International Research Journal of Engineering and Technology (IRJET) e-ISSN: 2395-0056
Volume: 06 Issue: 06 | June 2019 www.irjet.net p-ISSN: 2395-0072

MUNICIPAL SOLID WASTE MANAGEMENT PLAN FOR KOTTAYAM CITY

Anu Paul[1], Aleena Paul[2], Anjaly Francis[3], Anu Baby[4], Sandra Shaji[5]

[1]Assistant Professor, Dept. of Civil Engineering, Viswajyothi College of Engineering and Technology Vazhakulam, Kerala, India
[2,3,4,5]UG Students, Dept. of Civil Engineering, Viswajyothi College of Engineering and Technology Vazhakulam, Kerala, India

---

Abstract -. *Solid Waste is an unavoidable byproduct of most human activities. Kerala state being enriched by natural resources and good environmental conditions is also going through the phase of urban development. Kottayam City is considered as the administrative capital of Kottayam district located in south-west of Kerala. The waste treatment practices of the city have major impact on human health, air quality, water quality, ecological, aesthetic and development dimensions. The dumping yard for Kottayam Town and nearby places like Panachikkad, Athiranpuzha, Naatakam, Aimanam, Puthupalli, Vijayapuram and Ettumannor is located at Vadavathoor. Currently at Vadavathoor, waste is dumped in an unhygienic manner. The present study suggests an integrated solid waste management consisting of a material recovery, composting unit, incinerator. For biodegradable waste, windrow compost is designed. For plastic waste, paper, rubber etc.. incinerator is designed. The scope of this project is to design a effective landfill by using suitable parameters.*

***Key Words*: Solid Waste, Windrow Compost, Incinerator**

1. INTRODUCTION

Municipal Solid Waste is one of the major concerns of present society. Due to rapid urbanization and increase in population the amount of Municipal Solid Waste generation rises to a level that it requires a properly integrated waste management system. Municipal Solid Waste includes commercial and residential waste generated in a municipal or notified area in either solid or semi-solid form. It excludes industrial hazardous waste but includes treated bio-medical waste. Increasing solid waste generation and subsequent issues are one of the major problem faced by a developing country like India. One of the major functions of municipal authorities is the management of solid waste. Due to lack of facilities and outdated methodologies, the effective management of waste become impossible. The main two causes of increase in solid waste is rapid urbanization and change in lifestyle of people. Physical composition of municipal waste indicates that there is 40-60 percent of compostable matter and 10-25 percent of recyclable matter.

1.1 Methodology Adopted in Kottayam

Kottayam Municipality is an area in the central part of Kottayam district with an area about 15.99m^2 and consists of 52 wards. Average amount of waste generated in Kottayam Municipality from all sources is about 52.3tonnes/day.The waste generated was dumped at a yard located at Vadavathoor which is about 5 km from the heart of the city. Due to unscientific processing of waste and public protest the yard was closed in 31st December 2013.

1.2 Vadavathoor Dump Yard

The dump yard at Vadavathoor is located in the Vijayapuram Panchayat of Kottayam Municipality and is 7.42 acres in area. Earlier the dump yard consisted of a compost manufacturing unit treating organic, putreceable matter. But due to change in composition of waste generated the treatment process became inefficient which resulted in open dumping. Segregation of waste was not done in a proper way which added to this menace. Increased dumping of collective waste in the yard gave rise to many public problems. Due to this the air had a bad stench and the ground water table was polluted due to the leachate leaking problems. Finally the yard was forced to shut down.

1.3 Present Scenario

Now the dump yard has no activities of waste treatment going on but problems arise due to leaking of leachate leading to water pollution resulting in degradation of the drinking water quality and making it unfit for drinking purposes. Various contagious diseases were reported due to the consumption of this water.

Table -1: Quantity of Municipal Solid Waste in Kottayam

Municipal Solid Waste Generation sources	Quantity (t/d)
Organic, Putrescible Wastes	38.3 tons
Paper and Packing Paper Materials	5.4 tons
Plastics	3.0 tons
Glass	0.9 tons
Metals and metallic wastes	2.2 tons
Cloth, leather, etc	0.8 tons
Others	1.7 tons

2. POPULATION PROJECTION

The population details for the last 3 decades collected from the census of India official website. Population projection dependent on factors governing future growth and development in the considered jurisdiction. Growth in all development sectors should be considered. Population growth can be estimated using multiple methods which are suited for cities of different sizes and stage of growth. In this study we need geometrical increase method.

$$P_b = P_a[\ 1+r]t$$

P_b= population of the year for which projection to be made
P_a= population of the base year
r = the rate of growth divided by 100
t= number of years between a and b

Table -2: Population Projection

Year	Population
2011	55374
2019	56479
2020	56619
2021	56759
2022	56899
2023	57040
2024	57181
2025	57322
2026	57464
2027	57606
2028	57748
2029	57891
2030	58034
2031	58178
2032	58321
2033	58466
2034	58610
2035	58755
2036	58900
2037	59046
2038	59192
2039	59338
2040	59485
2041	59632
2042	59779
2043	59927
2044	60075

3. PROJECTED WASTE GENERATED

Waste generated is projected for a design period of 25 years using exponential growth method. The formula used is;

$$P_T \ = P_0[1 + r]t$$

P_T = per capita waste at time T
P_0 = per capita waste at initial time
r = growth rate (1.41/annum)
t = elapsed time in years from initial time

Table -3: Projected Waste Generated

Year	Population	Waste Generated(g/h/d)	Total Waste (t/d)
2011	55374	691.65	38.3
2019	56479	773.62	43.69
2020	56619	784.53	44.41
2021	56759	795.59	45.15
2022	56899	806.81	45.9
2023	57040	818.19	46.66
2024	57181	829.72	47.44
2025	57322	841.42	48.23
2026	57464	853.29	49.03
2027	57606	865.32	49.84
2028	57748	877.52	50.67
2029	57891	889.89	51.51
2030	58034	902.44	52.37
2031	58178	915.17	53.24
2032	58321	928.07	54.12
2033	58466	941.16	55.02
2034	58610	954.43	55.93
2035	58755	967.88	56.86
2036	58900	981.53	57.81
2037	59046	995.37	58.77
2038	59192	1009.4	59.74
2039	59338	1023.64	60.74
2040	59485	1038.07	61.74
2041	59632	1052.71	62.77
2042	59779	1067.55	63.81
2043	59927	1082.6	64.87
2044	60075	1097.87	65.95

4. DESIGN OF WINDROW COMPOSTING

Total amount of waste generated for a design of 25 years = 5,13,289 tonnes. (data from projected waste generated)

Annual tonnage = 20,532 tonnes.

Compost pad area worksheet:

STEP 1: Determining the planning figure for site

Determine the total annual volume.

Annual volume = Annual tonnage / bulk density

$= (20{,}532 \times 10^3) / (267.81\ kg/m^3)$

$= 76{,}666.29\ m^3$ / year

During composting ,materials can lose one half or more of their initial volume. It represents the loss of CO_2 and water to the atmosphere. The volume of material obtained can be multiplied by an average shrinkage factor of 75% (1-0.25)

TCMV 76,666.29 m^3/year x 0.75 = 57,499.71 m^3 /year Total reduced volume (TRV) = 57,499.71 m^3/year

(TCMV- Total Combined Material Volume)

(TRV - Total Reduced Volume)

If the composting period is less than one year, multiply the total reduced material volume by the no of months in the composting period divided by 12.

57,499.71 m^3/year x40 days / (365 days / year) = 6,301.33 m3 (total adjusted volume)

STEP 2: Calculate active pad size

Calculate the cross sectional area of a single windrow

Let the cross section be oval.

Area = 2/3 x base width x height

Assume base width =14 feet and height =7 feet (1 feet = 0.30482m)

Area = 2/3 x 7 x 14 x.304822 = 6.1 m^2

Calculate of volume of single windrow

Pile volume = cross section x pile length

Pile volume = 6.1 x 30 =183 m^3

No of windrows = Total volume /volume of one windrow

= 6,301.33/183

= 34.44 windrows = approx. 35 windrows

Pad width = total width of piles across site +total width of aisles between piles + equipment lanes

Number of aisles = Number of piles – 1

Total width of piles = width of each pile x number of piles provided in one row

=7 x 14 x .3048 = 30 m

Total width of aisles = (7-1) x width of each aisles

=6 x1.5 =9 m

Total pad width = width of piles + width of aisles + perimeter space

Assume perimeter space of 2.5m

= 30+9+2.5+2.5= 44m

We provide 7 piles in each row and 5 piles in each column.

Total length of piles=5x30= 150m

Total length of aisles= (5-1)x1.5= 6m

Assume perimeter space of 2.5 m

Total pad length = Total length of piles +Total length of aisles + perimeter spaces on both sides= 150+6+2.5+2.5=161m.

Pad area = pad width x pad length=44x161 =7084m^2

In general, each windrow should be allowed to stay on the compost pad for 35 days; at the end of the 35th day, the compost is ready for use. Each windrow should have a flag board depicting the age of the waste. Fresh incoming waste is always depicted as "Age 1." The numbering on the windrow changes from Age 1 to Age 2 on the second day, Age 2 to Age 3 on the third day, and so on. Each windrow may be turned manually or mechanically. This turning process has to be done every 7th day. Hence, only those windrows having a flag board showing Age 7,14, 21, and 28 should be turned. Figure 5.1 below illustrates an indicative arrangement of windrows. Incoming waste on day 1 is placed in pile A1. Waste that comes in on day 2 is placed in pile A2, waste on day 3 in pile A3, and so on. On the 7th day after receiving the first batch of waste A1, the pile or windrow is turned or mixed, and the pile is moved to location B1. On the 14th day, pile B1 is turned or mixed and moved to C1, and so on. Pile D1 will therefore be moved to E1 on the 28th day. On the 35th day, the compost pile from E1 should be screened for further refinement. Each of the piles or windrows A2 to A7 are managed similarly. Waste that is received on 8th day is placed in the initial location of pile A1, since this pile would already move to B1 on the 7th day, hence this location would be free to receive a new pile or windrow.

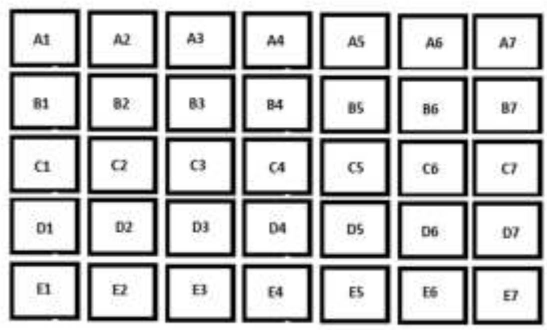

Fig -1: Arrangement of Windrows

5. DESIGN OF INCINERATOR

Design of Primary Chamber

For designing the primary chamber, initially volume of the chamber is to be found out. For finding out the volume 100kg of waste is dumped as a heap and the volume of the heap is considered.

Volume of the heap = 5m^3

Assuming a suitable depth of 2.2m, we can find out the area of the chamber

Area = volume/depth

= 5/2.2= 2.3m^2

Assume length and breadth as 1.5:1

Therefore, L/B =1.5/1

L =1.5B

Dimensions of the primary chamber = L*B*H

Therefore, A = L*B

2.3 = 1.5B*B

2.3 = 1.5 B2

B = 1.238m

L = 1.857m

H = 2.2m

Heat and Material Balance Sample Calculation

A heat and material balance is an important part of designing and/or evaluating incinerators. The procedure entails a mathematical evaluation of the input and output conditions of the incinerator. It can be used to determine the combustion air and auxiliary fuel requirements for incinerating a given waste and/or to determine the limitations of an existing incinerator when charged with a known waste.

Table -4: Higher Heating Values

Components	Fraction of components %	Empirical Formula	Molecular Weight	Higher Heating Value(KJ/Kg)
Plastic	29.7	$(C_2H_4)n$	28.1	3664
Paper	53.5	$(C_6H_{10}O_5)n$	162.1406	45466
Glass	8.91	SiO_2	60.08	0
Rubber	7.92	$(C_5H_8)n$	68	32934

Step 1: Assumptions

An incinerator is to be designed to incinerate about 100 kg/h of Waste. The auxiliary fuel is natural gas; the waste has been ignited; and the secondary burner is modulated.

Design requirements are summarized as follows:

➢Secondary chamber temperature: 1100°C

➢Flue gas residence time at 1000°C: 1 second

➢Residual oxygen in flue gas: 6% minimum

Calculations involving incineration of waste are usually based on a number of assumptions. In our design, the chemical empirical formula, the molecular weight and the higher heating values of each of the main components of waste have been taken as above.

▪Input Temperature of waste, fuel and air is 150C.

▪Air contains 23% by weight O2 and 77% by weight N2.

▪Air contains 0.0132kg H2O/kg dry air at 60% relative humidity and 26.70C dry bulb temperature. For any ideal gas 1kg mole is equal to 22.4m3at 00C and 101.3kPa.

▪Latent heat of vaporization of water at 150C is 2460.3kJ/kg.

Step 2: Calculation of Material Input

The above table provides a range of characteristics for various types of waste. Sound judgment should be exercised when making use of this table to assign the component weight percent required performing heat and material balance calculations. Based on an input of 100 kg/h was assumed to have the following composition.

Table -5: Input Composition of Component

Component	Empirical Formula	Composition
Plastic	$(C_2H_4)n$	0.297 x 100 = 29.7 kg/h
Paper	$(C_6H_{10}O_5)n$	0.5346 x 100 = 53.46 kg/h
Glass	SiO_2	0.0891 x 100 = 8.91 kg/h
Rubber	$(C_5H_8)n$	0.0792 x 100 = 7.92 kg/h
		Total = 100 kg/h

Step 3: Calculation of Heat Input of Wastes (kJ/h)

Table -5: Total Heat Input

Component	Higher Heating Value(kJ/h)	Input (kg/h)	Total Heat in kJ/h
$(C_2H_4)n$	3664	29.7	108820.8
$(C_6H_{10}O_5)n$	45466	53.46	2430612.3
SiO_2	0	8.91	0
$(C_5H_8)n$	32934	7.92	260837.2
Total	82064	100	2800270.3

Step 4: Determination of Stoichiometric Oxygen for Wastes

The total stoichiometric (theoretical) amount of oxygen required to burn (oxidize) the waste is determined by the chemical equilibrium equations of the individual components of the waste and are provided in the following:

1. $(C2H4) + 3O2 = 2CO2 + 2H2O$

   28.1 3(32) 2(44) 2(18)

   1.0 3.43 3.14 1.29

   29.7 101.87 93.25 38.31

2. C6H10O5 + 6O2 = 6CO2+ 5H2O

   162.1 6(32) 6(44) 5(18)

   1.0 1.19 1.63 0.56

   53.46 63.6 187.13 29.93

3. $(C5.H8) + 7O2 = 5CO2 + 4H2O$

   68 7(32) 5(44) 4(18)

   1.0 3.29 3.23 1.06

   7.92 26.05 25.58 8.39

The stoichiometric oxygen required to burn the combustible component of the waste (191.53kg/h) is 190.98kg/h oxygen (sum of 101.87, 63.61 and 26.05).

Step 5: Determination of Air for Waste Based on 150% Excess

From step 4, stoichiometric oxygen is 191.53 kg/h.

Therefore, stoichiometric air =190.98*100/23 = 832.73kg/h air

Total air required for waste (at 150% excess) = (1.5*832.73) + 832.73=2081.82kg/h

Step 6: Material Balance

Total Mass in Waste = 100.0 kg/h

Dry air = 2081.82 kg/h

Moisture in air = 27.48kg/h (2081.82 x 0.0132) [step1]

Total Mass = 2209.3kg/h

A. Dry Products from waste

Air supplied for waste = 2081.82kg /h

Less stoichiometric air for waste = 832.73 kg/h

Total excess air = 1249.09 kg/h or 150%

Add nitrogen from stoichiometric air 0.77 X 832.73 = 641.20kg/h

Sub-Total = 1890.29kg/h

Add total CO2 from combustion:

CO2 formed from $(C5.H8)$n= 25.58 kg/h

CO2 formed from (C2H4) x = 93.25kg/h

CO2 formed from C6H10O5= 87.13 kg/h

Total Waste Dry products = 2096.25kg/h

B. Moisture

H2O from combustion reactions = 76.63kg/h

H2O in combustion air = 27.48kg/h [step 6]

Total Moisture = 104.11 kg/h

Step 7: Heat Balance

A. Total Heat in From Waste (Qi)

Qi = 2800270.3 kJ/h [see Step 3]

B. Total Heat out Based on Equilibrium Temperature of 1100°C (Qo)

i) Radiation loss = 5% of total heat available

= 0.05 x 2800270.3

= 140013.5 kJ/h

ii) Heat to dry combustion Products = mCpdT

= (2096.25) (1.086) (1084.5)

= 2468894kJ/h

Where m = weight of combustion products =2096.25kg/h

Cp = mean heat capacity of dry products = 1.086 kJ/kg°C (assumed average value)

dT = (1100-15.5) °C = 1084. 5°C

iii) Heat to moisture = (mCpdT) + (mHv) = (104.11x 2.347 x 1084.5) + (104.11x 2460.3) = 264993+ 256142 = 521135kJ/h

Where m = weight of water = 104.11kg/h

Cp = mean heat capacity of water = 2.347 kJ/kg. °C

dT = (1100-15. 5) °C = 1084. 5°C

Hv = latent heat of vaporizations of water = 2460.3 kJ/kg

Total Heat Out (Qo) = sum of (i, ii, iii) = 3130042.5kJ/h

Net Balance = Qi – Qo= 2800270.3– 3130042.5= - 329772.2 kJ/h (deficiency)

Auxiliary fuel must be supplied to achieve Design temperature of 1100°C.

Step 8: Required Auxiliary Fuel to Achieve 1100°C

Total heat required from fuel = 329772.2 + 5% radiation loss

= 346260.81 kJ/h

Available heat (net) from natural gas at 1100°C and 20% excess air = 15,805.2 kJ/m^3(assumption)

Natural gas required =346260.81 /15,805.2 m^3/h = 21.90m^3/h

Step 9: Products of Combustion from Auxiliary Fuel

Dry Products from Fuel at 20% Excess Air = 16.0 kg [8] x21.90 m^3/h m^3 fuel = 350.4kg/h

Moisture from Fuel = (1.59 kg (8)m^3 fuel) x21.90 m^3/h

= 34.82kg/h

Step10: Secondary Chamber Volume Required to Achieve One Second Residence Time at 1000 °C

i) Total Dry Products from waste + fuel =2096.25kg /h + 350.4kg/h = 2446.65 kg/h

Assuming dry products have the properties of air and using the ideal gas law, the volumetric flow rate of dry products (dp) at 1000°C (Vp) can be calculated as follows:

V_p = 2446.65 kg dp/h x (22.4 m^3)/29kg dp) x (1273K / 273k) x (1 h/3600s) = 2.44 m^3/s

ii) Total Moisture from waste + fuel = 104.11 kg/h +34.82kg /h = 138.93 kg/h

Using the ideal gas law, the volumetric flow rate of Moisture at 1000°C (Vm) can be calculated as follows:

V_m = (138.93kg H2O/h) x (22.4 m3/18kg H2O) x (1273K/ 273k) x (lh/3600s) = 0.2239 m^3/s

Total Volumetric Flow Rate = sum of (i, ii) = 2.44+ 0.2239 = 2.66 m^3/s

Therefore, the active chamber volume required to achieve one second retention is 2.66 m^3('dead' areas – with little or no flow should not be included in the retention volume). It should be noted that in sizing the secondary chamber to meet the one second retention time required, the length of chamber should be calculated from the flame front to the location of the temperature sensing device.

Note: The secondary chamber gas residency shall be atleast one second at 1050+/-500C with in maximum of 60 minutes prior to waste charging and with minimum 3% oxygen in the stack gas.

K = °C + 273

Step 11: Residual Oxygen in the Flue Gas

The residual oxygen (%O2) can be determined using the following equation:

EA (excess air) = % O2/ (21%-%O2)

Therefore, (150 /100) = % O2/ (21%-%O2) ; %O2 = 12.6%

6. CONCLUSION

The solid waste treatment technology in Kottayam has revealed the critical issues related to solid waste management challenges faced by the state. This is the most solution seeking problem of the state today, since social, economical as well as the health environment is seriously affected by the improper solid waste treatment technologies in the state. Instead of repeating the failed technologies it is better to develop an innovative system which will be suited to the diversified and changing characteristics of municipal solid waste. Thus an integrated waste management solution is proposed. For its successful implementation, all the data regarding the municipal solid waste management are collected. The municipal solid waste management practice in the city includes composing of organic waste and open dumping of other wastes. This method is not sufficient for the city. An integrated solid waste treatment is required. Integrated solid waste management (ISWM) takes an overall approach to creating sustainable system that is economically affordable, socially acceptable and environmentally effective. An ISWM system involves the use of a range of different treatment methods, and key to the functioning of such a system is the collection and sorting of the waste. According to this system one single treatment method cannot manage all the waste materials in an environmentally effective way. Thus in this study, we proposed different treatment and disposal option suited to the particular community, and reached to the conclusion that the integrated solid waste treatment method is a sustainable solution for municipal solid waste management.

REFERENCES

[1] RenuPawels, Asha P Tom(2013), "Assessment of Technological Options for Solid Waste Treatment in Kerala", Volume 3, Issue 8.

[2] Harikrishnan G, (2014)"Solid Waste Management; A Comparitive study between Kerala and Tamil Nadu",Volume 3, Issue 2.

[3] R.Ajaykumar,(2014) "Status of Municipal Solid Waste Generation in Kerala and theirCharacteristics".

[4] Hridya K, PrincyLukose, Rajesh, (2016), "Solid waste management in Cochin India:Practices, challenges and solutions",Volume 3, Issue 9.

[5] P.B.Vyas, (2017) "Municipal Solid Waste Management at India",Volume 1

[6] BeenaPuthillath, Dr.R.Sasikumar, (2015), "Integrated Solid Waste Management ScoreBoard- A Tool To Measure Performance In Municipal Solid WasteManagement."Volume 4, Issue 5.

[7] ShijuEaso John, C.NajundaSwamy, (2011), "Design of Incinerator for Treatment OfBio-Medical Solid Waste in Chikmagalur City", Volume 2, PP.173-179.