A review on solid waste management in different areas of India

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***Abstract* - Increasing population levels, extremely rapid economic growth and rise in community living standard accelerates the generation rate of municipal solid waste (MSW) in Indian cities. Inadequate management of SW (Solid Waste) causes hazards to inhabitants. The objectives of the study are to determine the quantitative and qualitative characteristics of SW along with basic information and to the importance of GIS maps. The generated Arc GIS maps give needful information concerning static and dynamic parameters of the municipal solid waste management (MSWM) problem such as the generation rate of MSW in different wards, collection point locations, MSW transport means and their routes, and the number of disposal sites and their attributes. Determining the characteristics of SW Municipal Solid Waste Management (MSWM) is one of the most problematic and abandoned aspect of Indian Cities. Also, high population growth and industrialization put strain on the basic infrastructural and municipal services, urbanization, which in turn results in a corresponding increase in MSW. In the present study, an attempt has been made to provide a comprehensive review of the characteristics, generation, collection and transportation, disposal and treatment technologies of MSW practiced in different areas of India. The study related to MSWM for different cities has been carried out to evaluate the current status and identify the major problems. The study is concluded with a few fruitful suggestions as a solution, which may be beneficial to encourage the competent authorities/ researchers to work in sake of improvement of the present system.**

***keywords* - Pelletization, biomethanation, incineration, municipal solid waste, geographic information system. Environmental conservation, municipal solid waste management.**

I. INTRODUCTION

There is a grave need to diminish the current levels of waste generation and increase in material and energy recovery, which are considered as the essential steps towards an environmental friendly waste management system. Landfill is also no longer the first choice for disposal among the other methods such as recycling, composting and incineration, but a last step after all possible material and energy recovery in solid waste management practices. Initially, incinerators globally were used to reduce waste mass but energy is being recovered from incinerators nowadays. Electricity and heat is produced from the recovered bio-gas from landfill. From a mass view point of material recycling, composting of organic waste is considered as the most important system (Marchettini et al., 2007). The difficulties arising from solid waste can be solved by using innovative technologies. Nowadays, different types of waste-to-energy (W-T-E) schemes are available through which energy can be efficiently recovered and used, such as anaerobic digestion (i.e. both dry and wet, thermophilic and mesophilic), thermal conversion (i.e. rotary kiln incineration, mass burn incineration, starved air incineration, fluidized bed combustion, pyrolysis and gasification, plasma technology, thermochemical reduction, refuse derived fuel and landfilling (i.e. landfill gas utilization and bioreactor landfill). Each type of technology handle the specific composition and quantity of solid waste (Tatamiuk, 2007). It seems to be difficult to propose suitable waste management plans and technologies without determining the quantity and composition of generated waste (Idris et al., 2004). Globally, wastes are used to produce electricity and fertilizer or used for recycling. Recently, Europe and United States (US) are recycling waste about 41% and 32%, respectively. China is also investing US 6.3 billion dollar to achieve 30% recycling of its waste by 2030 Currently, out of more than 800 incineration plants working throughout world, about 236 are in Japan and 400 in Europe. The plants in Europe have capacity to provide electricity approximately 27 million inhabitants .There are two methods used for the treatment of solid waste in India, namely the composting (vermin-composting and aerobic composting) and waste-toenergy technologies (pelletization, biomethanation and incineration). Although the latter method is working successfully in the developed world

II **Status of SWM & MSW:**

. The overall operation of solid waste management (SWM) system comes under four heads, namely, cleaning, collection, transportation and disposal, the **cleaning and collection** operations are performed by the public health wing; while transportation and disposal of MSW are being performed by the **transportation.** Waste can be divided into four classified**: solid waste**, **hazardous waste, biomedical waste, and electronic waste**. Municipal solid waste (**MSW) comprises** what is thrown out by households and the commercial sector, such as food leftover, yard abstract, and construction debris. It is very significant to consider because it is the waste that the normal public has the most contact with, and has a high political profile because the public is made up of voters. Also, MSW is one of the complicated types of wastes to manage as it has many different elements, so if it can be managed efficiently, then management of other types of solid waste that are homogenous by nature will be easy to manage.

Main sources of Solid Waste :Household waste, Commercials waste, Hotels, Clinics and dispensaries waste, Construction and demolition waste, Horticulture, Sludge .

The world health organization **(WHO) has defined the waste** as an object that arises from animals or human activities which has to be disposed as unwanted. Solid waste is the unwanted or useless solid materials generated from combined residential, industrial and commercial activities in a given area. This source can serve a great source of alternative to present energy crisis, to meet our energy needs. Before jumping the utility if municipal solid, it's essential for us to manage this well in order to ensure its availability.

Impacts :1. The most deteriorating effect of waste mismanagement is on the Economy of a city, as the city grows the waste generation also increases which in turn enhances the burden of waste management on the city infrastructure in terms of space and resources.

2. The next effect of mismanagement of waste occurs on the Environmental aspect.

3. The aesthetics of the city changes in adverse manner, and health of the residents which comes in direct contact of waste mismanagement area endangered the most. Leeching of hazardous material into ground water causes difficult health concerns and incurable diseases too.

4. If the waste is not segregated nor disposed of properly in the city it may follow the footsteps of Italian city of Campania, which is now called the Toxic waste land of Italy.

III. MATERIAL INVESTIGATED:

To manage the solid waste, following steps are required:

1**. Collection**-Waste collection techniques and methods.

2. **Transportation**-Transportation of waste from household level till the waste dump.

3. **Disposa**l-Disposal of waste using landfill site or waste to manure plants.

As the calorific value of Indian waste is 800kilo cal/kg .It becomes 2600 kilo cal/kg by let to get dry. In Indian incinerator is not environmentally feasible, as it produces canceric gases.

1**. Collection for better Management**: This is the stage at which maximum resource can be saved. The collection of waste must be in the segregated form which means the waste must be segregated at the source i.e. the household levels. The waste must be packed in separate bags which can be differentiated according to their color or according to their labels.

2.**Transportation of Waste for better Management**: This stage can act as the most time saving stage from. Collection trucks can be fitted with the G.P.S system which can enable them to choose the most convenient route to the disposal site during rush hours. Trucks need to be provided with automatic tipping platform with different stacks which in turn help in reducing the time of manual filling of trucks .The waste lifting platforms should be provided in such a manner that manual labor requirements are minimum.

3.**Disposal of Waste in a better Way:** The disposal of waste is the final stage of solid waste management. It can be achieved by segregating waste at the source of the waste .If the waste is segregated at the source it can be used most efficiently and easily for proper disposal.

IV**. RESULT AND DISCUSSIONS** The solid waste management has been reviewed in some part of India including Ahmedabad ,Jalandhar, Jaipur, Lucknow and Delhi

Ahmedabad:

Municipal Solid Waste (Msw) Generation, Collection, Processing, Disposal And Budget

A. Generation

It was found that, majority of waste is generated from households (57%), followed by 24% from street sweeping, while only (2 %) waste is generated by kitchens of hotels and restaurants.

Category	unit	Waste Generated	Percentage
Residential	Tons/Month	63,080	57%
Street sweeping	Tons/Month	26,561	24%
Hotel's and restaurant's kitchen	Tons/Month	2,213	2%
Special markets (e.g. veg & nonveg markets, mandis	Tons/Month	NA	NA
Commercial establishments(incl.offices,institutions)	Tons/Month	NA	NA
Construction and Demolition waste,etc)	Tons/Month	18,814	17%
Total	Tons/Month	110,667	

Table 1: A detailed break up of MSW generated by various categories of use (Estimated Waste Generation in Ahmedabad) Source (AMC)

B. Collection

Approximately 106,000 to 110,000 MT (around 98%) of waste is collected monthly by AMC from various stream or sources of generation including: Door/gate to dump system (includes residences, hostels, commercial establishments, offices, institutes, etc.), Street sweeping, Hotels and restaurants' kitchen waste, Construction & Demolition (C&D) waste. Waste from special markets (including slaughter house, meat / fish / vegetable markets), Lifting of dead animals.

C. Processing

Ahmedabad has currently 2 operational MSW processing plants contracted out to private agencies. One of them converts MSW to compost while the other produces Eco fuel in the form of refuse derived fuel (RDF). Details of waste processed in Ahmedabad have been provided in table2.

Details of MSW received at Processing/Disposal Facilities	Unit	2011
Quantity of MSW received. Processing & Recycling Facilities	Tons/Month	10,763
Direct Disposal at dumping site	Tons/Month	97,591
Quantity of MSW taken away by recyclers from intermediate points	Tons/Month	100
Total MSW received at processing/Disposal facility & Recycled	Tons/Month	1,08,454

Table 2: Summary of quantity of MSW processed Source (AMC)

Ahmedabad city processes 10,763 MT of MSW monthly through private agencies contracted for processing in December 2011. Nearly 100 MT of MSW is picked up daily by rag pickers from secondary collection points and from open dumping site at Pirana.

D. Disposal

AMC dumps nearly 97,500 MT/month at Pirana by open dumping in 84 acre of open area. Dumpers dispose solid waste including restaurant and hotel solid waste over 800 times a day at Pirana. [2]

1) Emissions from Disposal Site:

The major sectors responsible for the emission of GHGs are energy supply with 26% followed by industrial activities with 19%, commercial areas including buildings and residential with 8% and waste sector with 3%. Out of the total emissions from waste sector, the solid waste contributes nearly 22 % of total greenhouse gas emission in Indian context which in turn is the 3% of the total sectorial emissions. The studies reveal that this MSW comprises of more than 50% of organic portion in Indian context as it contains vegetable, food waste, paper, cloth and other biodegradable components as well. The total CO2 released on account of municipal solid waste is in order of 5218119.24 tons/year out of which 22838.88 tons/year in form of transport sector and remaining 5195280.37 tons/year from disposal of waste at dump site at Pirana presently.

The waste which is dumped at Pirana dumping site is of mixed variety and no segregation is done at the source except some valuable materials. There is quantifiable amount of heavy metals found in MSW dumped at Pirana through heavy metal analysis done by the SGS India Pvt. Ltd. For the waste samples before the composting is done by M/s EXCEL plant at Pirana. The quantity of heavy metals such as arsenic, cadmium, chromium, copper, nickel and lead are in order of 6.02, 8.02, 18.55, 1152.96, 150.39, 391, 1950 tons respectively of year 2011. As it is open dumping, these quantities may post threat to eco system of soil, subsurface of water and ground water over period of time. Methane emissions from these are in order of 71394717 m3 per year and 75.23 m3 per ton of waste.

JALANDHER:

Poor Conditions of Collection Containers and Areas around them .The condition of the open containers used during the primary collection and storage is very unhygienic. Foul smell, propagation of flies and other disease causing vectors are quite common at these sites.

TABLE I COMPOSITION OF MUNICIPAL SOLID WASTE IN JALANDHAR

Biodegradable	Non-biodegradable
Food scraps	Non usable sports products
Worn out cloths	Plastic
Ash	Rubber
Vegetables	Bottles
Charcoal	E-waste
Wood	Tile debris

Smart Waste Management (Govt. of India, Smart Cities Guidelines)

The three main criteria for waste management are **Collection**, **Transportation** and **Disposal**

Need for Solid Waste Management in Jalandhar City:

With population of above 10 lakh Jalandhar is fast growing toward progress but this progress comes with a price, in the form of solid waste management, encroachments and urban transport problems. There are total 60 wards in Jalandhar which soon be increased to 63 with the delimitation of some wards. Total waste generated in the city is 500metric tones *per capita waste generation per house in Jalandhar is 1.5 kg. Being located in the center of Punjab it is the hub of medical and educational activities. There are total 1500 sweeper ** employed which is highest in Punjab.

Land use and Waste Generation in Jalandhar City:

Maximum waste is generated by the residential area as it is the main constituent on the city population. Waste is not segregated at the household level or even at the ward level mixed waste is then transported to the dump site.

TABLE II PERCENTAGE OF WASTE GENERATED

Sr.no.	Waste type	Waste generated tone per day
1	Residential waste	212
2	Commercial waste	124
3	Institutional waste	13
4	Hotel & Resorts	85
5	Recreational & Landscaping waste	7
6	Street sweeping	65
	Total Waste	500

Source -Jalandhar M.C 2015

Sweeping:

There are total 2714 safai sewak including drivers of tipper truck ,in total there are 1500 sweeper employed by municipal corporation Jalandhar ,excluding the man power employed by the private company Jindal infratech limited. Sweeper in Jalandhar generally works 7 hours a days ,6 days a week. The assigned length of road given to each sweeper is 1km .There is no automatic machine in Jalandhar for sweeping roads.

TABLE III QUALITY WISE SERVED AREA IN JALANDHAR

Source	Type of activities and facilities	Types of M.S.W
Residential and open spaces 90%	Single and multi family,bus stand	Paper,card board,organic matter
Commercial and street sweeping 5%	Offices and institution	Paper,plastic,inorganic,organic waste
Industrial 5%	Small and medium industries	Toxic ,organic,waste

Collection:

The total collection of solid waste in Jalandhar is carried out by municipal corporation Jalandhar and jindal infra tech limited in collaboration. An estimated 90-95% of city area is covered by municipal and Jindal Infratech tippers. No segregation of waste is done at source or at the transfer station or either at the disposal site. Bins provided by M.C are generally of 1m3 and 4.5m3 and at some places the there is four walled space provided which act as an waste collection dump

PROBLEMS

1.Turning Waste Into Sustainable Substance, A Distant Dream for Jalandhar

2. Proposed Site Mired in Controversy:

The civic authorities here have failed to break the deadlock with villagers of Jamsher Khas to set up a Municipal Solid Waste (MSW) plant in their area. Wariana dump is exhausted which makes the MC dumps waste in villages. Due to lack of MSW processing facility here, the decadeold lone garbage dump spread over 14 acres in Wariana village has exhausted over a dozen times its capacity in the past 80 years causing a severe health hazard to around 2 lakh people living nearby. As the dump could not accommodate further, JITF Urban Waste Management (Jalandhar) Ltd, the MSW Company for Jalandhar cluster, had begun to dump around 480 metric tons of daily garbage at secluded areas in the city's periphery and in the two ponds at Qadian and Jugral villages situated nearby. Though the Municipal Corporation of Jalandhar (MCJ) has proposed to construct a solid waste management plant at around 25 acres at Jamsher Khas village, people of nearby villages have opposed the plan.

PROPOSALS FOR JALANDHAR CITY

1. New Waste Disposal Site

A new waste disposal site is proposed at Jamsher village which is present of the Jalandhar -Nakodar road and is outside the present municipal and local planning area boundary of the city. As the site is proposed to be 25 acre it can be made as an engineered landfill site just as in the case of Ahmadabad city.

2. ZERO WASTE Ahmadabad-A national Model

2.1 AMC-Solid Waste Management Practices

1. Daily collection of 4000 metric tones (More than 600 Grams per head per day)

2. More than 12,500 Street sweepers-1484 km road area swept on a daily basis.

3. 100% coverage in street sweeping on a daily basis

4.Collection from all residential and commercial units under Door / Gate to Dump project, more than 600 vehicles are deployed and daily 1600 metric tons of waste is collected in this manner.

5.Identified more than 850 locations as waste collection points where 1050 closed body 7 cubic meter M.S. Community storage bins have been provided. AMC ensures that these containers are lifted at least once in a day and daily 1100 metric tons of waste is collected in this manner.

2.2 Scientific Disposal of Construction & Demolition Waste

DNP Infrastructure Pvt. Ltd has been awarded the project for Design, Construct, Operate & Maintain a daily 300 tons processing plant for Construction & Demolition waste and collection & transportation of such waste from city area on public Private

Partnership mode for 30 years. AMC has allotted 5 acres of land for processing plant. It will be operational in October, 2016 and going to make Bricks, Tiles & other materials from such waste.

3 New Transfer Station Site

Two new secondary disposal sites are proposed one at

1. Ravidass chownk on Jalandhar –Nakodar road and the other at ,
2. Ram a Mandi flyover on Jalandhar –Hoshiarpur road.

As now there is only one secondary site which is present at the Burtlon park area the waste from throughout the city reaches the Burtlon park ,which causes lot of inconivence and environmental impact as the waste is dumped at Burtlon park which is located at the center of the city.

JAIPUR: Management in Jaipur

Solid Waste

Central Pollution Control Board conducted a study on the status of Municipal Solid Waste Collection, Treatment & Disposal in and around Jaipur City in 2007-2008. Most of the population of the city does not store the waste at source and instead disposes the waste into the garbage bins, roads, openspaces, drainage pipes, etc. Isolation of recyclable waste is not practiced. Most of the recyclable material is also disposed of with domestic and trade waste. Therefore, recyclable waste is generally found mixed with rubbish on the streets, into the garbage bins and at the dumping zones from where part of this waste is picked up by the street sweepers. There is no door-to-door collection systemavailable of waste except in case of few housing societies. Street sweeping is thus the only process of primary collection of waste. There has been a momentous increase in the production of solid waste in Jaipur over the last few decades. The daily predicted generation of municipal solid waste in Jaipur city is about 1050 to 1150 TPD (tonnes per day), which is collected through street sweepers and from community waste storage sites. Thewaste generally transported every day is 900 TPD, which is about 85% of the waste generated in the city. Remaining solid waste is transported through specialdrives which happen weekly. This report further explain about SWM of Jaipur city is that the main system of primary collection of waste is street sweeping. There are about6400 streets sweepers in the city for street cleaning. Some roads are cleaned each day and some are cleaned periodically, twice a week or once in a week. Transportation of waste is done through a variety of vehicles such as 3-wheelers, tractors and trucks. Thevehicles are loaded manually with help of labours and these are used for 2-3 shifts in a day. Insufficient number of transport vehicles is also a major concern. The transportation system also does notis in sync with the systemof primary collection and waste storage facilities.

Status of SWM in Jaipur City

It was observed that there was lack of community garbage collection facility in slums; slum dwellers community dump their garbage nearby the living area.

The refuse bins in old Jaipur area were very dirty and overflowing. People often threw thegarbage outside the garbage bins. The inconvenience of huge garbage on streets and sorting by the sweepers or moving stray animals on the streets represent very ugly scene. It was observed at many places in the morning, thick black smoke spreaded over large areas on the roads due to burning of fallen leaves, plastics and other wastes. Most of the drains along the road and even main sewer lines near Mother Dairy, Bais Godam, Durgapura and Pratapnagar were found blocked due to indiscriminate dumping of Garbage

The use of commercial trucks with or without hydraulic system for waste transportation was very common in Jaipur City. It has a carrying capacity of 3.5 to 8.0 Ton waste at a time. Garbage from the roadside garbage bins is lifted manually and thrown into the trucks. Besides this, tractor, dumper placer, mobile compactor etc. were also used to transport waste to the dumping site. JMC had one mechanized sweeping machine to pick garbage from not reachable places. Presently, JMC uses this machine on highways, mainly in traffic congested areas.

D. Quantities of Waste Generated and its characteristics in City

Waste Quantity-916 TPD Waste Generation Rate-0.59 kg/c/day Compostables-45.50% Recyclables-12.10 % Moisture Present-21%

E. System Implementation

Solid waste is managed by the JMC. Sweepers bring the waste to a municipal bin. Two to three sweepers come to one container. The JMC bought about 800 waste disposal bins to be distributed throughout the city. In theory, one-cubic-meter waste disposal bins with a storage capacity of half ton of waste are placed every 250 meters along streets. Currently 55 of the 77 wards have containers; the wards of the Old City are not containerized due to past objections, likely regarding space concerns. Those containers that are in usage are often in very poor condition, with holes so big that waste is spilling out the sides. There are approximately 40 such bins in Civil Lines, according to a permanent garbage worker who works there. In Civil Lines at least, JMC lorries are observed to arrive around 7:30 AM to remove the waste. Two large bins of 2.5 or 3.5 cubic meters can fit on each lorry. Each bin is mechanically hoisted up onto the back of the lorry, and in its place an empty bin is left. In other areas such as along JLN Marg, residents dispose of their own waste in community bins which are shared by about 20-25 homes. A municipal van comes daily to pick it up.

Most of the drains along the road and even main sewer lines near Mother Dairy, Bais Godam, Durgapura and Pratapnagar were found blocked due to indiscriminate dumping ofGarbage

F. Issues in waste management in Jaipur There is a rate of 10-20% absenteeism at the work place.30 At times, rather than coming to work, workers will just send someone else in their place. The percentage of recyclable waste is very much low as these are picked up by the street sweepers from the houses. Treatment and disposal methods in use in India for MSW mainly include land

filling, composting and very few wastes to energy initiatives (incineration, RDF and bio methane). Jaipur is also facing the similar situation where open, uncontrolled and poorly managed land filling is common.

G. Disposal sites in Jaipur Mathura Das Pura: This site is located in the east of the city. Total area for the site was 176 Bighas. This site is the old most site and is about 17 Km from the main city. Approximately 300-400 TPD of garbage is being dumped every day at this site.
Langariyawas: This site is located in the east direction of the city, 3-4 Km from the Mathura-Das-Pura. The area of this landfill site is 483 bigha.
Sewapura: This site is located at a distance of 20 Km from the main city on Jaipur-Delhi highway. Its total area is 200 bigha.Approximately, 200-300 TPD of garbage was being gone every day to this site.
In improving Disposal of solid waste Treatment of organic waste -Household waste can contain 40 or 50 percent organic waste. Waste from vegetable markets contain even higher in amounts. As organic waste cause major hygienic and environmental problems in cities and at landfills, the 2000 rules mandate improved management and treatment of this fraction before final disposal. Several treatment methods for organic waste are available like composting, anaerobic digestion, Incineration etc. Treatment of Inorganic Waste-The inorganic portion of municipal household waste can be divided into recyclable materials and non-recyclable materials. The earlier recyclable materials are separated from the solid waste, the higher their value and the easier will be the further processing methods. The appropriate treatment method for inorganic waste will depend on its physical and chemical characteristics and also on its reuse potential. In India, the principal treatment method for inorganic waste is recycling.

E. Disposal in Landfills In areas falling under the jurisdiction of "development authorities," it is the responsibility of authorities to identify the landfill sites and to handover those sites to the concerned municipal authority for development, operation, and maintenance of the site. Landfill sites must be selected to make use of a nearby waste process infacility. Landfill sites must be large enough to last for 20 to 25 years.

Lucknow:
As we know lucknow is a major city and capital of Uttar Pradesh State It is about 525 km from Delhi and about 920 km from Calcutta. Today it continues as an important centre of education, commerce, aerospace, finance, pharmaceuticals, technology, design, culture, tourism, music and poetry. Lucknow stands at an elevation of 123.45 metres above sea level and covers an area of 689.1 km2. It is surrounded on the eastern side by District Barabanki, on the western side by district Unnao, on the southern side by Raebareli and on the northern side by Sitapur and Hardoi districts. The city is on the north western shore of Gomti river, which flows through it. Lucknow Municipal Corporation (LMC) is responsible for the management of the MSW generated in the city. The entire operation of solid waste management (SWM) system is performed under four heads, namely, cleaning, collection, transportation and disposal. In the city area of about 70 km2, the cleaning and collection operations are performed by the public health wing of LMC; while transportation and disposal of MSW are being performed by the transportation wing of LMC.
In Lucknow city the cleaning and collection pro-cess involves collection of MSW from the street in wheel- barrows and thereafter, it is dumped into depots (52 depots). MSW is then loaded into the transportation vehicles, which transport the waste to different disposal sites Every year LMC spends on average 21% of its total budget on solid waste management.

MSW sources in Lucknow

Sources of waste	Percentage
Households	42
Restaurants	28
Street sweeping	6.8
Market	8.3
Shops and workshop	7.5
Offices	4.2
Hospitals	1.7
Hotels	1.5
Total	100

3. Geographic information system (GIS)
Arc GIS is a complete and integrated system for the creation, management, integration, and analysis of geographic data. It consists of a geo-referenced spatial database, which includes all required parameters for MSWM. These parameters involve sanitary wards, collection points, transportation road network, as well as the location and capacity of disposal sites and its connection with different wards. Arc-GIS has the capability to input and store the geographic (coordinate) and tabular (attribute) data, to find specific features based on location or attribute value, to answer questions regarding the interaction between multiple data- sets, to visualize geographic features using a variety of symbols and to display the results in a variety of formats, such as maps and graphs. The GIS Desktop includes three integrated applications, i.e., ArcMap, ArcCatalog and ArcToolbox. ArcMap is the primary GIS application for performing analysis and making maps; it is used for displaying, querying, editing,creating and analyzing GIS data. ArcCatalog application helps to organize and manage all GIS data. It includes tools for browsing and finding geographic information recording and viewing metadata, quickly viewing any data- set and defining the schema structure for

geographic data layers. Arc Toolbox application provides tools for data conversion, managing coordinate systems, and changing map projections

Quantity and composition of generated waste :

The quantity and composition of waste has important value for the selection of different energy recovery technologies. The quantity of waste stream relatively has more importance for waste-to-energy recovery technology compared to composition because without sufficient amount of waste it becomes difficult to recover capital cost and also to maintain and operate a waste-to-energy technology in a cost effective manner (Tatarniuk, 2007

S.No.	Income Group	Percent of Total population	Waste Generation (gm per capita per day)	Waste Generation (tonnes per day)
1	High	17	797	94.8
2	Middle	38	560	149.0
3	Low	30	200	21.0
4	Slums	15	200	21.0
Total				326.7

Relationship of economic conditions of different communities with per capita waste production in 2009

Estimation of the MSW constituents in Lucknow

Constituents	Quantity generated in million tonnes p.a.
Soil,sand and gravel	4.20 to 5.14
Bricks and masonry	3.00 to 4.40
Concrete	2.40 to 3.67
Metals	0.00 to 0.73
Bitumen	0.25 to 0.30 MT
Wood	0.25 to 0.30 MT
Others	0.10 to 0.15

The results from data analysis in GIS are products of the appropriate format maps concerning static and dynamic parameters of the MSWM problem, such as the productiv- ity of MSW in the different wards, collection point loca- tions, types of MSW transport means and their routes, and the number of disposal sites and their attributes.

Remarks:

The segregation of waste at source and promotion of recycling or reuse of segregated materials diminishes the quantity of waste and the burden on landfills, and provides raw materials for manufacturers. The composition of MSW shows mostly organic matter (45.3%), so composting is a best way for the treatment and production of soil amendment. The rapid increase in the quantities of MSW and the inability to provide daily collection service cause a nuisance and health hazards. The study will be helpful in creating awareness among the people. The MSWM data obtained from ArcGIS maps were responsible for the retrieval, update and visualization of the information required.

Delhi:

PHYSICAL AND CHEMICAL COMPOSITION OF WASTE :

Table 1. Physical Components (as wt %) of MSW in Delhi. (IHPH,1982;Neeri,1995; teri,2002)

Parameters	2002	1995	1982
Biodegradables	38.6	38	57.7
Paper	5.6	5.6	5.9
Plastic	6	6	1.5
Metal	0.2	0.3	0.6
Glass and Crockery	1	1	0.3
Non- Biodegradable (leather, rubber, bones and synthetic material)	13.9	14	5.1
Insert (stones,bricks,ashes,etc)	34.7	34.7	28.9

Table 1 inform that biodegradable waste is generated maximum in all the three years (1982, 1995, and 2002) but in 1995 and 2002 the composition was almost unchanged. The inert matter is produced in huge quantity (i.e. 34.7 per cent in 2002 and 1995) which is because of high pace of construction and demolition activities in Delhi. The other major components of the MSW like paper, plastic metal, glass and crockery and non-biodegradable waste (leather, rubber, bones and synthetic material) has increased. In Delhi, the recyclable material, like paper, plastic and metal, are available in high quantities, but it is not properly processed, because of lack of knowledge, man power, machinery and financial support from the Government.

Table 2 discusses the chemical composition of municipal solid waste in Delhi.

Table 2, Chemical composition (as wt %) of MSW in Delhi. (IHPH,1982;NEERI,1995;TERI,2002)

Parameters	2002	1995	1982
Moisture	43.8	43.7	15.4
Organic carbon	20.5	20.5	22.8
Nitrogen as N	0.9	0.9	0.86
Phosphorus as P2O5	0.3	0.3	0.74
Potassium as K2O	0.7	0.7	0.52
C/N ratio	24.1	24	28
Calorific Value (Kcal/Kg)	713	712.5	661-1200

It has been found that the waste is characterized by high moisture content i.e. 43.8 per cent, which pave the way for the process of composting rather than incineration. If comparing the two studies which were conducted by TERI 2002 and NEERI 1995, it is worth noticing that the situation is almost unchanged. With urbanization, the substantial increase in use of paper is quiet obvious. However, in Delhi, it has been observed that the rapid growth of rag pickers has given rise to change in composition of waste collected, as the percentage of paper in MSW has remained unchanged.

MSW characterization and the report gives the composition of the waste at the landfill site as briefed in **Table 3.**

Table 3. Composition of waste reaching the landfill site (MCD,2004)

Parameters	Average %	Range
Biodegradable	73.7	20.9-94.6
Recyclables	9.2	2.8-16.3
Inerts	10.8	0.0-72.2
Others	6.3	0.3-61.9
Ash	15.3	3.4-61.9
Moisture	47	8-82
LCV (Kcal/kg)	1777	191-4495
HHV (Kcal/kg	3927	2042-5315

WASTE HANDLING, COLLECTION AND STORAGE

Waste collection and storage are interrelated with one another and are functional elements of solid waste management system. Several types of waste receptacles are used in the area of Municipal Corporation of Delhi (MCD) – (i) large masonry bins, locally called "Dhalao" (50 – 72 m3), used to serve about 10,000 – 15,000 residents with a capacity of 12 – 16 tonnes. (ii) Metal containers and dumper bins (1 m3 and 4 m3 respectively), are emptied by modern hydraulic refuse collection trucks (iii) 4 - wheeled plastic and FRP bins with large covers, which have been introduced in some areas recently and (iv) open unspecified space with no structure are also used for primary storage. Usually open dumpsites storage occurs in JJ clusters and other unorganised settlements, existing within the MCD periphery (Talyan, et al; 2008).

Residents do not deposit the waste directly into dhalaos, due to far distances. The placement of MSW receptacles does not follow any standards, as on an average about 2–3 collection points are placed per km2 whereas 16 collection points (Dhalaos, containers or open dumpsites) should be provided per 100,000 residents (TERI, 2002). In many areas of Delhi, the system of dhalaos as collection centres of garbage is not being fully accepted by the people.

Now, MCD plans to replace the old system of dhalaos by putting trolleys and smaller bins in the vicinity of people as there are a lot of complaints regarding animals seen roaming around the dhalaos, leading to in-aesthetical view and problems of odour. MCD, NDMC and DCB have employed about 50,000, 2600 and 370 sweepers or Safai Karamacharis (SKs), in their respective jurisdictions for primary and secondary MSW collection from waste receptacles and for street sweeping. In this context, lowest number of safai karamcharies serving per 10 sq. km. of area can be found in areas of outer Delhi, like Najafgarh and Narela. In the entire area under MCD, an average of 281 SKs are serving per 10 sq. km. of area. Only three zones namely Najafgarh, Narela and Central fall below the figure of 281, and the remaining zones indicate more than average SKs. The core areas of Delhi viz. Sadar Paharganj, Karol Bagh, and City have the highest number of SKs, serving on per 10 sq. km. of area. These three zones have only 3.21% of the total geographical area under MCD and 17.93% population of the total population under MCD, and generate 47.98, 33.46 and 33.01 metric tonnes waste on a per lakh population basis.

TRANSPORTATION OF MSW

It is observed that transport of waste from collection centres to processing or final disposal site is very important step for solid waste management system and for this purpose, suitable vehicles and equipments is required. In eight zones, the secondary collection and transportation of MSW from the receptacles (dhalaos) is done through private concessionaires and in other four zones, the same is done by the Corporation involving a large number of staff; mobile equipment and plant, whereas, the primary collection of the garbage is done by the residents themselves. A new initiative of the Corporation in two zones (Rohini and Civil Lines), from July 2009, takes care of the primary and secondary collection and transportation of waste to processing facility and sanitary landfill sites for processing i.e. door-to-door collection of garbage. MCD maintains a large fleet of vehicles for transportation and secondary collection of MSW from various waste receptacles to the disposal sites. In this process, MCD is using various types of vehicles i.e., mini-trucks and mechanical trucks of different makes (Tata Tipper trucks, Leyland and Shaktiman trucks) having 8.6m3 capacity and they transport the waste directly to the nearest disposal/landfill site. Front-End

loaders are also used for loading the vehicles from the dhalaos/dustbins. It has been estimated that approximately 60-75 percent waste is collected for the transportation to the disposal sites and the main constraints are non-availability of sufficient vehicles and their frequent breakdown. Currently, MCD uses around 6500 vehicles: 585 RRTs, and 137 loaders. In MCD area about 1000 auto tippers
are also used for primary collection of waste from houses. Besides, MCD has privatised 8 zone namely South, Central, City, Sadar, Paharganj, Karol Bagh, West, Rohini and Civil Lines zones under the Public Private Partnership (PPP) scheme. There, 305 Big Hydraulic Vehicles, Short Range Tippers/Dumpers are used for transportation of waste. The NDMC and DCB operate 55 and 26 trucks, respectively.

Table 4. Vehicles for Solid Waste Management. (North Delhi Municipal Corporation, 2015; South Delhi Municipal Corporation, 2015; East Delhi Municipal Corporation, 2015; New Delhi Municipal Council, 2015; Delhi Cantonment Board, 2015; Delhi Pollution Control Committee, 2015)

Name of the vehicle	No. of Vehicles				
	MCD			DCB	NDMC
	NDMC	SDMC	EDMC		
Truck-Tipper having capacity 8m3	101	138	140	15	14
Tractor-Trailer	Nil	40	Nil	Nil	Nil
Refuse Collector/Compactor having capacity 14m3	58	26	Nil	11	15
Dumper-placer/Bins having capacity 1100ltrs	222	1151	Nil	Nil	Nil
Front end loaders	22	30	26	Nil	Nil
Auto Tipper	398	256	302	Nil	26
PVC Bins having capacity 200ltrs	Nil	800	Nil	Nil	Nil
Tricycle	Nil	Nil	1000	Nil	144

There is improper distribution of waste transportation in all the zones of MCD. Although the available transport volume is inadequate for the MCD areas, the vehicles operate in two shifts and usually make one trip per shift depending upon the distance of the disposal site. Under-utilization of the fleet of vehicles is a problem that results in delay in transporting the waste from the collection points to the disposal site. The major reasons for this include, improper maintenance, haphazard parking of vehicles, time lost waiting in the queue for fuelling and travelling from one workshop to another for refuelling. As a result, the vehicles are found to operate only few hours in a day. The situation is further worsened by poor maintenance, improper route planning and shortage of staff. The situation is better in NDMC where operational efficiency is 75 percent as compared to 60 percent in MCD (Talyan, et al; 2008).

TREATMENT OF MSW

Composting

In Delhi, a huge amount of biodegradable waste is generated, and so there exists a good potential available for composting. Therefore, Delhi Government had initiated various composting plants (Table 8). The first composting plant was set up at Okhla in 1980. It was semi–mechanized plant with a capacity of 150 tonnes per day for composting the waste. Later this plant was expanded increasing its capacity in 1985.

However, this plant was in-operational during 1991-1995 due to low quantity of waste material and higher operational cost. In May 2007 ILandFS Company signed a concession agreement with the MCD to rehabilitate the Okhla compost plant wi th carbon support. The project uses the technique of multitreatment of municipal waste to avoid possible pollution. It involves mechanical sorting and composting of organic waste, recycling of materials like metals, plastics and paper and treating the residual organic waste using composting process. This plant converts approximately 73,000 tonnes of MSW into compost every year which is equivalent to 200 tonnes per day. Likewise, New Delhi Municipal Council (NDMC) had also set up a compost plant in Okhla. Then came two other compost plants in Bhalswa and Tikri Khurd. The plant in Bhalswa has been shut down by Delhi Pollution Control Committee (DPCC) since 28.03.2014, due to non compliance of rules.

Recently MCD has installed a compost plant at NarelaBawana with a capacity of 400 TPD and it is working since January 2012 (Table 5). The Compost facility processes approximately 400 TPD MSW (150 TPD from incoming solid waste, 150 TPD from MRF, and 100 TPD from screening section).

Table 5. Existing compost plants in Delhi. (North Delhi Municipal Corporation, 2015; South Delhi Municipal Corporation, 2015; East Delhi Municipal Corporation, 2015; New Delhi Municipal Council, 2015; Delhi Cantonment Board, 2015; Delhi Pollution Control Committee, 2015)

S.No.	Facility	Capacity (TDP)	Area(Ha.)	Year of Installation	Remarks
1	Okhla(MCD)	150	8	1981,2007	
2	Okhla(NDMC)	200	3.4	1985	
3	Bhalswa (Private sector)	500	12	1999	This plant has been closed by DPCC since 28.03.2014 due to non compliance of rules.
4	Tikri Khurd (APMC)	125	2.6	2001	
5	Narela-Bawana	500	2.7	2012	

Incineration (Waste to Energy)

Waste to energy facilities may generate steam, electricity, super-heated water or a combination of these. Incineration is a good alternative for waste processing, being used in India. The Government of Delhi also gave permission for 3 plants for conversion of solid waste into power:

Timarpur-Okhla Waste to Energy Plant: The Timarpur Refuse Incineration-cum-Power Generation station was commissioned by the Ministry of Non Conventional Energy Sources (MNES) in 1987 at a capital cost of Rs. 20 crores (US$ 4.4 million). Built by Volund Miljotecknik Ltd. of Denmark, the plant was designed to incinerate 300 tonnes of municipal solid waste per day to generate 3.75 MW of electricity. The plant ran for 21 days of trial operations, then was shut down due to the poor quality of incoming waste. In November 2007, the CDM Executive Board registered a project by the name Timarpur-Okhla Waste Management Company to build two facilities to handle 2050 tonnes per day of municipal waste.

Gazipur WTE Plant: The Gazipur project process 1,300 tonnes per day of municipal waste generated in the Trans-Yamuna area. The waste is collected to produce green electricity.

The Narela-Bawana waste to energy plant: 4000 TPD of municipal solid waste will be treated in two phases; Phase-I will process 1000 TPD of waste comprising of a Material Recovery Facility (MRF) to reclaim metals and recyclables, and sorting out organic and combustible material for composting and RDF facilities.

Phase-II comprising of a power plant based on Massburn technology, will process 3000 TPD of waste. These three wastes to energy plants have been established for the better management of municipal solid waste. These three plants incinerate some 8,000tonnes of MSW generated by the city daily and produce about 62.2 MW of electricity, 1.3% of the city's total consumption of 4800MW.

DISPOSAL OF MSW

It has been found that,presently in Delhi, there are four active sanitary landfill sites (Bhalswa, Gazipur Okhla and Narela-Bawana) which cover more than 200 acres of land, in different zones of the city, in different directions. The Municipal Corporations of Delhi (NDMC, SDMC and EDMC) is responsible for the management of all four existing landfill sites. Other agencies like Delhi Metro Rail Corporation (DMRC) and Agricultural Produce Market Committee (APMC) etc. dispose off their waste on the MCD controlled landfill sites. The civic bodies in the city other than MCDs (New Delhi Municipal Council and Delhi Cantonment Board) have no provision for disposal of their own waste produced. Hence, MCD permits these agencies to use its dumping sites by charging them and the tipping fee/charges may vary from ₹ 205 (US $3) to ₹ 235 (US $4) per refuse collector truck (4 Metric Tonnes). The three active landfill sites namely Bhalswa, Gazipur and Okhla have exhausted but illegal waste dumping by all the civic bodies continues, which has lead to overflowing and poses harmful impacts on human's health and environment.

CONCLUSION

In this study, various methods of solid waste management followed in different cities of India ,(example: Ahmedabad ,Jalandhar ,Jaipur ,Lucknow and Delhi) have been reviewed and it has been concluded that Ahmedabad is having the best SWM , lucknow is also following good techniques of GIS for SWM, Delhi is in developing stage in SWM but it requires many solutions to overcome the problem of solid waste management , Jalandher and Jaipur are at worst practices in SWM.

Major weaknesses associated with MSWM system are:

In Ahmedabad:

1.No segregation is done at the source.

2. Due to open dumping MSW may post threat to ecosystem of soil, subsurface of water and ground water over a period of time.

In Jalandhar:

1. Open containers are used during the primary collection.
2. There is no automatic machine in Jalandhar for sweeping roads.
3. No segregation of waste is done at source or at the transfer site or either at the disposal site.

In Jaipur:

1. There is no proper mechanism in the city for treatment of solid waste generated.
2. Dumping of waste in open areas causes various problems to environment as well as humans living in that vicinity.
3. Isolation of recyclables is not practiced.
4. Indiscriminate dumping of garbage blocks drains, roads and sewer lines.

In Lucknow:

1. Inability to provide daily collection service cause nuisance and health hazards.

In Delhi:

1. Mixed Waste
2. No Integrated Solid Waste management (ISWM).
3. Lack of planning: As a result, their waste scatters at any vacant place or plots or alongside roads.
4. Old equipment and Technology

PREFERABLE SOLUTION

Adopting segregation of waste at source can be beneficial based on our analysis. The dry refuse generated can be recycled and save public money of transporting it to the dump yards. Wet waste can be used for making manure by disposal waste at source, i.e. at their premises or zone wise. Composting and installing of biogas system are the ways in which garbage disposal can be done. Segregation of household waste at the source should be made compulsory. Government must promote composting, vermicomposting, incineration, refused derived fuel etc. processing and treatment methods for reducing the solid waste disposal problems because the processing of the waste is the only answer to the current scenario of municipal solid waste. Finally, there is also a need to develop a methodology of research for developing interactive techniques for system's design and operational control. Government should adopt 4R's: Reduce, Reuse, Recycle & Resource Recovery principle. Landfill should be restricted to nonbiodegradables. Bins should not be allowed to create unsanitary conditions. GIS (Geographic Information System should be used for for creation, management, integration and analysis of geographic data e.g Sanitary wards, collection points ,transportation ,road network.

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