Solutions of Landfills: WTEs or Circular Economy

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Abstract- **The growth in consumption economy world over has led to huge generation of waste and the disposal of this waste is one of the biggest challenges in the cities. Increase in consumption is also due to increase in population, urbanization and industrialization. Mass production due to industrialization has led to increased consumerism and therefore the demand for goods and materials has increased exponentially. The waste generated is often dumped into landfills has to be managed and therefore the landfills although an eyesore in city landscape have rapidly developed in cities.**

Options for management of solid Municipal waste include (1) incineration of MSW in boilers WHRBs (waste heat recovery boilers). These burn RDF (Refuse dry fuel) to produce steam which in turn drives a steam turbine to produce electricity or (2) total recycling of wastes back of same quality into nature to manage natural resources efficiently by a concept termed circular economy.

***Index terms*:** **MSW (municipal solid waste), WHRBs (waste heat recovery boilers), WTE (waste to energy), PCC (pre-cast concrete), PVC (poly vinyl chloride), Leachates, Circular economy, Landfills, dry, wet, C&D (construction & demolition) waste, RDF (refuse dry fuel), Dioxins, Furans, GHG (greenhouse gases)**

I. INTRODUCTION

World Bank report of 2016 estimates that world generated 2.01 billion tons of waste which is projected to increase to 3.4 billion tons by 2050 representing an increase of almost 70% in 30 years.

Number of studies have been conducted by (CPCB) Central Pollution Control Board to know the composition and amount of MSW generated in the country .A 2010-11 report by (CIPET) Central Institute of Plastics Engineering and Technology conducted a study at the behest of CPCB estimated that 59 cities in India generated 50,592 TPD (tons/day) of MSW, and in a later study of 34 cities and UTs conducted by CPCB reported amount of MSW generated as 1,43,449 TPD at an average of 0.11 kg/capita/day, further studies indicate that average MSW generated in kg/capita/day depended on population and per capita income and affluence of cities with figures of 0.4-0.6 kg/capita/day for cities having population above 10 lacs and 0.35-0.4 kg/capita/ day for cities with population of 5- 10 lacs and 0.3-0.35 kg/capita/day in cities with population 2-5 lacs and 0.2-0.3 in cities having population < 2 lacs

Another World Bank report 2018 puts India's per capita waste generation at 0.5kg/day as compared to world's average of 0.7 kg/day, World Bank also underlines the connection between the economic development and waste generation underlining that the fast growth of Indian economy in the coming decades shall lead to increase in waste generation

India's capital city Delhi generates everyday about 8500 TPD of trash which is sent to landfill sites Ghazipur, Bhalswa and Okhla for disposal. These are running out of space with the permissible limit of 20 m height, Ghazipur and Bhalswa have garbage mounds as high as Qutub Minar. These old landfill sites are not designed as per schedule 3 of MSW rules of 2000 as they were commissioned before year 2000 and therefore are not scientifically engineered and designed as the later modern sanitary landfill designs (that have leachate collection and disposal system) and since the trash is in direct contact with soil below in old landfill sites the leachates containing acids and heavy metals are able to percolate the soil and contaminate underground aquifers ,also the combustible gas methane generated keeps the trash burning releasing toxic furans and dioxins in the air and causing air pollution .They are also emitters of greenhouse gases like methane which is 84 times more potent GHG on a 20 year time compared to carbon dioxide.

Even the modern sanitary landfill design which incorporate leachate collection and disposal system with compacted clay layer at the base of landfill and a HDPE layer on top of that geosynthetic clay liner which is used to create an impermeable barrier do not guarantee that leakages won't happen. Besides the problems of soil and water pollution landfills also generate toxic gases like dioxins and furans due to various reactions of aerobic, anaerobic decomposition and fermentation leading to production of volatile organic acids and GHG gases like $CO_2$and methane (CH_4). The open landfills results in pollution in the air, land and water, due to bacteria and insects inside the tons of dumped garbage[4]

So then what are the preferred options for management of solid Municipal waste so that they don't end up in landfills a source of soil water and air pollution?

Recycling of garbage processing to create new products is one of them and requires segregation at the source of collection. Instances where recovery of material for reprocessing is not feasible then this waste can be burnt or incinerated in boilers WHRBs or waste heat recovery boilers) These burn RDF (Refuse dry fuel) to produce steam which in turn drives a steam turbine to produce electricity.

SMW is a type of biomass which mainly consists of food waste, paper, plastics, wood, textiles, metals, and glass[5]. RDF is the residual dry combustible fraction processed from incoming SMW (Solid municipal waste) and mainly consists of combustible fraction of MSW and includes materials like non-recyclable plastic, cloth jute, packaging material, leather, rubber, paper, coconut shells etc. Besides polymers also constitute a substantial part of MSW.

Polyethylene (PE), which is a polymer is further divided into two parts, the high-density polyethylene (HDPE) and low-density polyethylene. (LDPE), polypropylene (PP), polyethylene terephthalate (PET), polystyrene (PS) and polyvinylchloride (PVC) are the six main plastics found in MSW[8]

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Waste can be burnt in three ways incineration, pyrolysis and gasification where organic matter is burnt at different operating temperatures and under different oxygen supply conditions with different end products.

Whereas pyrolysis involves heating in absence of oxygen, its modern version plasma pyrolysis sets up a high temperature torch at 1000℃ for thermal degradation of biomass and plastic waste efficiently in a eco-friendly manner into combustible gases. Oxygen which mainly enters through condenser is expelled by use of nitrogen; however plastics like PVC and polyethylene are not burnt in pyrolysis as they produce chlorine and hydrochloric acid which attack the metallic parts of the reactor, absence of oxygen helps to prevent corrosion.

Gasification of MSW is burning or its partial oxidation in limited supply of oxygen at 700 to 900 ℃ with end product as syn gas which can be used as a fuel .Advantage of gasifying MSW is that emission standards can be met effectively to minimize environmental impacts however the disadvantage of gasifying MSW is that in India MSW has high moisture content (up to 45%) due to high amount of kitchen wastes, the amount of energy needed to dry RDF is more which results in lower energy and yields of syn gas .The gasification of MSW can be represented with the following sub-stoichiometric equation:

$$\text{Biomass (MSW) + Limited Air} \rightarrow CO + H_2 + CH_4 + H_2O + N_2 + CO_2$$

For the complete combustion of dry bone (with 0% moisture) MSW biomass the stoichiometric air: Fuel ratio is 4.5:1, in gasification a fraction of this ratio (25%) called the equivalence ratio (ER) is used. Thus gasification with ER of 0.25 requires 1.1 times by weight air than fuel to allow partial oxidation of biomass fuel.

Incineration of RDF obtained from MSW processing involves the combustion of organic substance at high temperature[7] producing bottom ash and fly ash as by-products.

Incineration is the combustion of MSW at high temperatures greater than 1000 ℃ with end products fly ash and bottom ash along with formation of NO_X . Materials like (PVC) polyvinyl chloride a plastic containing 90% chlorine content[6] has to be separated from trash before incineration as it forms toxic volatile organic compounds like polychlorinated di-benzo-p-dioxin/-furans (PCDD/Fs) , polychlorinated biphenyls (PCBs) besides poly-aromatic hydrocarbons (PAH) and other toxic heavy metals are also released by incineration which have very adverse health and environmental effects.

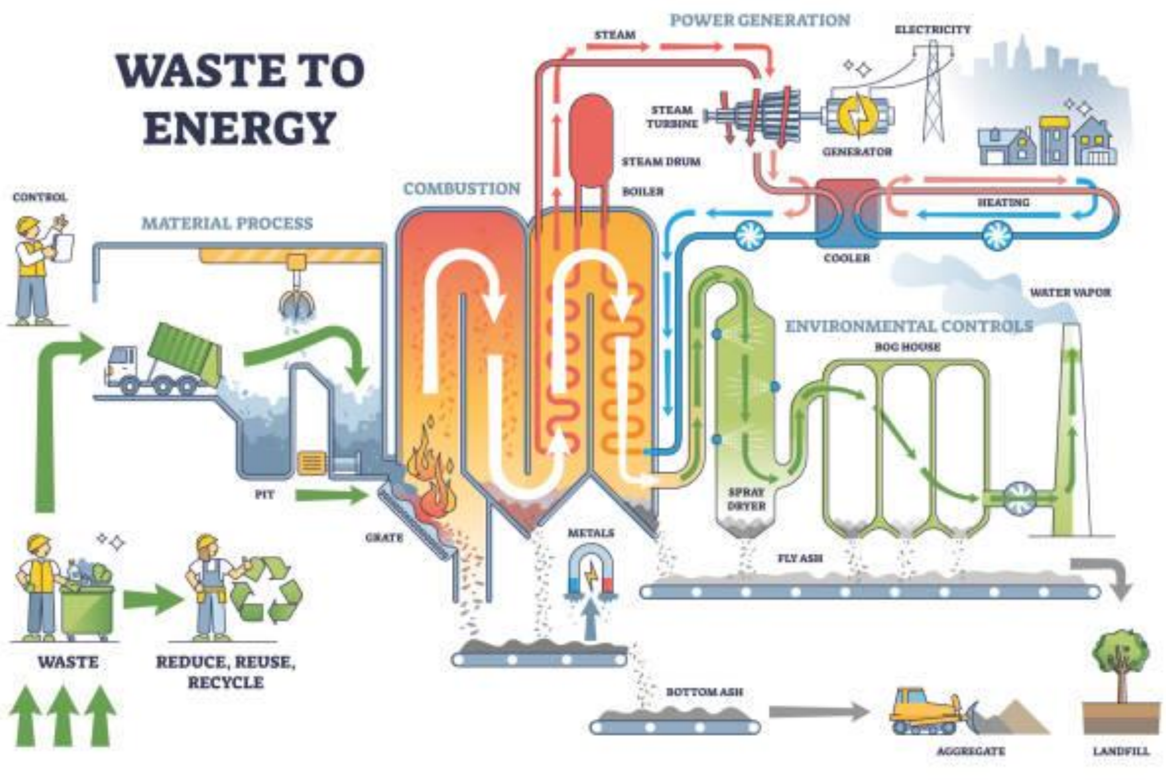
Polyethylene (PE), which is further divided into high-density polyethylene (HDPE) and low-density polyethylene (LDPE), polypropylene (PP), polyethylene terephthalate (PET), polystyrene (PS) and polyvinylchloride (PVC) are the six main plastics found in MSW[8]

Incineration can be seen as waste treatment process in which combustion of RDF obtained after processing MSW is carried out at very high temperatures in the presence of oxygen resulting in the production of bottom ash, fly ash, flue gas and heat.

WTEs or waste to energy plants deploy incineration or combustion of RDF at high temperatures >1200-1300 C in the presence of oxygen to produce bottom ash fly, ash, flue gas and heat. Incineration when carried out in such integrated system where RDF is burnt in WHRBs (Waste heat recovery boilers) where hot flue gas at temperatures exceeding 900 ℃ enters from bottom of WHRB and rise to exit from stack above transferring its heat across to water being carried in finned steel pipes to produce steam which is then used to drive a steam turbine connected to a generator to produce electricity. Generation in WTEs depend upon the moisture content and composition of RDF and about 65 to 80% of energy content of the organic matter can be recovered as heat in waste heat recovery boilers (WHRBs).

The important thing about WTEs to operate economically is that the input RDF must have a caloric value of at least 1500 KCAL/Kg .If the incoming RDF has a lower value lower than this additional supplementary fuel is used to sustain the flame in the boiler this makes the entire process uneconomical. This is the reason most WTEs are shut down after operating for few months or years.

Then there are problems from the people living around these WTE plants for instance Okhla WT plant which is situated in the middle of the residential area received a notice from (MoEF&CC), Ministry of environment forest and climate change ,Timarpur-Okhla WTE emission monitoring showed that dioxins and furans exceeded the permissible limits also the residents of the area demand the closure and shifting of the plant due to pollution as residents in the area do not want a polluting WTE plant nearby their homes.



Schematic of Waste-to-Energy plant showing the incineration of municipal solid waste

The main issue in WTEs is the emission of dioxins and furans which are formed in the presence of fly ash generated during incineration, fly ash acts as a catalyst for de novo synthesis at 250℃ so fly ash is removed by ESPs electrostatic precipitators having efficiency as high as 99%, thus emissions of dioxins and furans is prevented by keeping boiler temperature > 1200-1300℃. WTEs are in vogue as they help us to reduce landfill area by 95% .This is important as a planning commission report projects that waste generated shall reach 165 MT by 2031 in India and land required for landfills would be 66,000 hectares at 10 m high waste pile.

However, for sustainable development and protection of the environment economic activities should have climate consciousness. It is in this context the concept of circular economy becomes relevant today. A typical linear economy approach involves consumption of raw materials to make product and after its useful life discard as waste or the “take- make- waste" approach, circular economy on the contrary depends on recycling of the waste materials in such a way that they are converted back to their original form and quality, It thus minimizes the consumption of raw materials and thus stresses on efficient use of natural resources.

Circular economy is also central to the Atma Nirbhar Bharat and Swachh Bharat mission launched by Hon'ble PM Shri Narendra Modi in October 2014 which lay stress on sustainable waste management for optimum utilization of resources adopting scientific approach and technology.

Let us evaluate whether the transition of MSW from linear to a circular economy helps us in reducing the generation hazardous components of waste for instance whether a circular economy helps us in tackling the issue of microplastics in the oceans.

MSW is categorized under (1) Dry waste (2) Wet waste and (3) Construction and Demolition waste

Dry waste: It is that part of MSW which has maximum recyclables of economic value. Of the total MSW 35% is approximately dry waste it comprises of components such as metals, ceramics, tyres, paper, plastics, thermocol ,textiles, glass etc. Plastic Recycling in India 3 times global average and is expected to grow three times from the current levels. Rag pickers in informal sector of India recycle majority of the plastic waste .Plastics when dumped in oceans leach as microplastics and these enter our food chain through salt which is obtained by drying sea water. These microplastics are carcinogenic as they enter blood stream and being nano/micro sized disturbs the cellular chemistry. Plastic recycling is therefore the most important part of the MSW. Virgin plastic can be recycled up three times after which it loses its life and quality.

Various grades of plastic are found in trash mainly PET bottles and HDPE which are recycled easily. PVC is difficult to recycle. A good example is plastic recovered from garbage can be used to make plastic blocks which can be used to make roads these have a three times longer life compared to asphalt roads and are easy to maintain and repair as the faulty block can be replaced with a new one whereas the old one can be reprocessed again. Tetra packs commonly used in packaging have 3 layers comprising 75% paper 20% polyester and 5% aluminium are costly and difficult to recycle .

Recycling of Glass: 45% of glass that is aggregate in trash is recycled. Textile waste: As per McArthur report globally textile waste has increased in the last 15 years due to production and consumption of clothes having doubled and their time of the usage decreased by 40% as population and urbanization has increased .India discards about 1 million tons of textile yearly and about 25% is recycled or reused.

Rubber and tyres: Of the 6.5 lakh tyres produced daily in India about 2.75 lakhs are discarded every day and end up in landfills these can be recycled and used in roads along with asphalt and in making of rubberised roads.

Recycling coconut waste: India produces 72% of coconuts in the world it is special significance in our culture and it is used in temples, recycling of coconut shells and shredding is done to make jute.

Wet waste: It is that part of MSW which is biodegradable and includes kitchen waste, fruit and flower waste and falling leaves etc. It starts to decompose almost immediately as it is highly biodegradable and is acted by microorganisms that break it down into simple organic matter, rate of biodegradation is also affected by factors like temperature moisture etc. Wet waste has to be disposed properly and if it is dumped in landfills then it decomposes to form volatile organic acids and causing leaching of harmful metals and substances into leachates which then percolate into soil and contaminate the underground aquifers, also upon decomposition these are a source of GHG gases like $CO_2$and CH_4 therefore it is important that the wet waste is not dumped into landfills but it undergoes a controlled processing upon its arrival. Wet waste is biodegraded mainly by two methods (a) composting which is aerobic biodegradation process and (b) Biomethanation which is anaerobic process.

Composting requires larger land area and also is prone emit odours besides takes longer time to biodegrade then biomethanation. The products of biomethanation and composting can be used as manure and fertilizer.

The main challenge in tackling wet waste is its segregation at source. Improper segregation of wet part of MSW reduces the processing efficiency.

Construction and demolition waste: Percentage of C&D waste in a MSW generally ranges from 10 to 25% ,proper recycling of C&D waste helps in reducing air pollution by suppressing the generation of dust besides conserving resources ,the bulk of construction and demolition waste comes from waste construction surplus and rubble coming from demolition of buildings. It comprises mainly of cement ,concrete, soil, Steel, GI pipes, wood, plastic,(Bakelite, wire insulation, plastic switches**)** concrete, bricks, etc. India on an average generates about 12 million tons area of C&D waste every year with 95% potential of recycling.

C&D wastes are often dumped along roadsides and In open spaces adding to air pollution and if dumped in drains cause their chocking leading to flooding during rainy seasons .C&D wastes can be recycled thus saving natural resources besides preventing traffic congestion issues due to their dumping along roadsides. It also saves space at landfill sites. C&D waste management site in India was started by MCD in 2009 in collaboration with IL&FS Environmental Infrastructure and Services Ltd with a capacity of processing 500 TPD of C&D waste at Burari Jahangirpuri, Delhi. It involves collection and transportation of C&D waste to the processing facility where metal, plastics, glass, fibres, gypsum are segregated manually or by normal or trommel machines and is then crushed to get desired range of product. C&D waste is recycled to make paver blocks and PCC products such as pavement tiles, curbstones besides being used in filling road sub-base. Government of Delhi NCT has granted exemption of VAT as an incentive for using tiles and curbstones made from C&D waste.

CONCLUSION

We have seen that landfills which are the common landscape in today's cities are beset with great disadvantages of tackling the problem of percolation of leachates into soil and thus contaminating the underground aquifers and water bodies besides generating GHG gases and obnoxious odours, even the modern engineered and designed sanitary landfills do not guarantee the leakage of leachates after the garbage mound is piled up. Landfills require lot of expensive land in cities and their breeding of insect vectors and bad odours from release of H_2S from decomposing MSW are a source of great nuisance for neighbourhoods. Although WTEs reduce the load on landfill sites by 95%, but they are also prone to pollutant emissions from their boiler outlet stacks which are again a great irritant for neighbourhoods, besides they require RDF having calorific value minimum 1500 kcal/kg otherwise they require additional fuel firing which makes the power generation expensive. WTEs also require heavy investments and skilled manpower and latest technologies to keep emissions below the normal specified limits.

For sustainable development with climate consciousness concept of circular economy provides us a scientific and technologically feasible approach to deal with handling of solid municipal waste under three sub categories of dry, wet, and C&D wastes. Besides total recycling circular economy helps us in eliminating waste, avoiding landfills and WTEs, making efficient use of natural resources decreasing pollution of soil, water and air. Waste management by circular economy focuses on turning waste into resources and shall become the key partner in upcoming waste management business models.

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