Smart Solid Waste Management System

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Abstract— **Municipal Solid Waste Management needs more attention as less significant changes has been observed despite of ample campaigns and awareness programs. Increasing population and hence pollution has increased pressure on available resources. Tonnes of garbage are generated everyday by the millions of people living in urban India which is disposed of by municipal authorities' every day in an unhygienic manner raising major health environmental and health concerns. In the capital state - Delhi the municipal solid waste generated about 10050 MTPD and quantity has been consistently rising over the years. Starting from segregation, collection, transportation and disposal, the Municipal Solid Waste suffers from weak administrative and managerial problems. The present article is projecting a system for efficient segregation, storage and collection, transportation, disposal and processing of waste. The study concludes that with proper resource utilisation, waste segregation and application of technological developments we can reduce the waste generation and use it as a source of manure through composting and increase the energy generation through incineration. This will eradicate the problem of landfilling. Presently, all existing three landfills (Bhalswa, Gazipur and Okhla) are fully packed and overflowing. Simultaneously, it is necessary to reduce the burden on landfill sites in the future.**

Index Terms— **Composting, Energy generation, Incineration, Landfill, Municipal Solid Waste Management, Segregation**

I. INTRODUCTION

Urbanization and industrialization has led to increase in municipal solid waste at faster rate. Uplift in standard of living and change in lifestyle has led to municipal waste production. This problem is severely faced by developing countries and India is one of them. India is developing at a greater pace but the vision of making India clean cannot be achieved only by technological changes only but an emphasis on managerial and behavioural changes is must. It lacks in an efficient system right from the point it is being stored, collected, treated to the point it is being disposed. If this practice continues, it would lead to an epidemic and step-up the pollution to critical level. Developing countries are more vulnerable to it because of rapid economic growth. Delhi city covers an area of 1484 km^2 with population density 11312/$km^{2,}$ it is the most densely populated metropolitan city of India. The decadal growth rate in population during the last decade (2001-2011) was 20.96 present. Budding population has led to drastic escalation in waste generation. Delhi's garbage conundrum is not new. With garbage hills piling up and a systemic failure in the way the corporations are running, everything has come to a standstill. Landfill is being used by the Delhi authorities despite the major health and environmental concern but landfills are clearly not the answer.

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II. STUDY AREA

The area selected for the present study is National Capital Territory of Delhi (NCT-Delhi) because once the system will be developed in such complex and heavily populated metropolitan city, its replica can easily be adopted in other cities. Being a national capital of India, it has numerous government offices, institutions, organizations etc. The area of the National Capital Territory of Delhi is 1484.46 sq. km. Five municipal authorities are responsible for solid waste management in the city—the North Delhi Municipal Corporation (North DMC), South Delhi Municipal Corporation (SDMC), East Delhi Municipal Corporation (EDMC) the New Delhi Municipal Council and the Delhi Cantonment Board (DCB). The three corporations—North, East and South—alone manage 96 per cent of the total area of the city. As per information provided by MCDs, 10050 TPD of municipal solid waste is collected in Delhi. New Delhi Municipal Council and Delhi Cantonment Board constitute the 4 per cent area of Delhi whole.

III. OBJECTIVES OF THE STUDY

The purpose of the current research study is to understand and analyse the municipal solid waste management in Delhi. The current paper has the following objectives:

1. To find the root causes that are creating hindrance in development of efficient municipal solid waste management system involving qualitative and quantitative analysis of solid waste in Delhi.
2. Foster a way to improve the segregation, disposal and treatment of the waste.

IV. MAJOR IMPLICATIONS AND CHALLENGES IN SOLID WASTE MANAGEMENT IN DELHI

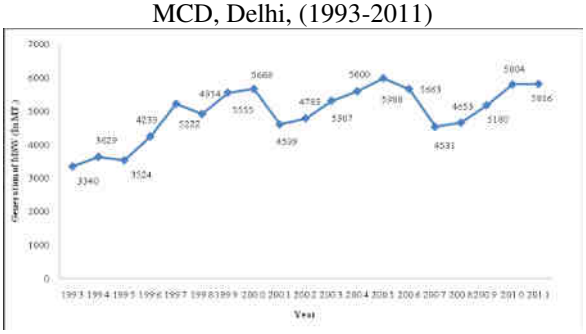
At present time, the increase in rate of waste generation is far more than population increase. Since 1993-2011 about 54 per cent growth has been recorded in MSW. This has following major implications on the resources of the city:

1. 1. Overflowing of landfill sites: All existing three landfills (Bhalswa, Gazipur and Okhla) are super saturated with waste and are overflowing as major part of waste is disposed through landfill. There is major unavailability of barren lands.
2. Inaccessibility to unauthorised colonies: The collection efficiency of waste is below 70 per cent due to lack and improper management of resources.
3. Lack of Infrastructure: Dumping sites are filled with scattered and mixed waste composites. There is

urgent requirement of maintenance of receptacles as it affects the waste segregation.

4. Sanitation Problem: Due to unsuitable handling of house and surrounding waste, there are many diseases which are directly related to improper management of solid waste. The rodent and vector insects transmit various diseases like dysentery, cholera, plague, typhoid, infective hepatitis. Hence there is need of public awareness, stringent compliances and involvement of local administrative bodies.

Figure 1: Growth of Municipal Solid Waste Generation in MCD, Delhi, (1993-2011)



V. Physica Composition (as wt. %) of MSW in Delhi

It has been observed that the waste is characterized by high moisture content i.e. 43.8 per cent. The organic carbon, Nitrogen, Phosphorus, Potassium, C/N Ratio and Calorific value of MSW is recorded at 20.5 per cent, 0.9 per cent, 0.3 per cent, 0.7 per cent, 24.1 per cent and 713 k Cal/kg. Composition of waste includes -

Parameters	2002	1995	1982
Biodegradable	38.6	38.0	57.7
Paper	5.6	5.6	5.9
Plastic	6.0	6.0	1.5
Metal	0.2	0.3	0.6
Glass and Crockery	1.0	1.0	0.3
Non biodegradable (leather, rubber, bones and synthetic material)	13.9	14.0	5.1
Inert (stonnes, bricks, ashes, etc.)	34.7	34.7	28.9

Source: TERI (2002), NEERI (1996), IHPH (1982)
Note: Cited from V. Talyan et al. (2008)

VI. Waste Receptacles in NCT-Delhi Area

Aging infrastructure has made the situation more problematic. Proper maintenance and retrofitting of receptacles (Dhalaos) is required. Following is the data of available resources.

Name of Zone	Dhalaos	Dustbins	Open Sites
South zone	227	136	72
Central zone	188	45	75
City zone	46	32	13
S. P. Zone	49	-	-
Karol Bagh zone	57	21	06
West zone	201	1	14
Najafgarh zone	56	1	135
Rohini zone	267	39	06
Narela zone	34	7	62
Civil Line zone	107	41	21
Shahdara (S) zone	157	18	18
Shahdara (N) zone	105	10	11
Total	1494	342	433

Source: MCD, 2012

VII. Root Cause and Action Plan

7.1 The root cause of the above mentioned problems lies in the fact that most of the people are unaware about the severe effects of improper management of the waste. It is continuously degrading the environment and is detrimental to human health. Moreover, people who are conscious about its ill impact do not take any action against it until the waste affects their sphere of influence. Hence major problem lies at the individual level.

7.2 Waste generated cannot be eradicated but it can be reduced by taking preventive measures. Accordingly its ill impact can be reduced by the setting up an effective system which involves improved storage followed by collection, segregation, reduction, reuse and disposal of waste.

7.2.1 Segregation of waste at the individual level:
It is the process of classification of the waste based on the characterization of the waste. Household waste comprises of organic and inorganic waste, recyclable and non-recyclable waste, dry and wet waste. Since Segregation is a problem that needs to be solved at individual level else it will keep growing exponentially. In conventional method segregation is done at the landfill sites by scavengers. Hence a proper method is need of hour. Bifurcation of waste can easily be done by two bin one bag method. Considering the environmental impact that is caused by the mismanagement of waste, Two bins one bag should be mandatory for every house as per the colour codes and it should be responsibility of local bodies in that area to advertise about the same to make the people aware and make it the a stringent policy. Since compliances and strict supervision of their enforcements is needed else things will remain unchanged. Two bin one bag method should be made mandatory by NGT in Delhi and media should assist in broadcasting the same method. Following is the brief description about two bin one bag method -

- Green bin for green waste: Waste such as vegetable scraps, fresh weeds, humus.
- Red bin for rejected waste: poisonous or non-biodegradable substances (leather, rubber).
- One bag for recycle waste: Plastic, paper, glass metal.

To make it easy for uneducated people we will make use of pamphlets and handouts to show the general household wastes' bifurcation. Dustbin making industries will be instructed to make only red and green dustbins with labels of waste demarcation (same content as on pamphlet) on it as Uniform colour code provides consistency for the entire city. Collection of segregated waste becomes more efficient.

Segregation at individual level is the only way to get over this problem and here is where two bins and a bag will play its role. It is easy to understand, convenient, and adaptive method. Additionally it will cut short the usage of plastic bags and subsequently reduce the environmental degradation. The colour coded system makes it uniform and effortless to follow. Following the best practices listed, this can be rolled out anywhere in a very short time. It will easily cover the whole city by involving each individual.

It can be promulgated in the campaigns and it is our responsibility to take the charge of the waste we generate by

properly segregating it and dumping it at the right spot. Seeing the condition of the Delhi, National Green Tribunal should make this process stringent else Delhi air will worsen even more. People should stop burning waste and dumping it in water bodies as this process is not the end solution rather it is paving a way towards end of human race by polluting the basic resources such air, water, soil on which human life totally depends. This should be inculcated as a habit not compliance.

Figure3: Sample pamphlet that can be stuck on the dustbins by the manufacturing industries -

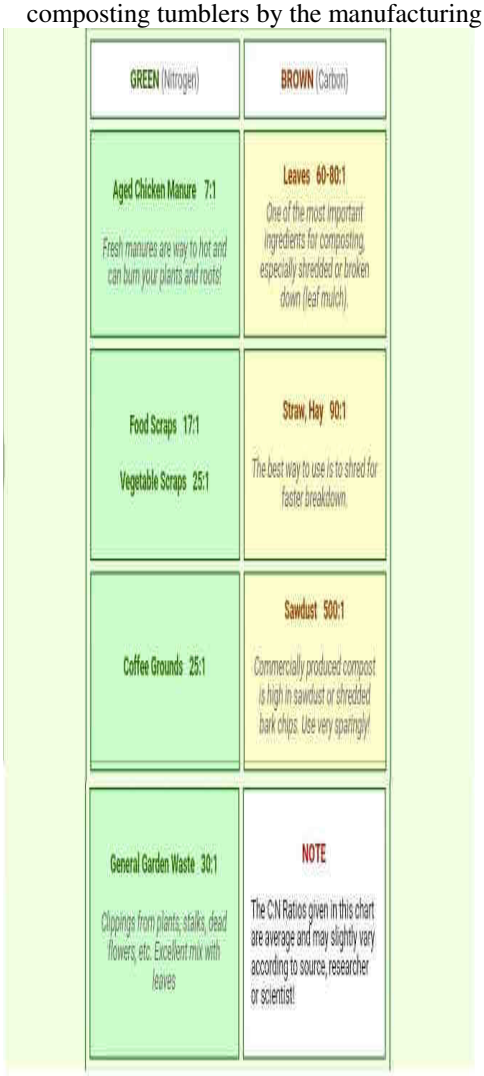
7.2.2 Waste collection by the Collectors: Municipal waste Collecting vehicles and privately owned waste collectors need to be partitioned proportionately their vehicles and rickshaw as per the color codes (for green and red waste).on the back side of the vehicle/rickshaw a bag will be hanged to collect recycled waste. Safai-karamcharis who sweep streets will be responsible for collecting just brown waste from parks and roadsides which includes shredded leaves, hay, woody chips, and twigs and carry them to nearby receptacles. Difficult part is sorting of waste as it is will be way easier by this method(not 100% but still it will reduce pressure on landfills and incinerators(if used) which are meant for organic waste and rejected waste. Remaining Recycled waste will reach to its destination since they are sold to junk dealers undoubtedly by the people which are bought by industries. In this way sorting of waste will be maintained in the midway and hence waste can be easily dumped in receptacles based on the characteristics of the waste.

7.2.3 Distribution of Waste and its processing: Lack of infrastructure development is one of an impediment to this system. Hence local bodies should provide revenues for their maintenance. Retrofitting and renovation of receptacles which is the mediator in accumulation of waste is a must requirement. Retrofitting includes building it as per the color code of green and red for proper collection of waste from waste collectors. Just as the in traffic system, the uniform colour coding has saved thousands of lives as people can easily acknowledge the process without any science involved in this. Same applies to the system of waste collection, loading and unloading at receptacles which involve semi-skilled, unskilled workers. Colour coding will be easy for them to understand and implement comparatively. Now the red waste which includes the rejected waste will go for incineration. On the other hand industries can be set up in the suburban areas to process the waste for production of manure and energy. Industries which are involved in turning composting will be given the green waste as per the requirement. It is composed of proper combination of Green (Vegetable, fruits Scraps) and brown Waste (Leaves), air, moisture which produce processed manure in 2-3 weeks. Recycled waste will be sent to industries on monthly basis. The part of workers for collecting the brown waste mainly leaves will collect it in receptacles after sweeping on streets. This is how it will completely segregate the waste and hence the input material will be good. Subsequently it will improve the quality of the present working system.

In order to boost up the working system, we will add up on site Tumbler composting (same as household composting) that needs proper combination of brown waste, green waste, and air. A compost tumbler is a compost bin designed to be rotated, so that materials inside are remixed for aeration and faster composting. Most are supported off the ground by a frame, so they can be situated on sealed pavement. The same materials that could be added to a compost tumbler, and often the tumblers are able to heat and break down the material faster and with far less water than a pile. The result is a rich, uniform fertiliser for the plants. Compost tumblers will be economical and the utility they offer makes them well worth considering. It will be accompanied by semi-skilled workers that will easily be put on work after short training with the help of NGO's which promote waste management like CHINTAN. All waste created cannot be treated on same day but can be reduced slowly and steadily which is far better than dumping. Location of these sites will be near to receptacles (for easy transportation of waste) or barren lands (for large amount composting). The manure produce from this is quick (2-3 weeks) and can be sold to industries (on tender) for further refinement so that it can be sold to farmers for agricultural use.

With time this will surely increase the rate of waste treatment, its efficiency of increasing the production of manure, reduction of load on landfilling and increase in employment(as composting can be done with basic knowledge that will be fulfilled with the help of NGO's who are working on waste management and employment).

Figure4: Sample pamphlet that can be stuck on the composting tumblers by the manufacturing industries.



VIII. Equation and Calculations

Considering two Receptacles in account which is of size (3m * 1.5m* 1m) in per kilometer square area.

Assuming each Tumbler will give end product in 21 days and its capacity to treat house hold waste that is vegetable and fruit scraps is 1125 kg (Assuming bulk density of solid waste is 250 kg/m3).

A. Assuming one Receptacle receives waste from circular area of radius 1 Kilometer.
B. Total Area for two receptacle is = 3.14 Square Kilometer
C. Population density per Square Kilometer=11,312
D. Therefore, total people in area of 3.14 Square Kilometer =(3.14*D) = 35,519 Persons
E. On an average total solid waste produced by person is = 0.5 Kg /Day/person
F. Total solid waste produced in a day = (D*E/1000) =17.76 Tons
G. Total solid waste accumulated in 21 days at two receptacles=(F*21) = 372.96 Tons
H. % of biodegradable waste/green waste in Solid waste= 38%
I. Total green waste accumulated in 21 days at two receptacles= (G*H) = 141.72 Tons
J. Assuming 12 tumblers will be provided nearby each receptacle.
K. Total capacity to treat green waste by tumbler composting in circle of 1 Kilometer = (2*12*1125/1000)= 27.00 Tons
L. Reduction in green waste per receptacle = (K/2) / (I/2) *100 =19.05 %

Hence reduction of 19.05% green waste can be achieved by introduction of tumbler composting near the receptacles. This figure can be increased by introduction of more tumblers in waste or barren lands or park if possible. The manures obtained can be sold to the industries for further processing.

IX. Man and Machinery

The possibility and success of this method can be accomplished certainly, if there would be adequate number of man and machinery. There is a need of effective coordination between the workers as well as cooperation is required from the local administration and management team for timely provision of the vehicles. Apart from this, training and awareness programs for workers, supervisors are must requirements to get the desired outcomes.

Following resources will be needed in the circle area of radius one kilometer –

1. 1 Safai-karamchari who will look after the receptacles and tumblers in that area. Maintenance of it will be his responsibility and to look after that private sweepers abide by the methodology.
2. 1 hand move cart for transport of waste.
3. MCD vehicle for collecting waste/Private sweepers.
4. 20-30 Tumblers
5. 1 Recycle Waste Dustbin
6. If there is any open non usable area in given part then tumblers can be put along with a helper for Safai-karamcharis.
7. NGOs will help in providing elementary education to private sweepers as well as increasing awareness in the citizens.

X. Digitalization of Waste Management

With promotion of digitalization in the country, waste can also be managed with the help of e-system. Development of vehicles which will work with the help of swipe cards as in case of Metro system. Every citizen will be given their swipe card which can be recharged online. For every ounce of waste introduced in the collection vehicle by the people, particular amount will be deduced from the card. It would also help in collection of data regarding the waste generation and taking more advanced steps if required to make the process smoother.

Conclusion

Waste generation is a never ending process. Hence a proper system needs to be developed which can be practiced by people. It has the potential to be the sustainable business

model. The must requirements are proper awareness of people, effective utilization of resources, proper monitoring of process to make it digital. Once this model will be established the end product can be increased by setting up a waste process industry in the outskirts or in middle of the city taking in account the environmental impact. The generation of manure from the proper segregated green waste will be of high quality. Additionally, windrow composting can also be used if there is large availability of land beside the industry to consume the ample amount of waste and turn it into manure. Manure can be sold directly to fertilizer producing industry for further refinement. The methane gas generated from the waste process can be utilized in meeting the power consumption required for waste treatment process. Apart from this the recycled waste from the receptacles can be given to other industries which need them on lump sum basis. The rejected waste can be sent to the incinerators for further decomposition.

The scope of this project is not limited to just one city. An efficient and sustainable model will be sufficient to meet demands of the people and then it can be implemented in other cities accordingly. In fact, there will be complete government assistance in such projects. There will be probability of generation of money by offering such green services which are in good faith of the nation. The only need of hour is efficient utilization of human resources, setting up an industry or acquires an already existed one, development of awareness in people to adopt the process, government and local bodies' assistance in distribution of pamphlets. Tenders are floated every year in regard to projects for waste management which can be a good source to step into this field.

To conclude, a thorough amalgamation of research and management can be essential in establishment of cost ineffective, green and sustainable plan in a due course of time.

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