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A Review : Sustainability from Waste

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ABSTRACT

The increasing volume and complexity of waste associated with the modern economy as due to the ranging population, is posing a serious risk to ecosystems and human health. Every year, an estimated 11.2 billion tonnes of solid waste is collected worldwide and decay of the organic proportion of solid waste is contributing about 5 per cent of global greenhouse gas emissions (UNEP). Poor waste management - ranging from non-existing collection systems to ineffective disposal causes air pollution, water and soil contamination. Open and unsanitary landfills contribute to contamination of drinking water and can cause infection and transmit diseases. The dispersal of debris pollutes ecosystems and dangerous substances from waste or garbage puts a strain on the health of urban dwellers and the environment. India, being second most populated country of the world that too with the lesser land area comparatively, faces major environmental challenges associated with waste generation and inadequate waste collection, transport, treatment and disposal. Population explosion, coupled with improved life style of people, results in increased generation of solid wastes in urban as well as rural areas of the country. The challenges and barriers are significant, but so are the opportunities. A priority is to move from reliance on waste dumps that offer no environmental protection, to waste management systems that retain useful resources within the economy [2]. Waste segregation at source and use of specialized waste processing facilities to separate recyclable materials has a key role. Disposal of residual waste after extraction of material resources needs engineered landfill sites and/or investment in waste-to-energy facilities. This study focusses on the minimization of the waste and gives the brief about the various initiations for proper waste management system. Hence moving towards the alternatives is the way to deal with these basic problems. This paper outlines various advances in the area of waste management. It focuses on current practices related to waste management initiatives taken by India. The purpose of this article put a light on various initiatives in the country and locates the scope for improvement in the management of waste which will also clean up the unemployment.

Keywords : Solid Waste Management, Sustainable Development, Waste to Energy, Landfill

I. INTRODUCTION

Solid Waste Management in Indian cities has emerged as a major concern over the past few years. The rise in urban population and economic growth in the absence of an effective management mechanism has manifested in the current state of solid waste management in Indian cities. Given the present situation, the quantum of waste generated in cities especially larger ones with higher population is expected to increase. Greater attention needs to be focused towards devising appropriate and effective mechanisms for waste treatment and disposal in urban centers.

Theper capitasolidwastegenerationinfewIndiancities:

Table:1 City Waste Generation rates

Cities	Kg per capita per day
Delhi	60
Bangalore	53
Calcutta	51
Hyderabad	35
Sonepat	343
Hardwar	40
Meerut	45

Source: Reports concerned Municipal Corporations/Committees

- The wastegenerationinremotecitiesislesserthandevelopedcities .
- Theamountofsolidwastegenerationisalsodirectlyrelatedtotheeconomicstatusoffamilies
- AsperstudiesconductedbyTataEnergyResearchInstitute, higherincomegroupgeneratemoresolidwastethan middleandlowerincomegroups
- ThelowerincomegroupsinNewDelhigeneratelessthan1/3rdofsolidwastethantheirhigherincomecounterparts .
- Asperstudiesconducted, insmallercitiesofpopulationabout3lakhsthegenerationofbiodegradablewaste(50 to 65%)ismorethannon-biodegradable waste(35 to 50 %).

There are certain trends and facts that more or less create the bigger picture in which the waste management industry will evolve. It is clear that new challenges are emerging, and the current situation must be seen in a different way because the disposal site is limited and also it has to be made cost effective [3].Increasing population can impact human lives by two ways:

1. Due to the rate of waste generation.
2. Secondly, its havoc effects on human health.

This account focuses on various options available for the disposal of municipal solid waste (MSW) sustainably and attempts to provide a standard picture of their suitability to India. The report is divided into two parts, Fragment I and Fragment II. The **first portion** will explain the present solid waste management (SWM) crisis in India, its impacts on public health, environment and quality of life and touch upon labors towards SWM in the past. The **second portion** deals with the challenges faced by the landfills and putting hands in converting the waste into energy, reviving our resources.

FRAGMENT: 1

1.1 A Brief

Solidwastes,referstotherefuse ,thesolidandsemisolidwastemattersofacommunityexceptthenightsoil . Solidwastecontainsorganicaswellas inorganicmatters [1]. Insimplemicroeconomicsterms,wecansaythatit'sa bad commodity, and no one in the economy would like to consume it. In fact if the assumption of non-negative prices is relaxed, we can relate such a commodity to negative prices, which means that the agents in the economy would be willing to pay in order to get rid of it or to dispose it. This is what we generally do; we pay a very nominal amount to the garbage picker to take away the waste generated in our home, created by us [4].

As a result with less knowledge and minimum skill they mix up all that waste and put it for the further process creating a messy situation for processing units to treat it accordingly .

Figure 1 : The above tabulated flowchart shows the sources of Solid Waste and processes [6].

1.2 Sources

According to the Municipal Solid waste management Rules 2000, "municipal solid waste" includes commercial and residential wastes generated in municipal or notified areas in either solid or semi-solid form excluding industrial hazardous wastes but including treated bio-medical wastes. It is a matter of concern because even if we want to dispose it off, it does not wiped out immediately.

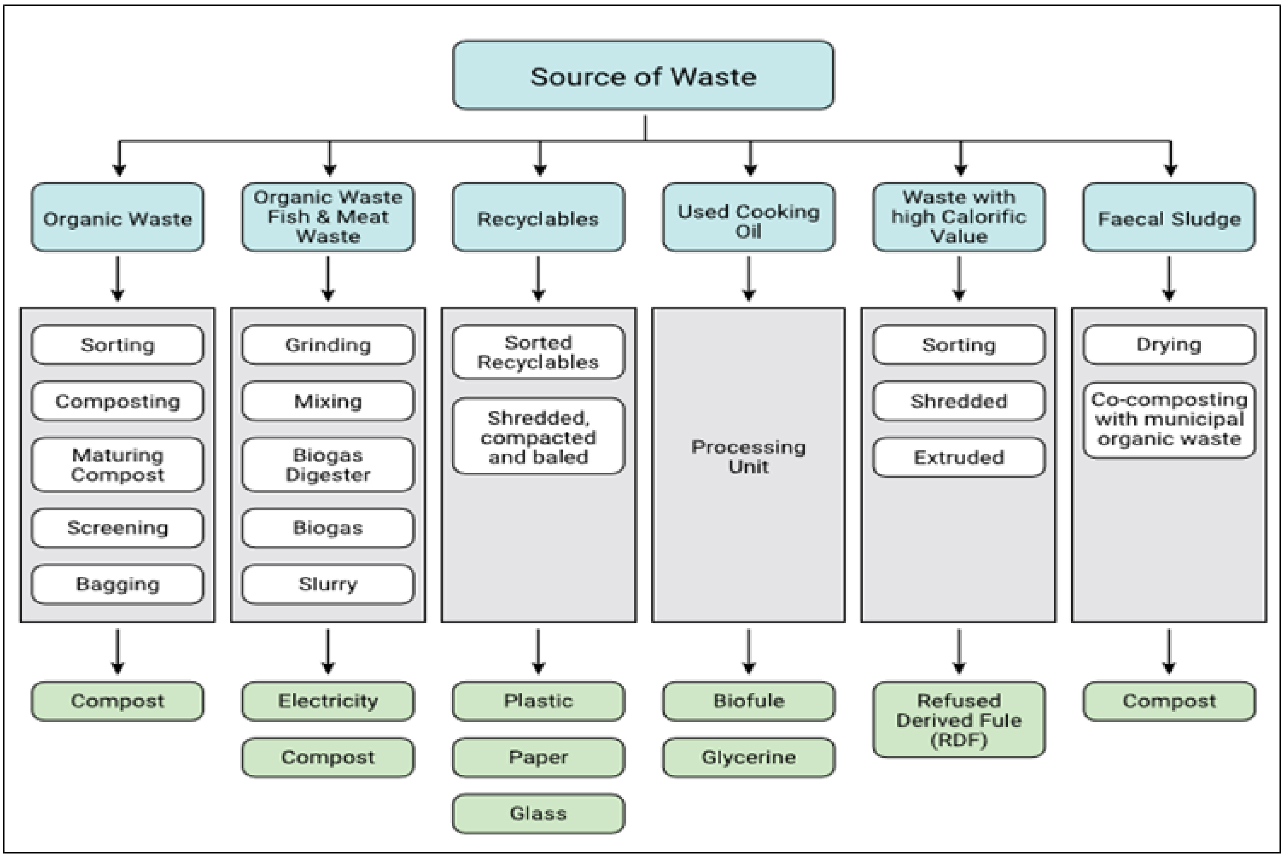

Figure 2 : The above tabulated flowchart shows the sources of Solid Waste and processes [6].

1.3 Generation of SW

Followingare themajorsourcesofgenerationofwasteaturbanlevel [1] :

1- SolidwastefromResidential Areas, Institutional /Community areas
2- Solid waste fromvegetablesmarkets (retailand wholesale)
3- Solid waste fromHotels , and restaurants
4- Solidwastefromcommercialareas
5- Biomedical wastefromhospitalsanddispensaries
6- Waste fromdomestic / strayanimals/dairies
7- Solid wastefromIndustries
8- Waste from street cleansing
9- Miscellaneous

At present, worldwide MSW generation levels are approximately 1.3 billion tonnes per year, and are predicted to increase to approximately 2.2 billion tonnes per year by 2025. This represents a drastic increase in per capita waste generation rates, from 1.2 to 1.42 kg per person per day in the next fifteen years. However, global averages are broad estimates only as rates vary considerably by region, country, city, and even within cities (Hoornweg 2005). According to the Central Pollution Control Board (CPCB), the average Indian generates about 490 grams of waste per day. Although the per capita waste is low compared to western countries, the volume is huge. The generation of solid waste in Indian cities has been estimated to rise with 1.3 percent annually.

Table : 2 Sources and Types of Municipal Solid Waste

Sources Typical	Waste Generators	Components of solid waste
Residential	Single and multifamily dwellings	Food wastes, paper, cardboard, plastics, textiles, glass, metals, ashes, special wastes (bulky items, consumer electronics, batteries, oil, tires) and household hazardous wastes
Commercial	Stores, hotels, restaurants, markets, office buildings	Paper, cardboard, plastics, wood, food wastes, glass, metals, special wastes, hazardous wastes
Institutional	Schools, government center, hospitals, prisons	Paper, cardboard, plastics, wood, food wastes, glass, metals, special wastes, hazardous wastes
Municipal services	Street cleaning, landscaping, parks, beaches, recreational areas	Street sweeping, landscape and tree trimmings, general wastes from parks, beaches, and other recreational areas

Source: Division of Technology, Industry and Economics. State of Waste Management in South East Asia, Types of Wastes - Sources and Composition. United Nations Environment Programme.

The expected generation of waste in 2025 will therefore be around 700 grams per capita per day. Considering that the urban population of India is expected to grow to 45 percent from the prevailing 28 percent, the magnitude of the problem is likely to grow even larger unless immediate steps are taken (Draft report for the 12th Finance Commission Management of Solid Waste in Indian Cities, Government of India).

Waste generation rate depends on factors such as population density, economic status, level of commercial activity, culture and city/region. Figure 3 provides data on MSW generation in different states, indicating high waste generation in Maharashtra (115 364 to 19 204 tonnes per day), Uttar Pradesh, Tamil Nadu, West Bengal (11 523 to 15 363 tonnes per day), Andhra Pradesh, Kerala (7683 to 11 522 tonnes per day) and Madhya Pradesh, Rajasthan, Gujarat, Karnataka and Mizoram (3842 to 7662 tonnes per day). Lower waste generation occurs in Jammu and Kashmir, Bihar, Jharkhand, Chhattisgarh, Orissa, Goa, Assam, Arunachal Pradesh, Meghalaya, Tripura, Nagaland and Manipur (less than 3841 tonnes per day).

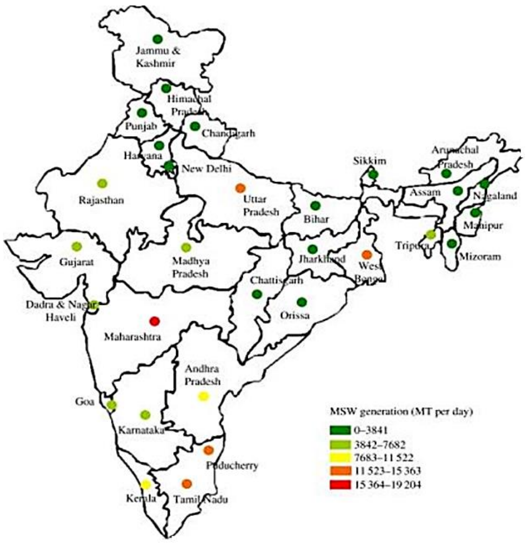

Figure3 : The figure above shows the state wise waste generation per day (in MT).

Source: Central Pollution Control Board, Govt. of India, 2012

One of the survey done by Federation of Indian Chambers of Commerce and Industry (FICCI) highlights the existing anomalies in the way municipal corporations are looking at the issue of solid waste management in cities vis a vis the waste generation. There is potential for setting up proper waste management infrastructure for proper treatment and disposal of waste in cities especially those which generate more than 500 tonnes per day of waste (Ahmedabad, Delhi, Greater Mumbai, Indore, Jaipur, Kanpur, Lucknow, Ludhiana, Pune, Surat and Vadodara). The existing infrastructure in cities is not adequate for management of the quantum of waste generated. There appears to be a lack of understanding of waste management practices which leads to a gap in proper planning and implementation of the available waste management options. The reasons due to which the actual efforts fall short of harnessing the existing opportunities in solid waste management are mainly the lack of knowhow, technology, trained manpower and funds [8]. As India is experiencing rapid urbanization while remaining a country with physical, climatic, geographical, ecological, social, cultural and linguistic diversity. Notwithstanding significant development in social, economic and environmental areas, SWM systems in India have stayed relatively unchanged.

1.4 Composition

Thesolid waste is categorized not only on the basis of sources, generation as per the larger cities, smaller cities or states but also on the footing of the variant components present into abulk clutter. It can be a plastic, dung, fiber materials, clothes etc. as we have the habit to mix all kind of waste in one cluster and throw it out of the house andcreating a pseudo-hygiene behavior. As we have discussed earlier that if we compare the urban areas with the rural areas , the urban ones produces more non-biodegradables waste. Comparing the data the digits are tabulated below and the waste is broadly divided into (1) Compostable(2) Recyclable(3) Inerts (wet weight) and shown as following:

Table 3: Composition of MSW in India and Regional Variation [10]

Region/City	MSW (TPD)	Compostables (%)	Recyclables (%)	Inerts (%)	Moisture (%)	C.V. (MJ/kg)	C.V. (kcal/kg)
Metros	51,402	50.89	16.28	32.82	46	6.4	1523
Other Cities	2,723	51.91	19.23	28.86	49	8.7	2084
North India	380	50.41	21.44	28.15	46	9.8	2341
East India	6835	52.38	16.78	30.85	49	6.8	1623
South India	2343	53.41	17.02	29.57	51	7.6	1827
West India	380	50.41	21.44	28.15	46	9.8	2341
Overall Urban India	130000	51.3	17.48	31.21	47	7.3	1751

CPCB reported the physical characteristics of MSW in different cities of India, which is shown in Table 3 (CPCB, 2000).

Table : 3 Physical Characteristics MSW in Indian Cities

City	Paper	Textile	Leather	Plastic	Metal	Glass	Ash, Fine earth, others	Compostable matter
Ahmedabad	6.0	1		3			50	40
Banglore	8.0	5		6	3	6	27	45
Bhopal	10.0	5	2	2		1	35	45
Mumbai	10.0	3.6	0.2	2		0.2	44	40
Culcutta	10.0	3	1	8		3	35	40
Coimbatore	5	9		1			50	35
Delhi	6.6	4	0.6	1.5	2.5	1.2	51.5	31.78
Hyderabad	7	1.7		1.3			50	40
Indore	5	2		1			49	43
Jaipur	6	2		1		2	47	42
Kanpur	5	1	5	1.5			52.5	40
Kochi	4.9			1.1			36	58
Lucknow	4	2		4	1		49	40
Ludhiana	3	5		3			30	40
Madras	10	5	5	3			33	44
Madurai	5	1		3			46	45
Nagpur	4.5	7	1.9	1.25	0.35	1.2	53.4	30.40
Patna	4	5	2	6	1	2.0	35	45
Pune	5			5		10	15	55
Surat	4	5		3		3	45	40
Vadodara	4			7			49	40
Varanasi	3	4		10			35	48
Visakhapatnam	3	2		5		5	50	35
Average	**5.7**	**3.5**	**0.8**	**3.9**	**1.9**	**2.1**	**40.3**	**41.8**

Source : World Scientific News 66 (2017) 56-74 (CPCB, 2000)

1.5 Challenges with SWM

(1) Awareness to enhance segregation

Ecological awareness and citizen participation to segregate waste at source, door-to-door collection, and disposal in appropriate collecting bin is imperative [11]. The awareness plays an important role in MSWM and augments the efficiency of waste management stream. It is the most critical phase in the whole process of MSWM, which helps in handling solid waste leading to ultimate success. Except for industrial waste where due to organized nature of sector, segregation is sometimes practiced and for healthcare waste due to regulatory requirements, there is virtually no organized and scientifically planned segregation source in India [12]. Sorting is mostly done by unorganized sector (scavengers and rag pickers) and rarely done by waste generators. Therefore, the efficiency of segregation is quite low as the unorganized sector tends to segregate only those waste materials which have relatively higher economic return in the recycling market. Lack of appropriate collection system, lack of and/or inadequate collection facilities such as waste disposal bins, collection vehicles etc., lack of funds, lack of and enforcement of appropriate regulation etc. are the main factors are responsible for such low collection efficiency.

(2) Characterization of municipal solid waste

India is a vast country divided into different climatic zone, different food habits, and different living standard thereby producing waste of different types. Till date, no comprehensive studies have been conducted to cover almost all cities and towns of India to characterize the waste generated and disposed on landfill [11]. The policy-makers rely on the limited source of information available from few places thereby are unable to provide appropriate solutions for the kind of waste produced for a particular region. Treatment and disposal Municipal solid waste is generally disposed as such without any treatment.

Most of the municipal solid waste is still disposed of in dumps causing sever environmental and health risks. The progress in moving towards sanitary landfills and/or disposing through well designed and well operated incinerators is rather slow [12].

(3) Policy Issues

In India there is no any strong policy framework to give a direction and thrust to environmentally sound waste management. Policy measures to encourage waste minimization, recycle and recovery are rather lean. To pact with overall issue of waste management in line with country's economic development programme, there is no any national mark has been set up. The environmental policies are 'discharge end control' based instead of shifting to 'source end control' based approach [12]. The industrial policies carry on to rely on manufacturing from virgin resources and a rational pricing mechanism and/or market based instruments to accelerates waste minimization and support greater use of recycled materials are not in place. Most of the present-day policies are in support of end-of-pipe approach creating enormous burden on municipal authorities[12]. There is a need to create dedicated group of officers and skilled staff for ULBs with specialization in MSWM. Adequate training and hands-on experiments would enable them to identify bottlenecks at implementation level and take appropriate action [11].

(4) Appropriate technological solution

In India, it is need of the day to launchtargeted efforts for expansion of technologies for material and energy recovery from municipal solid waste. To build confidence and test the application of such technologies in the context of developing countries preliminary demonstration projects need to be established. To facilitate assessment of recycling /recovery potential and design/development of technologies, this in turn will require wide data collection on waste classification and quantification. In this direction almost no efforts seems to be taking place. Most of the work is focused on supplementing waste collection and building disposal facilities.

(5) Finance, cost recovery and resource constraints

One of the most pressing issues is the availability of funds to support waste management. The local authorities are mostly in a dire financial situation and are barely able to maintain the basic jobs of waste collection and somehow dispose it. Municipal level waste management continues to be heavily subsidized by governments. To promote use of environmentally sound technologies, for technology development and demonstration are conspicuous by absence.

With the population growth, challenge to provide adequate infrastructure in urban area and new landfill site selection is important. Most of the landfill sites are running beyond their capacity in metropolitan cities. Inadequate financial support to cater to waste management problem aggravates it. Due to financial crunch ULBs do not have adequate infrastructure to provide suitable solutions.

(6) Transparency between Centre and State:

There is less dialogue between Central and State government. Delay in submission of information from State to Central delays appropriate level implementation at ground level. Such lack of coordination for specific action plan and poor strategy at implementation level by ULBs are main hindrance [12].

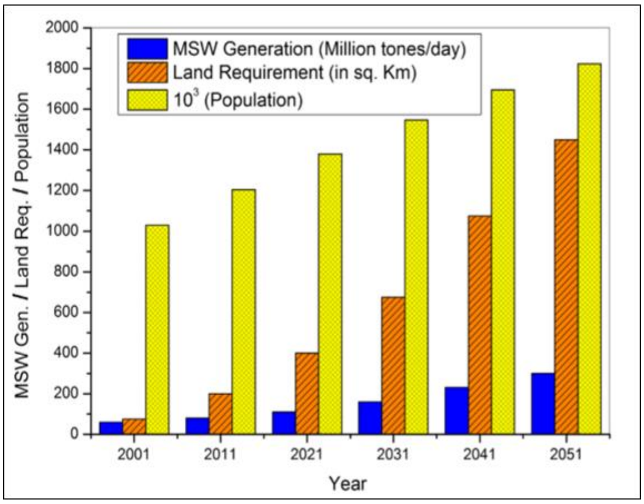

Figure 4 : Prediction Plot for MSW generation, land requirement, and population from 2001 to 2051 [11].

Solid waste management has become one such concern that it has many unknown facts behind, plus limited knowledge to process but still with the challenges the initiatives by many cities and states of India move hand in hand. Not only in India globally the scientists, researchers, engineers are playing vital role in minimizing the waste or processing it as much as possible. Day to day upcoming new technologies and eventually little steps taken up by citizens also creating and spreading a clean behavioral aspect. Hence, gradually moving towards social hygiene from personal hygiene.

FRAGMENT: 2

2.1 Solid Waste Management Methodology

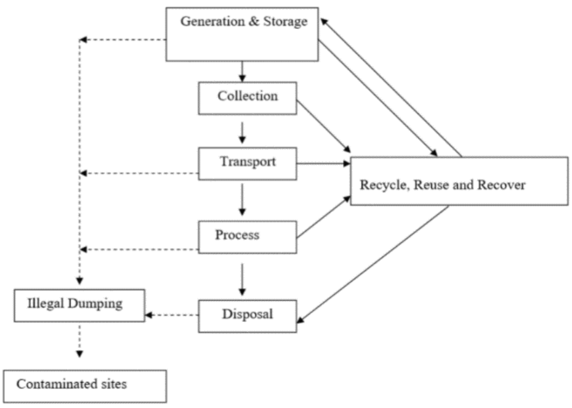

Figure 5 : The Municipal Solid Waste Stream [13]

The traditional Indian hierarchy stream for waste handling is been followed by all over the states and cities. The stereotype of waste collection and processing has no defects but if it is performed by more skilled people plus trained human resource will create a proper departmental influence with better improvisation in work force. Here the governmental intervention also need to work on the technological aspect as to make work easy; automated so it becomes less hazardous for the occupants. The most difficult section in waste care is segregation, while sensitive part is its processing. Hence processing with the new upcoming methods and making best out of it is the only way to get rid of this huge bulk.

2.1.1 The Waste Stream in brief

Waste handling and categorization involves activities associated with management of wastes until they are placed in storage containers for collection. Handling also encompasses the movement of loaded containers to the point of collection.

a) Sorting is an important element of waste management and best-done onsite. However, there are various stages of sorting. These can be renowned as the following:

- At the source or house hold level
- At the community bin (municipal bin)
- At transfer station or centralized sorting facility
- At waste processing site (pre-sorting and post sorting)
- At the landfill site

b) Sorting Operations can be done in three ways:

- Manual sorting
- Semi-mechanized sorting
- Fully mechanized sorting

c) Onsite storage is significant with regards to public health. Open ground storage, make shift containers should always be avoided and only closed containers should be used. Processing at the source involves backyard composting. Storage of wastes can be done at three levels:

- At source
- At community level
- At transfer stations

2.1.2 Collection

This includes gathering the solid wastes and recyclable materials and transport of these materials to either the processing facility, transfer facility or the disposal site.

Types of Collection

- Community bins
- Door-to-Door collection
- Block collection
- Curbside collection

The homeowner is responsible for placing the containers to be emptied at the curb on the collection day and for returning the empty containers to their storage location until the next collection (Tchobanolous, G et al 1993). Street cleansing is another type of collection method mainly for collection of street litter [13].

2.1.3 Segregation

Segregation of our waste is essential as the amount of waste being generated today caused immense problem. If we do not dispose of the waste in a systematic manner than more than 1400 sq.km of land which the size of the city of Delhi would be required in the country by the year 2047 to dispose of it.

Note: Construction and Demolition (C&D) waste is no longer a part of municipal solid waste. C&D Waste Management Rules 2016, Plastic Waste Management Rules 2016, E-Waste Management Rules 2016, Biomedical Waste Management Rules 2016, and Hazardous and Other Waste Management Rules 2016 are separately notified by MoEF&CC

Figure 6 : Definition of Municipal Solid Waste [14]

2.1.4 Transfer and transport

This involves two steps:

The transfer of wastes from smaller collection vehicle to larger transport vehicle and, the subsequent transport of the wastes usually over long distances, to a processing or disposal site. The transfer usually takes place at a transfer station.

2.1.5 Processing

Solid waste processing reduces the amount of material requiring disposal and, in some cases produces a useful product. Examples of solid waste processing technologies include material recovery facilities, where recyclable materials are removed and/or sorted; composting facilities where organics in solid waste undergo controlled decomposition; and waste-to-energy facilities where waste becomes energy for electricity.

- **Recycling and reuse**

The process, by which materials otherwise destined for disposal are collected, reprocessed or remanufactured and are reused. The recycling and reuse (the use of a product more than once in its same form for the same or other purpose) sector of waste management in cities of Asian developing countries is potentially high. Its economic assessment is a difficult task since it is practiced in an informal way.

Composting

It is a biological process of decomposition carried out under controlled conditions of ventilation, temperature, moisture and organisms in the waste themselves that convert waste into humus-like material by acting on the organic portion of the solid waste (Sathish kumar, et al 2002). It produces a sludge, which is high in nutrients and can be used as a fertilizer. This is one element of an integrated solid waste management strategy that can be applied to mixed municipal solid waste (MSW) or to separately collected leaves, yard waste or food waste. There are various methods of composting, which are:

- Windrow composting
- Vermicomposting

- **Recovery**

Energy recovery Processes:

The main factors, which determine the potential of recovery of energy from wastes (including MSW), are:

- Quantity of waste, and
- Physical and chemical characteristics (quality) of the waste

The important physically requiring consideration include:

- Size of constituents
- Density
- Moisture content

Smaller size aids in faster decomposition of the waste. Waste of high density reflects a high proportion of biodegradable organic matter and moisture. Low-density wastes, on the other hand, indicate a high proportion of paper, plastic and other combustibles.

High moisture content causes biodegradable waste fraction to decompose more rapidly than in dry conditions. It also makes the waste rather unsuitable for thermo-chemical conversion (incineration, pyrolysis / gasification) for energy recovery, as heat must first be supplied to remove moisture.

(1) **Bio-chemical conversion:** This process is based on the enzymatic decomposition of organic matter by microbial action to produce methane gas or alcohol. It is preferred for wastes having high percentage of organic biodegradable (putrescible) matter and high level of moisture/water content, which aids microbial activity.

- **Bio gasification**

It is also called bio-methanisation is the process of decomposing biomass with anaerobic bacteria to produce biogas. This process produces Biogas containing approximately 60:40 mixtures of methane (CH_4), and carbon dioxide (CO_2) and simultaneously generating an enriched sludge fertilizer- with an energy content of 22.5 MJ/m3. In Anaerobic digestion (AD) the organic fraction of municipal solid waste offers the advantage of both a net energy gain by producing methane as well as the production of a fertilizer from the residuals (Edelmann, W et al 2000).

City	Developer	Installed Capacity (TPD)	Output
Pune	Nobel Exchange	300*	Bio-CNG: 4 TPD Manure: 7.5 TPD
Bengaluru	Nobel Exchange	250#	Bio-CNG: - TPD Manure: 25 TPD
Solapur	Organic Recyclers	400#	Electricity: 3 MW Manure: 60 TPD
Chennai	Ramky	30	Electricity: 0.26 MW Manure: 3 TPD

Table 4: Medium and Large-scale Biomethanation Plants in India

* Operational capacity as of 2017 is 25%

Currently operational capacity not available

Source: Municipal Bodies of different cities/ miscellaneous

- **Landfill gas recovery:**

The waste deposited in a landfill gets subjected, over a period of time to anaerobic conditions and its organic fraction gets slowly volatilised and decomposed. This leads to production of landfill gas containing about 45-55% methane, which can be recovered through a network of gas collection pipes and utilised as a source of energy.

(2) Thermochemical conversion:

- **Incineration:**

It is one of the most effective means of dealing with many wastes, which reduces their harmful potential, and often to convert them to energy form (Tchobanoglous, et al 2002). Incineration is the controlled burning of waste in a purpose built facility. It involves the process of direct burning of wastes in the presence of excess air at the temperatures of about 800°C and above (The Expert Committee, 2000). The process sterilizes and stabilises the waste. For most wastes, it will reduce its volume to less than a quarter of the original. Most of the combustible material is converted into ash and carbon dioxide (Sathishkumar, et al 2002). In practise, about 65-80 % of the energy content of the organic matter can be recovered as heat energy, which can be utilised either for direct thermal applications, or for producing power.

- **Pyrolysis:**

It is also referred to as destructive distillation or carbonisation. It is the thermal decomposition of organic matter at high temperature (about 900°C) in an inert (oxygen deficient) atmosphere or vacuum, producing a pyroligenous liquid having high heat value and is a feasible substitute of industrial fuel oil.

- **Gasification:**

It involves thermal decomposition of organic matter at high temperatures in presence of limited amounts of air/oxygen, producing mainly a mixture of combustible and noncombustible gas (carbon monoxide, hydrogen and carbon dioxide). This process is similar to Pyrolysis, involving some secondary /different high temperature (> 1000°C) chemistry which improves the heating value of gaseous output and increases the gaseous yield (mainly combustible gases $CO+H_2$) and lesser quantity of other residues.

- **Landfill**:

Itis a vacated land area onto or into which waste is disposed. It is an essential part of any planned municipal solid waste management system. After pertinence of all available management options, they are the final depot of any city's municipal solid waste. In most of the developing countries, open dumping is the most, lucid and economical practice is implemented. Among all available management practices, about 51% open dumping takes place in Asia (World Bank 2012). The aim of landfilling of municipal solid waste is to avoid any contact between the solid waste and the surrounding environment, particularly the ground water. There are three types of landfills, which are-

A-Open dumps or open landfills These are the most common in almost all developing countries, involve the refuse simply being dumped haphazardly into low lying area of open land.

B-Semi-controlled or operated landfills These are designated sites where the dumped refuse is compacted and a top soil cover is provided daily to prevent nuisance. In this type of landfills, all kinds of municipal, industrial and clinical hospital wastes are dumped without segregation. The management of leachate discharge or emissions of landfill gases is not engineered in this type of landfills.

C-Sanitary landfills This type of landfills have facilities for interception and treatment of the leachate using a series of ponds, and generally used in developed countries. For the control of gases from the waste decomposition, this type of landfill have arrangement (Tchobanoglous et al., 1993).

Landfilling continues to be required even if solid waste processing technologies are employed because all of these technologies produce some sort of residue or handle only a portion of the waste stream. For example, landfilling is still required for ash and bypass Waste (waste that can't be burned) from waste to energy facilities. Thus, solid waste processing technologies do not replace landfilling; rather they are a part of an integrated system that reduces the amount of material that requires landfill disposal.

2.1.6 Disposal Non-engineered disposal:

This is the most common method of disposal in low-income countries, which have no control, or with only slight or moderate controls. They tend to remain for longer time and environmental degradation could be high, include mosquito, rodent and water pollution, and degradation of the land.

2.2 SWM Ventures

In India during past, the management of solid waste has received considerable attention from the **Central**, **State Governments** and **local municipal authorities**. A number of partnership are found to working for waste mangement in Indian cities.

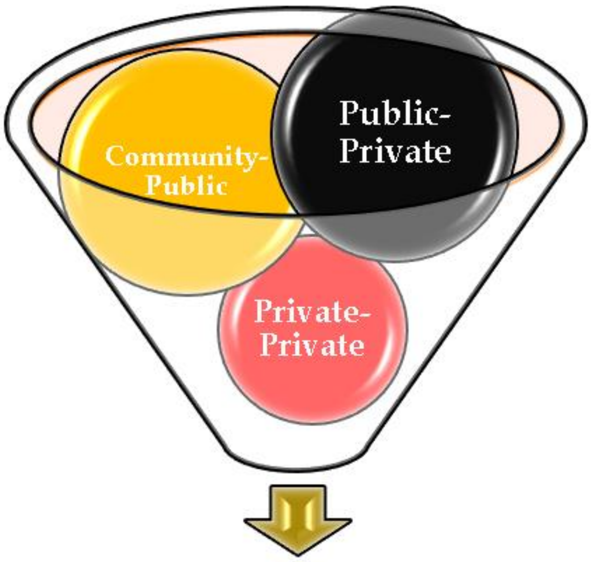

Figure: 7 Various Alliance working for Solid Waste Management

These alliances are working in categories divided as under shown in the below table 4. To study these categories will make easier to identify the authorities playing various roles.

Sectors	Comprises
Public sector	Local authority and local public department in cities
Private formal sector	Large and small enterprises processing the waste
Private informal sector	Small-scale non-recognized sector; waste pickers, dump pickers, itinerant waste buyers, traders
Community representatives (NGOs)	
Public – Private	Local authority and private enterprises
Public – Community	Local authority and NGOs
Private – Private	Small and large-scale recycling

	enterprises, waste pickers, dump pickers, itinerant waste buyers, traders, dealers, wholesalers
Public–Private-Community	Local authority, private enterprises and NGOs

2.2.1 Governmental Interventions

The Central , State governments and the local authorities are working simultaneously for the various disposal techniques and to maximize the efficiency of waste to be converted and reused in any of the way after recovery.

National Solid Waste Association of India (NSWAI) is the only leading professional non-profit organization in the field of Solid Waste Management including Toxic and Hazardous Waste and also Biomedical Waste in India. It was formed on January 25, 1996. NSWAI helps the Ministry of Environment and Forest (MoEF), New Delhi in various fields of solid waste management makes policies and action plans and is entrusted the responsibility of collecting information and various data related to solid waste management from the municipalities of Urban Class-I cities (population more than 1Lakh) and Urban Class-II cities(population above 50,000), collate and disseminate the information to website which is linked to national and international organizations. The association is a member of the International Solid Waste Association (ISWA), Copenhagen, Denmark and provides forum for exchange of information and expertise in the field of Solid Waste Management at the national and international level [15].

As per NSWAI, there are 303 projects till September 2009 running in the country related to waste management, environment and others. The CPCB in collaboration with National Environmental Engineering Research Institute (NEERI), Nagpur has undertaken a detailed survey of 59 cities in the country to assess the existing status of solid waste management in these cities (MoEF –India). The 59 cities selected for study cover 35 metro cities. The objective of the survey was to assess the compliance status of 59 cities with Municipal Solid Wastes (Management and Handling) Rules, 2000 and initiatives taken for improving solid waste management practices [15].

The timeline (figure 9) given below briefs about the ventures taken up by these sectors and working under it.

2.2.2 Hand prints by Indian corporate

In India, there are various initiatives taken by many corporations. For example HCL Info system believes that the producers of electronic goods are responsible for facilitating an environmental friendly disposal, (European Scientific Journal June 2015) once the product has reached the end of its life. HCL Info system supports the ongoing initiative for separate e-waste legislation in India. HCL has been working on an easy, convenient and safe programme for recycling of e-waste in India. HCL has created the online process of e-waste recycling request registration, where customers (both individual and corporate) can register their requests for disposal of their e-waste. Apart from corporate customers, HCL has extended its e-waste collection program to retail customers also through its HCL Touch spread points spread across the country HCL extends the recycling facility to its users regardless of the fact, when and where they purchased the product. To promote recycling of electronic waste, Nokia India launched a 'Take Back' campaign where customers can drop their old handset in the company's stores and win gifts. The take-back campaign is aimed at educating mobile phone users on the importance of recycling e-waste. As a part of this initiative, Nokia encourage mobile phone users to dispose their used handsets and accessories such as charges and handsets, regardless of the brand, at any of the recycling bins set up across Nokia Priority Dealers and Nokia Care Centers. ITC Ltd has chosen energy management, environmental & waste management and social & farm forestry as major focus areas for CSR.

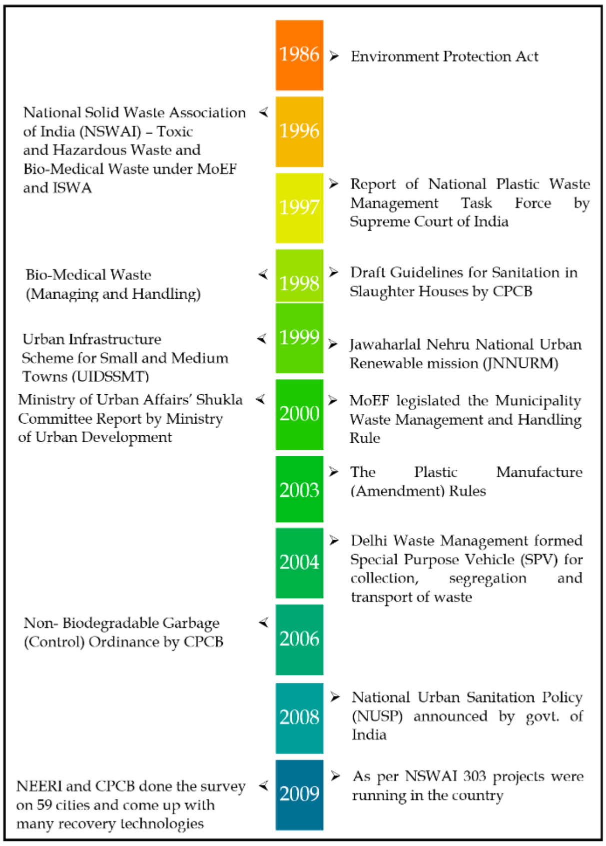

Figure:8 The above timeline showing the initiatives done by government in several years

Specific processes include recycling/reuse of paper mill back water for dilution of bleached pulp, recycling of paper machine primary clarifier outlet water for miscellaneous uses, etc. These are few examples to show that Indian corporate is not behind in producing initiatives related to waste management [15].

2.2.3 Ventures by Private Companies

Box : Subhash Projects and Marketing Limited (SPML)

SPML is a l eading Engineering and Infrastructure development organization with 26 years in Water, Power and Infrastructure. Today SPML is surging ahead in Urban Infrastructure, Solid Waste Management, Water and Waste Water Systems, Cross Country Pipelines, Ports and SEZs, through BOOT/PPP initiatives. "SPML Enviro" is an integrated environment solution provider arm of Subhash Projects and Marketing Limited (SPML). It provides complete solution in relation to collection, transportation & disposal of municipal / hazardous waste, segregation and recycling of municipal waste, construction & management of sanitary landfill, construction & operation of compost plant and waste to energy plant at the Delhi airport and Hyderabad Airport. SPML Enviro has invested in the necessary resources and partnerships to provide solid and water treatment solutions. It expertise includes solid waste-to-resources' solutions – universal, industrial and medical waste. SPML Enviro has teamed up with PEAT International, North Illinois, USA, a waste-to-resources company specializing in treating and converting waste to usable resources. PEAT's proprietary Plasma Thermal Destruction Recovery (PTDR) technology is an environmentally friendly process, that converts wastes into non-toxic synthetic gas (which is a valuable source of alternative energy) and other useful end-products. The PTDR is a proven, cost-effective, environmentally clean and commercially viable solution for waste remediation. SPML Enviro together with its joint-venture partners, has proven capabilities to successfully execute projects on turn-key basis involving Okhla sewage treatment plant, Delhi Jal Board, Bewana common effluent treatment, Delhi State Industrial Development Corporation, Delhi State Industrial Development Corporation, Yelahanka primary/tertiary sewage treatment plant, Bangalore Water Supply and Sewerage Board, Okhla common effluent treatment plant, Sewage treatment plant, Mysore, Karnataka water supply and sewerage board, etc. SPML has also formed a joint venture with the US based Company INSITUFORM Technologies (INC.).

INSITUFORM is a pioneer in sewer rehabilitation projects worldwide. The Company brings with them a No Dig Technology, that eliminates replacement of old sewers. In this, pipe within a pipe concept - a liner is inserted into the sewer, which makes it as good as new.
Source: [15]

2.3 Waste to Energy

2.3.1 Generation

The waste is generated as the population is increasing. The per capita waste generation rate is strongly correlated to the gross domestic product (GDP) of a country. Per capita waste generation is the amount of waste generated by one person in one day in a country or region. The waste generation rate generally increases with increase in GDP. High income countries generate more waste per person compared to low income countries as discussed in above sections. The average per capita waste generation in India is 370 grams/day as compared to 2,200 grams in Denmark, 2,000 grams in US and 700 grams in China (17) (18) (19).

The Census of India classifies cities and towns into 4 classes, Class 1, Class 2, Class 3, and Class 4, depending upon their population. Most of the cities studied during this research done by Earth Engineering Center fell under Class 1. For the purpose of this study, these Class 1 cities were further categorized as Metropolitan, Class A, Class B, etc., until Class H depending upon the population of these cities. This finer classification allowed the author to observe the change in waste generation closer. However, the waste generation rates did not vary significantly between Class A, B, C, D, E, F, G & H cities. They fell in a narrow range of 0.43-0.49 kg/person/day. They generated significantly less MSW per person compared to the six metropolitan cities (0.6 kg/day). The per capita waste generation values of Class 2, 3 and 4 towns calculated in their report are not expected to represent respective classes due to the extremely small data set available. Data for only 6 out of 345 Class 2 cities, 4 out of 947 Class 3 cities and 1 out of 1,167 class 4 towns was available. Despite the lack of data in Class 2, 3, and 4 towns, the 366 cities and towns represent 70% of India's urban population and provide a fair estimation of the average per capita waste generation in Urban India (0.5 kg/day).

Generation of MSW has an obvious relation to the population of the area or city, due to which bigger cities generate more waste. The metropolitan area of Kolkata generates the largest amount of MSW (11,520 TPD or 4.2 million TPY) among Indian cities.

Among the four geographical regions in India, Northern India generates the highest amount of MSW (40,500 TPD or 14.8 million TPY), 30% of all MSW generated in India; and Eastern India (23,500 TPD or 8.6 million TPY) generates the least, only 17% of MSW generated in India. Among states, Maharashtra (22,200 TPD or 8.1 million TPY), West Bengal (15,500 TPD or 5.7 million TPY), Uttar Pradesh (13,000 TPD or 4.75 million TPY), Tamil Nadu (12,000 TPD or 4.3 million TPY) Andhra Pradesh (11,500 TPD or 4.15 million TPY) generate the highest amount of MSW. Among Union Territories, Delhi (11,500 TPD or 4.2 million TPY) generates the highest and Chandigarh (486 TPD or 177,400 TPY) generates the second highest amount of waste.

Year	Source	Annual Generation (million tonnes)
2017	**Our estimate 1** based on 450 gm per capita daily generation and urban population of 440 million*	72
2017	**Our estimate 2** based on 400 gm per capita daily generation and urban population of 440 million*	64
2014-15	**Central Pollution Control Board**	52
2014-15	**Ministry of Urban Development**	52
2013-14	**Task Force on Waste to Energy, Planning Commission**	62

Table 6: Alternative Estimates for Municipal Solid Waste Generation [14]

*Based on projections from United Nations estimates
Source: Central Pollution Control Board, Ministry of
Source: Urban Development, and Planning Commission

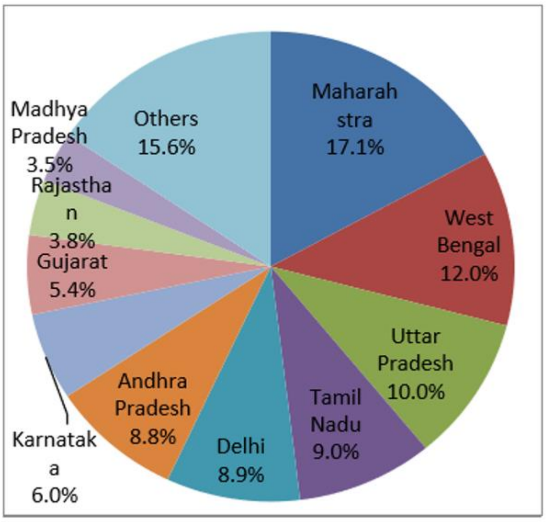

Figure 9: Share of States and Union Territories in Urban MSW Generated [10]

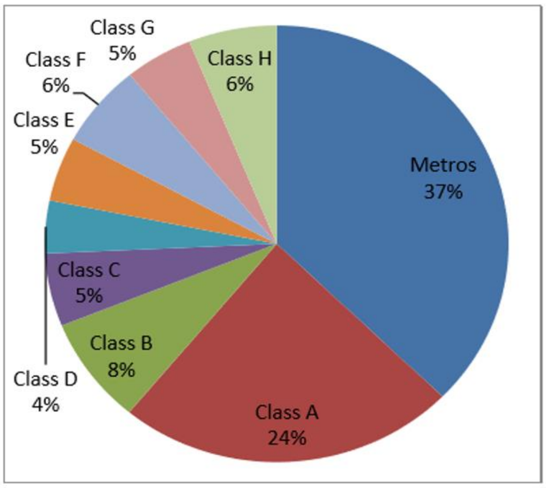

Figure 10: Share of Different Classes of Cities in Urban MSW Generated [10]

2.3.2 Recent Practices in India

Landfilling would continue to be extensively accepted practice in India, though metropolitan centers like Delhi, Mumbai, Kolkata and Chennai have limited availability of land for waste disposal and designated landfill sites are running beyond their capacity (Sharholy, Ahmad, Mahmood, & Trivedi, 2008). The development of new sanitary landfills/expansion of existing landfill are reported in the states such as Andhra Pradesh (Vijianagaram), Delhi (Bhalswa, Okhla and Ghazipur), Goa, Gujarat (8 sites), Haryana (Sirsaand Ambala), Karnataka (12 sites.), Madhya Pradesh (Gwalior and Indore), Maharashtra (Nashik, Sonpeth, Ambad, Pune, Navapur and Navi Mumbai), Punjab (Adampur), Rajasthan (Jodhpur), and West Bengal (17 sites) (CPCB, 2013). According to CPCB, 2013 report, till date, India has 59 constructed landfill sites and 376 are under planning and implementation stage. Apart from this, 1305 sites have been identified for future use [11].

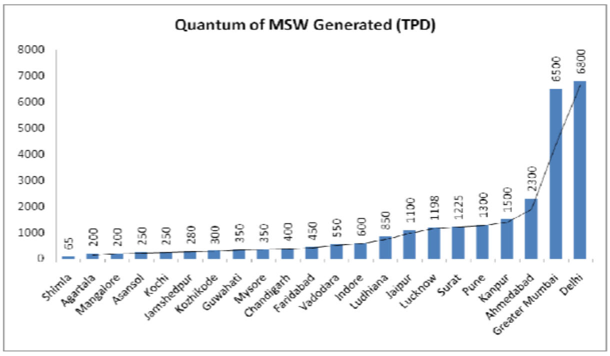

Figure 11: Bar graph representing the quantum of waste generated [8]

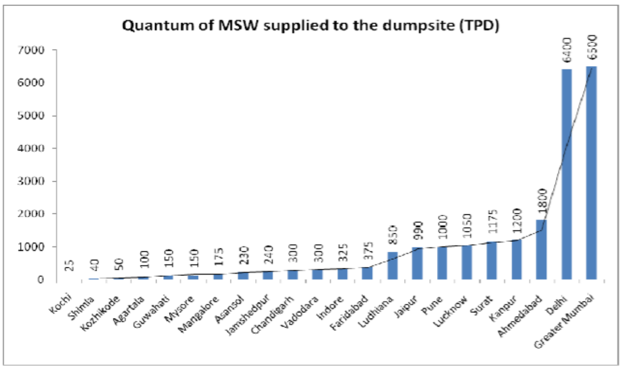

Figure 12: Bar graph representing the quantum of waste supplied to the dumpsite [8]

The above graph gives a snapshot for various cities waste generation and also the amount of waste is supplied to the dumpsite. In waste to energy this process solid waste is used for creating energy like electricity, steam. The SW in enclosed in device for combustion and the residue will be an ash. It is the best option for the handling of the mixed solid waste because the residue of this process (bottom ash) contains inert inorganic materials and minerals, which could be used for construction material. This process decreases the volume of wastes, which is useful to prolong the life of landfill for many years. The input of this process should be the rejects from material recovery. So it is best option for sustainable SW.

Bioreactor landfill

A bioreactor landfill is a further development in landfill technology. These types of landfills are mainly designed, constructed and operated for optimization of moisture content and increasing the rate of anaerobic biodegradation. Leachate recirculation is the principal function that make bioreactor landfills different from conventional landfills. The main goal of formation of bioreactor landfills is to increase the rate of bio-degradation to achieve maximum gas generation rate and output so as to optimize recovery for energy production. This method is also reduce the period of monitoring and inability and also aims to minimize the landfill stabilization time. While permitting and encouraging rapid stabilization of the readily and moderately decomposable organic waste components, the bioreactor option is a direct result of engineering and building a new generation of environmentally sound landfills; it provides environmental security (Gupta et al., 2007) [18].

Refuse Derived Fuel (RFD)

In this method municipal solid waste produces an improved solid fuel or pallets. This plant reduces the pressure on landfills. Combustion of the RFD from municipal solid waste is technically sound and generating power. Without any ill effects for generating heat, RDF may be fired along with the conventional fuels like coal. Operation of the thermal treatment system not only costly but also a relatively higher degree of expertise. In the country many plants are in operation, in Bangalore RFD plant was established and has regular production of fuel pallets since October, 1989, compacting 50t/day of garbage, converting in to 5t of fuel pallets, which can be designed both for industrial and domestic uses. For processing garbage into fuel pallets, the RDF plant at Deonar, Mumbai was set up in the early 1990s. It is based on indigenous technology. However, at present the plant has not been in operation for the last few years and it is owned by Excel India. The Hyderabad RDF plant was commissioned in 1999 near the Golconda dumping ground with a 1000t/day capacity (but receiving only 700 t/day at present). The RDF production is about 210t/day as fluff and pellets, and it is going to be used for producing power (about 6.6 MW) (Yelda and Kansal, 2003).

Table 7: RDF Plants operations in India [14]

Location	Developer	Capacity (TPD)	RDF (TPD)
Kochi	Kochi MC	400	100
Jaipur	Vikram Cements	500	150
Surat	Hanjer	500	125
Chandigarh	Jaypee	500	300
Pune	Rochem	400	250
Navi Mumbai	Pyrocrat	300	-
Bengaluru	MSGP	500	-
Bengaluru	KCDC	200	-

Source: Municipal Bodies of different cities/ miscellaneous

2.3.3 Outcomes

The best way to treat the waste to transform its energy and utilize it in our daily use. It can be also termed as recovery. A waste-to-energy (WtE) plant is a waste management facility that burns wastes to produce electricity. This type of power plant is sometimes called a trash-to-energy, municipal waste incineration, energy recovery, or resource recovery plant [16].

Waste-to-energy plants are similar in their design and equipment with other steam-electric power plants, particularly biomass plants. First, the waste is brought to the facility. Then, the waste is sorted to remove recyclable and hazardous materials. The waste is then stored until it is time for burning. The waste can be added to the boiler continuously or in batches, depending on the design of the plant.

Most waste-to-energy plants burn municipal solid waste, but some burn industrial waste or hazardous waste. Waste-to-energy plants emit less air pollution than coal plants, but more than natural gas plants.

From landfills mainly methane (CH_4) and carbon dioxide (CO_2) gases are produced. These gases have significant greenhouse effect. CH_4 emission from landfill is about 13% of global CH_4 emission and is about 818 million metric tons per annum in terms of CO_2 equivalent (Rachel, Damodaran, Panesar, Leatherwood, &Asnani, 2007). In India, estimated methane emission is about 16 million metric CO_2 equivalents per annum through landfills (International Energy Agency, 2008). The energy potential from landfill gas available at selected sites in Delhi (Balswa, Gazipur and Okhla) is 8.4 MW, Mumbai (Deonar and Gorai) 5.6 MW, Ahmadabad (Pirana) 1.3 MW, and Pune (Urli) had 0.7 MW annually (Siddiqui & Khan, 2011). Planning Commission Report (2014) indicated that 62 million tons of annual MSW generated in urban area can produce 439 MW of power from combustible component and RDF, 72 MW of electricity from landfill gas and 5.4 million metric tons of compost for agriculture use as CH_4 has 23 times higher global warming potential than CO_2. The utilization of landfill gas, particularly CH_4 for energy production is important as it finally converts into primary constituents (i.e. CO_2 and H_2O). A study conducted by United Nations Environmental Program (UNEP) has shown that greenhouse gas emission from landfill can be significantly reduced by following environmentally sound management of hazardous and other wastes (UNEP, 2008, 2010):

(1) Waste minimization.
(2) Recycling and reuse.
(3) Reductions in fossil fuel by substituting energy recovered from waste combustion.
(4) Energy derived by CH_4 from landfill site can be used for in situ energy requirement.

Non-availability of requisite quality of MSW at plant site, presence of low calorific matter in MSW i.e. inert and C&D waste, reservation to use compost generated from MSW by farmers, lack of appropriate market policy for use of RDF, and compost makes such projects economically non-viable. Ministry of New and Renewable Energy (MNRE), Government of India installed 3 Mega Watt (MW) capacity plant at Solapur, Maharashtra, 16 (MW) capacity at Okhla, Delhi, and planned to support few more waste to-energy projects at Bangalore (8 MW), Hyderabad (11 MW), Pune (10 MW), and Delhi at Gazipur (12 MW) (MNRE Annual Report, 2014–2015) also in Delhi, Narela (24 MW) waste-to energy plant is under installation.

Table 8: Waste-to-Energy Plants in Operation in India

Location	Developer	Capacity (TPD)	Electricity Generation (MW)
Delhi – Okhla	Jindal	1,950	16.0
Delhi – Ghazipur	IL&FS	1,300	14.0
Delhi – Bawana	Ramky	2,000	24.0
Hyderabad	Ramky	2,400	20.0
Hyderabad	IL&FS	1,000	11.0
Chennai	Essel	300	2.9
Jabalpur (MP)	Essel	600	9
Shimla	Elephant Energy	70	1.75

Source: Municipal Bodies of different cities/ miscellaneous

Though, in developed countries to acquire enhanced biodegradation and gas recovery, the leachate/liquid/supplemental water is added/recirculated in landfill sites (Barlaz, Ham, & Schaefer, 1990; Reinhart, McCreanor, & Townsend, 2002). But unfortunately, MSWR does not permit leachate recirculation in India. Hence, a vast opportunity for enhanced energy recovery from landfill remains untapped.

2.3.4 Surat WTE Success

One of major success was gained by the Surat waste to energy plant in India , which was presented in Vibrant Gujarat 2017 in 8th Global Summit.

Surat is a city located on the western part of India in the state of Gujarat. It is the second largest city in Gujarat, after Ahmedabad [16].

- Located 284 kilometres south of the state capital, Gandhinagar; 265 kilometres south of Ahmedabad; and 289 kilometres north of Mumbai.
- Surat is one of the cleanest cities of India and is also known by several other names like "The Silk City", "The Diamond City", "The Green City", etc.
- Surat has been selected as one of twenty Indian cities to be developed as a smart city under the Smart Cities Mission.
- Population 44,66,826 (2011 census) Area 326.515 Sq. Km.
- Maximum temperature (avg.): 36.7°C Minimum temperature (avg.) : 15.2°C

Being well interconnected to the cities of Gujarat as well as other states of India the project went well with it infrastructure component. The concept of the project was based on the conversion of the passive energy and store it in the form of active one. The following figure will brief the conceptual programme of this waste management step.

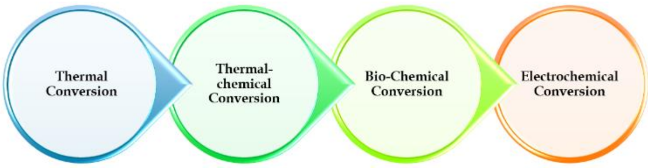

Figure: 13 Conceptual Motive Waste to Energy Project

Project Process [16]:

The residual waste is tipped into a bunker. A crane grabs the waste and places it into the feed hopper. The action of the moving grates turns the waste to allow it to burn fully.

- The burnt out ash passes through the ash discharger onto an ash handling system, which extracts metal for recycling. The remaining bottom ash is recovered and can be used in the construction industry.
- Hot gases produced in the combustion process pass through a boiler where heated water becomes steam
- A turbo-generator uses the steam to produce electricity for export to the local power grid. The heat can also be used for industrial processes or residential district heating near the WtE plant.
- The gases from the boiler go through an extensive flue gas cleaning process. This consists of a scrubber and a bag filter where particulates are filtered out. The cleaned gases are finally released to the atmosphere through the chimney.

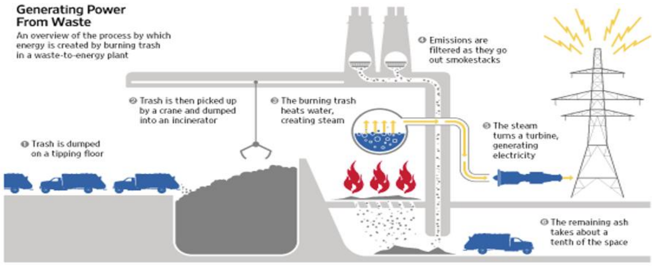

Figure 14: Waste to Energy Plant Process [16]

Surat being a business hub for country wide has profoundly given a way for municipalities for their day to day hurdles in the traditional concepts. The following are the points which gives fine results of the project:

1. **Guaranteed market for electricity produced**

- In an amendment to Electricity Act 2003, the Ministry of Power has incorporated a provision to buy 100% power generated by WtE plants.
- The Central Electricity Regulatory Commission has recently fixed a tariff of INR 7.04 per unit for power derived from municipal solid waste. Thus, there is a guaranteed market for the plant operators.

2. Generation of Municipal Solid Waste (MSW)

- Total MSW generation in India is 62 million tonnes per year. It is estimated to increase to about 165 million tonnes in 2030 and 230 million tonnes in 2041.
- Around 10,200 MT per day municipal solid waste is generated in the state of Gujarat. Thus, there is no shortage for the plant in the state.

3. Push to Renewable Energy

- India is giving a strong push to renewable energy in line with its commitment to cut carbon emissions by 35% and increase the use of renewable energy sources to generate at least 40% of its power needs by 2030.
- Ministry of New & Renewable Energy , Government of India announced the renewable energy target of installing 175 GW capacity by 2022. Moreover, 15 GW of capacity is targeted outside of solar and wind energy.

4. Rising urban development in India

- India has the second highest urban population in the world. Population of Indian cities will increase from 340 million in 2008 to 590 million by 2030–40 percent of total population. This will lead to increased waste production and increased energy needs.
- The investment required for building urban infrastructure in India, over the next 20 years, is estimated at approximately USD 1 trillion.

5. Good urban infrastructure in Gujarat

- All the municipal authorities are required to arrange for collection, segregation, transportation and suitable disposal of municipal wastes from the municipal towns/ cities according to the MSW (M&H) Rules 2000-a must for Waste to Energy plant.
- Having an organized system for waste collection, segregation and transport is an essential precondition for the continuous and smooth functioning of a WtE plant. Thus, plant operators do not have to go through unnecessary hurdles.

II. CONCLUSION

The prominence of the report was on effect of solid waste due to non-engineering and non-scientific disposal. It is found that with rise in the global population and the increasing demand for daily essentials, there has been a rise in the amount of waste being generated by each household. Waste that is not properly managed, especially excreta and other liquid and solid waste from households and the community, are a serious problem for social and economic view. There are lacks in the collection systems and vehicles are not also adequate and are very old requiring frequent maintenance. Additional budget for maintenance is required. The current stationary container system needs to be replaced. Some community bins are not in good condition and disposal sites are not always in preferred locations. Community bins need to be relocated and one or more new disposal sites need to be developed in an appropriate manner with treatment and engineered landfilling. Land is scarce and public health and environmental resources are precious. The current SWM crisis in India should be approached with long term solutions, focus on the solving the present problems.

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