The Ecofriendly Optimal Disposal and Treatment of Biodegradable Municipal Solid Waste - A Case Study of Ahmedabad City

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Abstract--- Ahmedabad is one of the largest and fastest growing cities of India. The rate of growth of MSW (municipal solid waste) in the city is at the rate of 87181 tons per year. The management of MSW is an area of universal concern for both the developed and developing world. As per the latest data from AMC (Ahmedabad Municipal Corporation), 4000 tons of MSW is generated daily. AMC has done an agreement with several groups of industries to treat MSW by giving 108 acres of land on lease. The total cost for set up of these industries is Rs.430 crores. Optimal solution to this problem is the need of present time. This paper focuses on the optimal disposal and treatment of biodegradable MSW of Ahmedabad City. This paper also gives quantitative assessment of recycling of biodegradable waste. The proposal given in this paper is not only economic but also an ecofriendly.

Keywords: Municipal solid waste, biodegradable, disposal, quantitative assessment, cost, benefits

I. INTRODUCTION

The solid waste is dumped in the open landfill site, so the nearby area and water resources are affected. The huge heap of waste contains large number of flies and organisms which create nuisance. Open dumps attract numerous birds that feed on the wastes, which can make them more serious disease vectors than flies or rodents. The solid waste, in this dumping process, undergoes slow, anaerobic decomposition over a period of 30-50 years and generate substantial amount of leachate with decomposition products, heavy metals and a variety of hazardous pollutants which may seep from the landfill site into underground aquifers and thus polluting much needed urban water resources. There are also possibilities of surface runoff and/or overflow of the leachate to the surrounding agricultural lands, ponds, canals and rivers causing surface water quality deterioration [1].The present paper focuses on the ecofriendly disposal of biodegradable waste in the compost pit. The design is done considering the waste to be generated in the future. The cost involved in this project is calculated and the benefits incurred from the project are also found. Then finally the benefit cost ratio is calculated.

II. DESIGN

As per the data from AMC, the waste generation in the year 2013 was 4000 tons/day [2]. Out of the total waste, about 50% is the biodegradable waste, i. e. 2000 tons/day. But we will design the compost yard by considering the amount of the waste to be generated in the future years. We are going to design the compost yard which can accommodate 4000 tons/day of the biodegradable waste. We will consider the design period of 6 years. The compost yard can be built near the landfill site of Ahmedabad city i.e. Pirana which can convert huge amount of nonhazardous waste into useful source. Total composting of the waste takes about 3 months. Fig. (1) Shows the shape of the pit or trench selected for composting the biodegradable waste of Ahmedabad city.

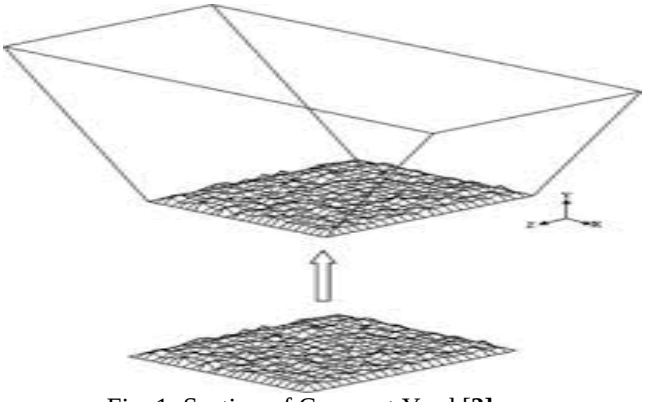

Fig. 1: Section of Compost Yard [**3]**

- We are designing the compost yard for 4000tons/day of biodegradable waste i.e. 4000*1000 kg.
- The average density of the biodegradable waste is about 500 kg/cu.m.
- Total volume of the waste = mass/density = 4000000/500 = 8000 cu.m. Per day.
- The size of the pit should be such that it can easily accommodate 8000 cu.m. Of the waste.
- Let the size of the top cell and bottom cell is 50m*50m and 40m*40m.
- The depth of the trench is 4m.
- The volume of the pit can be calculated by using the following equation :
  (Area of top cell*Area of bottom cell)*depth of trench/2 = (50*50+40*40)*4/2 = 8200 cu.m.
- Total composting takes about 3 months. So the total volume of the waste for 3 months will be 8000*90 = 72000 cu.m.
- Number of pits =Total Volume of waste/Volume of 1 pit = 72000/8200 = 87.80 say 95. The extra pits are provided to meet the fluctuations during the periods of high waste generation.

III. QUANTITATIVE ASSESSMENT OF THE PROJECT

We will calculate the cost of the following:

- Land
- Machinery and Equipment
- Fuel
- Staff salary
- Brick masonry
- PCC (plain cement concrete)
- Excavation

A. *Cost of land*

- Total area required with sufficient margin = 53*53*95 = 266855 sq.m. = 26.68*10^4 sq.m. = say 27*10^4 sq.m.

- 1 bigha = 2378 sq.m. So area 27*10^4 sq.m. = 27*10^4/2378 bigha = 113.54 bigha = say 114 bigha
- The cost of land per bigha is about 10 lacs. So the total cost of land is 114*10 lacs = 1140 lacs = Rs. 11.40 crores.

B. *Number of trucks and jcbs required:*

1) For Trucks

- Calculation is done by considering that the staff works 8 hours/day.
- The approximate time taken by 1 truck to collect the waste from the landfill site to the compost yard is about 1.5 hrs. I.e. 1 hour 30 minutes. So in 1 day 1 truck can make 5 trips.
- The volume of 1 truck is 8 cu.m. This means that 1 truck can carry 40 cu.m. Of waste per day.
- Number of trucks = Volume of waste per day / Capacity of 1 truck per day = 8000 cu.m. /40 cu.m. = 200 trucks.

2) For JCBs

- The time taken by JCB for filling 1 truck is 15 minutes. So in 1hour it can fill 4 trucks. And in 1 day it can fill 32 trucks. Let it be 30 trucks per day.
- Total number of trips by 200 trucks per day = 200*5 = 1000 trips.
- Numer of JCBs required = 1000/30 = 33.33 = say 34 JCBs

C. *Cost of trucks and JCBs :*

- Cost of 1 truck = 20 lacs Rs. So for 200 trucks = 200*20 = 4000 lacs Rs = Rs. 40 crores
- Cost of 1 JCB = 35 lacs Rs. So For 34 JCBs = 34*35 = 1190 lacs = Rs. 11.90 crores.

D. *Cost of fuel required by trucks and JCBs:*

- One truck travels about 20 km/trip. This means that 1 truck travels 20*8 = 160 km/day.
- Total number of trucks is 200. So total travel is = 200*160 = 32000 km/day.
- The average of 1 truck is 5 km/hr. The amount of fuel used = 32000/5 = 6400 litres.
- The cost of diesel is 60 Rs/litre. So the total cost is = 6400*60 = 384000 Rs/day = 384000*30 = 11520000 Rs/month.
- One JCB requires about 40000 Rs of diesel per day. So for 1 month it needs 40000*30 = 1200000 Rs of diesel.
- Total cost of fuel for 200 trucks and 34 JCBs per year = (11520000+1200000)*12= 152640000 Rs = Rs. 15.26 crores

E. *Cost for staff salary*

Sr. No.	Position	Numbers	Salary/month (in Rs.)	Total (in Rs.)
1	Truck Driver	200	10000	2000000
2	JCB Driver	34	12000	408000
3	Supervisor	2	10000	20000
4	Helper	4	6000	24000
5	Watchman	4	6000	24000
	Total	244	44000	2476000

Table. 1**:** Staff Salary

- Total cost per year = 2476000*12 = 29712000 = Rs. 2.97 crores

F. *Construction cost*

Cost of the following two major works is calculated:

- Brick Masonry
- PCC (Plain Cement Concrete)

1) Brick masonry

- Cost of brick masonry for 1 pit is calculated and it is multiplied by the total number of pits to obtain the total cost.
- Area of trapezoid section = (Top width + Bottom width)*slant height*0.5
- = (50+40)*6.40*0.5 = 288 sq.m.
  Slant height = sq. rt. (4^2+5^2) = 6.40m
- In one pit, 4 trapezoid sections are there. So total area = 288*4 = 1152 sq.m.
- Volume of masonry work = 1152*0.2 = 230.4 cu.m. = say 231 cu.m.
- Cost of the following four items are calculated :
  1) Bricks
  2) Cement
  3) Sand
  4) Labour

2) Cost of Bricks:

- Number of bricks required in 1 cu.m. = 500
- Total bricks required in 231 cu.m. = 231*500 = 11550
- Cost of 1 brick = Rs. 5
- Total cost of bricks = 11550*5 = 577500 Rs

3) Cost of Cement:

- Wet volume of mortar = 231*0.25 = 57.75 cu.m.
- Dry volume of mortar = 57.75*1.2 = 69.3 cu.m.
- 1:6 mortars are used. So volume of cement = dry volume of mortar *ratio of cement / total ratio = 69.3*1/7 = 9.9= say 10 cu.m.
- Number of cement bags required in 1 cu.m = 30.
- Total number of cement bags = 10*30 = 300.
- Cost of 1 cement bag = 300 Rs.
- Total cost of cement = 300*300 = 90000 Rs.

4) Cost of Sand:

- Volume of sand = dry volume of mortar *ratio of sand / total ratio = 69.3*6/7 = 60 cu.m.
- One truck contains 8 cu.m. Of sand. So total number of trucks = 60/8 = 7.5 = say 8 trucks.
- Cost of 1 truck of sand = 5000 Rs.
- Total cost of sand = 8*5000 = 40000 Rs.

5) Labour cost:

- Cost of 1 mason = 700 Rs.
- Cost of 1 labourer = 350 Rs.
- Cost for 1.25 cu.m. brick masonry with 1 mason and 2 labourers = 700+350*2 = 1400 Rs. [4]
- So cost for 231 cu.m. Brick masonry = 231*1400/1.25 = 258720 Rs.

Sr. No.	Items	Cost (Rs.)
1	Bricks	577500
2	Cement	90000
3	Sand	40000
4	Labour	258720
	Total	966220

Table. 2**:** Total cost for 1 pit for brick masonry

Total cost of brick masonry for 95 pits = 966220*95 = 91790900 Rs. = Rs. 9.17 crores.

6) Cost of PCC (1:2:4):

- Volume of concrete = Bottom area * 0.15 = 40*40*0.15 = 240 cu.m.
- Wet volume of concrete = 240*1.52 = 364.8 cu.m.
- Cost of the following four items are calculated :
  1) Cement
  2) Sand
  3) Aggregates
  4) Labour

7) Cost of Cement:

- Volume of cement = wet volume of concrete*ratio of cement / total ratio = 364.8*1/7 = 52.11 cu.m.
- Number of cement bags required in 1 cu.m = 30.
- Total number of cement bags = 52.11*30 = 1563 = say 1570
- Cost of 1 cement bag = 300 Rs.
- Total cost of cement = 1570*300 = 471000 Rs.

8) Cost of Sand:

- Volume of sand = wet volume of mortar *ratio of sand / total ratio = 364.8*2/7 = 104.22 cu.m.
- One truck contains 8 cu.m. of sand. So total number of trucks = 104.22/8 = 13.02= say 13 trucks.
- Cost of 1 truck of sand = 5000 Rs.
- Total cost of sand = 13*5000 = 65000 Rs.

9) Cost of Aggregates :

- Volume of aggragates = wet volume of mortar *ratio of aggragate / total ratio = 364.8*4/7 = 208.44 cu.m.
- One truck contains 8 cu.m. Of sand. So total number of trucks = 208.44/8 = 26.055 = say 26 trucks.
- Cost of 1 truck of sand = 15000 Rs.
- Total cost of sand = 26*15000 = 390000 Rs.

10) Cost of Labour:

- The cost of labour is 30% of the material cost = 30% * (471000+65000+390000) =0.3*926000 = 277800 Rs.

Sr. No.	Items	Cost (Rs.)
1	Cement	471000
2	Sand	65000
3	Aggregate	390000
4	Labour	277800
	Total	1203800

Table. 3**:** Total cost for 1 pit for PCC

Total cost of PCC for 95 pits = 1203800*95 = 114361000 Rs. = Rs. 11.44 crores.

G. *Cost of excavation:*

- Cost of excavation of 100 cu.m. Volume = 10950 Rs.
- Volume of 1 pit = (50*50+40*40)*2/2 = 4100 cu.m.
- The depth is taken as 2 meter instead of 4 because the excavation is done for 2 meter and the excavated earth is laid for the for the remaining 2 meter.
- So cost of excavation of 1 pit cu.m. Volume = 10950*4100/100 = 448950 Rs.
- Cost for 95 pits = 448950*95 = 42650250 = Rs. 4.26 crores.

Sr.No.	Items	Cost (in cr. Rs.)
1	Land	11.40
2	Machinery	51.90
3	Fuel	15.26
4	Staff Salary	2.97
5	Brick Masonry	9.17
6	PCC	11.44
7	Excavation	4.26
	Total	106.4

Table. 4**:** Total expenditure per year

Total expense is Rs. 106.4 crores.

IV. Benefits From The Project

Amount of the waste in 1 pit = 4000 tons = 4000*1000 kg.
After considering some losses, amount of manure obtained from 1 pit = 3500 tons = 3500*1000 kg.
Density of manure = 600 kg/cu.m.
Volume of manure from 1 pit = 3500*1000/600 = 5833.33 cu.m.
Capacity of 1 truck = 8 cu.m.
Number of trucks of manure obtained per day = 5833.33/8 = 729.16 = say 730
Cost of 1 truck of manure = 15000 Rs.
Total income per day = 15000*730 = 10950000 Rs.
Total income per year = 10950000*365 = 3996750000 Rs. = 399.67 cr. = say Rs. 400 crores

V. Benifit Cost Ratio (B/C):

Total Benefit / Total Expense = 400 cr. Rs / 106.4 cr Rs. = 3.75

VI. Conclusion

4000 tons of MSW is tackled by the present proposed method. The cost incurred initially is recovered after 7 months from the date of starting the disposal plant after its construction and subsequently each month gives a huge amount of Rs. 33.33 crores which can be utilized for efficient collection system of MSW in Ahmedabad city.

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