellular enzyme activity, followed by consumption of these partially decomposed matter. They are said to consume organic matter five-times their body weight. The cast from worm is fine, odourless and granular and serve as bio fertilizers in agriculture. Some shortcomings of the method are the amount of time consumed; only a specific class of organic waste can be treated and at top of all, it requires large area. If waste is not segregated properly then this process cannot be used.

*3. Anaerobic Composting (Bio Methanation)*

In this process organic waste is buried in pits under partially anaerobic conditions which will are later treated by anaerobic microorganisms that release gases like methane and carbon dioxide and the resulting residual matter is good manure. This process is very slow but can become much faster and commercialized by implications of latest technology. It generates 55-60% methane which can be used directly. As this process is slow and due to the high amount of waste collection in cities every day which is rapidly increasing, this process cannot cope with the status quo. Also this process is specific to only solid organic waste.

## III. THERMAL TECHNIQUES

*1. Incineration*

Incineration is method of destruction used to dispose toxic wastes from hospitals and recover energy for it. It is a process that entails controlled and complete combustion, for burning solid wastes. Temperature of incineration varies from 980°C to 2000°C. The process of incineration reduces volume of waste by 80-90%. But in India, incineration is not much practiced due to following nature of waste: high organic content, high moisture content, high inert content, low calorific value. First incineration plant was opened in New Delhi in India in the year 1987 but the plant was only functional for 6 months and was later forced to shut down due to poor performance.

*2. Gasification*

Gasification is a process of incineration of solid waste under deficient conditions. The main purpose of this method is to produce fuel gas, which would be stored and used when required. Gasification can be used in treatment of MSW after drying and removing the inert and small size substances. About 25% of gas produced can be reused to support the gasification process; the remaining is recovered and used for power generation. Again, it is found that the process in not efficient.

*3. Refuse Derived Fuel (RDF)*

It is a technique used to produce and improve solid fuel or pellets from MSW. An RDF plant was commissioned in Hyderabad in 1999 near Golconda dumping ground with 1000 tonnes/day capacity. The RDF produced is used for power generation. It reduces the pressure on landfills and this process is directly capable of generating power from MSW. The method is a viable replacement to current apparatus of waste treatment but requires a high initial investment.

➢ *Recovery of Recyclable Materials from Open Dumping*

Many materials in MSW like paper, plastic, glass, rubber and non-ferrous metals are suitable for recovery and reuse. The total amount of recyclable objects varies from 13% to 20%. Indian rag pickers play a crucial role in SWM. While making comparisons with other countries, 40-80% plastic waste in India is recyclable whereas in other countries it is only 10-15%. Even though the global recovery rate is increasing, the total waste production is increasing at a faster rate. Also, this a labour intensive work and requires lot of man hours to search the dumping grounds for appropriate plastic waste.

Hence, it was found that the methodology adopted till now has some flaws and lacunas associated with its implementation and application.

❖ *Stage 2: Problem Definition (Define Stage)*

➢ *Amount of Waste Produced*

Bengaluru is one among the largest five cities in India with an estimated population of around 12.3 million (2017). At present only 10% of the waste is recycled. Most of the literature reported that the waste generation rate is 0.4–0.6 kg/capita/day. 0.5 kg/capita/day is proposed as waste generation rate for Bengaluru city [3][4]. Bengaluru wastes have 21.27% of the recyclable materials: paper, polythene, cloth, rubber, glass and metals [5]. Presently, the city employs a quasi-centralized collection system (predominantly open dumping of collected waste). The extent of waste collected ranges from 75-90% of the waste generated. In this way there is a significant level of satisfaction among the citizens for cleanliness thus achieved, albeit occasional lapses at the local level. The primary collection systems transfer the waste to large bins that are directly transported by tippers and dumper placer trucks to locations outside the city.

Bengaluru generates about 6200 - 6400 tonnes of solid waste daily, according to recent data. The BBMP is carrying out collection, street sweeping, transportation, processing and disposal of Municipal Solid Waste from generators. BBMP has a system of door to door collection for collecting the MSW. The MSW collected has to be processed before landfilling. BBMP has taken several steps to streamline the MSW management in the city

➢ *City Statistics*

- Area: 800 sq. km
- Population (estimated): 12.3 million
- Households: 2.5 million
- Commercial Properties: 3.5 million
- No of Zones: 8; No of Wards: 198
- Estimated MSW generation from all sources for BBMP zones: 6200 tonnes/day
- Per capita waste: 350 gm/day (domestic waste)
- Households contribute to ~ 54% percent of the total waste; Markets & function halls contribute to 20% and commercial establishment & institutions contribute to 17% and others 9%
- Segregation of waste at source: 10%

➢ *Effect of MSW*

Most of the waste is dumped in water bodies results in pollution of rivers and lakes leading to increased toxicity of the water. An estimated 400-600 million litres of untreated sewage are let into the lake catchment every day.

In a study regarding the check on water quality, 2209 groundwater samples were analysed, covering the entire city area and analysed. Nitrate content is in excess, that is above the permissible limit in 29% of the samples, iron in 10%, and total hardness in 8.5% and fluoride in 0.6% of the samples. After accounting for samples in which more than one parameter was beyond permissible limits, it was concluded that 31% of the groundwater samples were not up to drinking water standards**.**

A health survey done by environmental support group team near the landfill areas of Bengaluru. It was discovered that with regard to children there is a very high incidence of respiratory disorders (like frequent cough), Bronchopneumonia, Meningitis, Skin infections (fungal) and susceptibility to vector borne diseases (Dengue) and also widespread viral fever. In addition, developmental malformations were noticed.

In the case of women, several reported constant headaches, skin infections, respiratory disorders, and menstrual disorders. In addition, diabetes mellitus was observed in many cases. Similarly, menstrual and skeleto-muscular disorder were common. There were also several cases where Hysterectomy (uterus removal surgery) had been performed. Besides, there were instances of Lung Cancer, Kidney Failure, and the rare Fatty Liver condition. Vector borne diseases like Dengue, Chickungunya and other psychosomatic disorder were also observed in the inhabitants of the area.

The men were also found to have Skin Infection, Respiratory Disorders, Diabetes Mellitus, Oesophagus Cancer, Kidney Failure, Cardiac Arrest, Vector borne diseases like Dengue and other psychosomatic disorder.

➢ *Transportation of Waste*

About 670 MSW transportation vehicles including 240 Compactors, & 430 Tipper Lorries, Dumper placers & Mechanical Sweepers both of BBMP and contractors are used for transportation of MSW to the processing and landfill sites.

Transportation of waste has to be managed to collect the waste from following sources:

- Residential homes- Garbage trucks are scheduled to collect waste through door to door services
- Community bins- regulating the transportation of waste through bins has to be made much more frequent
- Self-delivered or Contracted/delegated service- These waste collections are usually transported by the collector itself. The collector can be the producer of waste or rag dealers or several start-ups that are emerging rapidly to solve the city crisis

❖ *Stage 3: Ideation*

Four different concepts for improving the waste management have been identified; Integrated Solid Waste Management, Integration of the informal sector, Private Public Partnerships and Decentralization [6]. Some

techniques in lines of these concepts have been elucidated here in detail.

1. *Waste sorting-*

Solid waste can be segregated by using mechanical means at the source and at the landfills. This waste can be segregated via mechanical means by a mechanical sorter or magnetic sorter.

A US patent no. 4,660,758 explains the design of a separator-receptacle for holding waste products.

2. *Resource Recovery*

Curb side collection is the best way to combat resource recovery. Bins can be separated for three types: one for recycling, second for general waste and another for garden material. Paper waste can be segregated into boxes or bags for further recycling. If the curb side collection is organized, resource recovery can be done easily incorporating recycling techniques [5].

3. *Direct waste transportation system from homes*

For new cities and townships that are built, a network of garbage collection pipelines can be established, removing the garbage trucks entirely from the street. The terminals of these waste collection pipelines will be at the houses and the collection centre. It will just not be limited to houses and offices, other public places will also be connected to the same.

a. A suction system will be in place wherein the garbage will be sucked in from end (the collection centre)
b. The user of the system can put the garbage at the other terminal (the source).
c. There will be sub terminals that will be used to clean and remove the waste that gets stuck during the entire process.

4. *The disposal plastic is one of the biggest issues in our country right now; it clogs the sewage lines, being non-biodegradable and stays in the environment for a long time.*

a. New government law should mandate the use of biodegradable plastic ha
b. Usage of biodegradable polymers can prove to be helpful in this regard. Biodegradable polymers like *Poly*(3-*hydroxybutyrate-co*-3-*hydroxyvalerate*) or commonly known as PHBV and nylon 2-nylon 6 can be used.
c. Enzymatic biodegradation of the plastics is also a viable option wherein the plastic is injected with a certain culture of microorganisms to degrade it. Examples of such microbes are*: Burkholderia xenovorans LB400* and *Rhodococcus sp. strain RHA1*

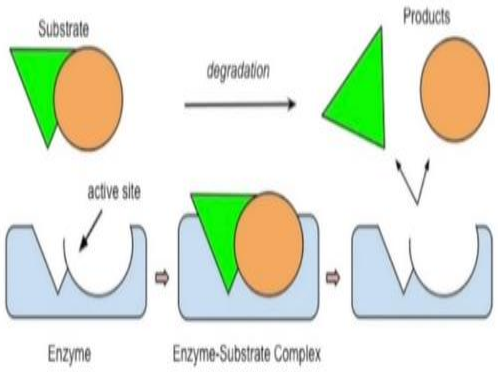


Fig 1:- Mechanism of enzymatic breakdown

5. *Existing state of operation: Cleaning up of oceans*

a) A huge ocean cleaning program is in place where countries around the world have joined hands to clean up the solid waste from oceans.
b) They have different methodologies of working and operation. Most of them are trying to catch hold of waste physically
c) Other proposed methodologies:
i. Usage of microbes that degrade the plastic into some other simpler organic compound
ii. This will ensure that the leached particles that have been dissolved in the water are also consumed and it no longer is a harm to the aquatic life in the region.
d) Since India has the largest coastline in South East Asia, it also becomes one of the largest contributor to waste in seas.
a. The above methods can be extended to Indian subcontinent for cleaning up of seas and oceans
b. The landfills should not be set up near coastal areas, they should be at great distance from any water body to avoid the problems of leaching.

6. *Innovation for the garbage dumps (an implication of IoT):*

a) As the garbage dump gets filled, the IoT device sends a notification to the nearest local municipal corporation.
b) The time for which the garbage dump is full, an auxiliary garbage collection box opens up, which can collect the waste meanwhile the garbage truck comes and collects the waste

7. *Induction of biodegradable plastics at a very cheap rate:*

This will drive out the non-biodegradable plastic manufacturers from the market creating space for new innovation and new types of plastic in a market

## IV. CONCLUSION

Bengaluru has been the home of the first effort to change policy on solid waste management and therefore has been the key to various society driven experiments to ameliorate the environmental and societal impacts of USW management in cities [7].

This paper has analysed the various methods of treatment of waste by design thinking principles. It has been found that solid waste is a rampant issue in developing nations such as India especially at places where there is dense population (i.e. a large population residing in a small area per person in comparison to other parts of the country and the world). By dissecting the various review papers on this topic of solid waste management, it was found that the developing nations face the extremum of the issue whereas the developed nations are able to cope up with them. The ways to cope up with the waste production, management and disposal is elucidated. Some innovation has also been proposed. A rigorous analysis is to be done in order to perform the functional feasibility of the said innovations.

If they are found to be successful, the implementation of the next stages of design thinking that is prototyping and testing can be done.

## FUTURE SCOPE

The proposed model of design thinking can be extended and utilized to other places across the globe. However, the situation on ground at different geographical arena will vary on account of number of factors like population, economy, education level, administration, waste management history, infrastructure available, geographical factors, kind of waste produced and the amount of waste produced per capita. A rigorous analysis has to be done in order to extend the proposed model to other regions. The methodology proposed for the same is as follows:

1. The geographical area must be identified wherein the solid waste management needs to be done.
2. The available resources are mapped and an inventory of the same is prepared.
3. The history of solid waste management strategies adopted before must be analysed and the shortcomings pertaining to it should be documented.
4. A dry run of the design thinking principle is done on paper and shortcomings that might come should be analysed and tackled with.
5. Finally, the design thinking principle is applied over the geographical area and the results are obtained and examined in intervals of months and years.
6. Continuous improvements have to be made to keep the model viable.

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