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WASTE MANAGEMENT OF BASE HOSPITAL MANARKAD

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ABSTRACT

Healthcare is one of the most essential services in any growing society. The government has made major efforts to ensure its services and outreach to reach remote rural area. Competing with all of the other environmental problems faced by developing countries, medical waste is often overlooked or simply viewed as solid waste issue. However, sound medical waste management is kept to protecting health in the country and requires dedicated planning, training and tracking throughout the medical waste collection, storage, treatment and disposal process. Incineration is one of the best methods among various disposal facilities to detoxify medical waste. Incineration may be defined as the thermal destruction of the waste at elevated temperature say 12000C to 16000C under controlled operational condition. The products of combustion are carbon-dioxide, water and ash as a residue. The unit in which the process takes place is termed as Incinerator. This paper points to an effective waste management in hospitals which is crucial for public health and the environment, and the proposed information system can improve waste management and minimize environmental impacts.

Keywords: Environmental impacts, Incinerator, Medical waste management

1. INTRODUCTION

Hospital waste is a type of waste generated in hospitals during the diagnosis, treatment, and research of human beings or animals. It is a special type of waste that carries a high potential of infection and injury. If not handled properly, hospital waste can have serious health effects. Hospital waste management involves managing waste produced by hospitals using techniques that check the spread of diseases. Hospital waste consists of both risk waste and non-risk waste. The developed countries have a properly organized infrastructure for hospital waste disposal, while in developing countries, there is a lack of awareness and attention to medical waste management

Hospital hazardous waste is unique due to the variety of wastes generated, although the volume is relatively small compared to industrial facilities. Hospitals use toxic chemicals and hazardous materials, including chemotherapy drugs, formaldehyde, photographic materials, radioactive substances, solvents, mercury, waste anesthetic gases, and other corrosive and toxic chemicals.

To address these issues, every healthcare facility in India is required to develop a biomedical waste management plan in accordance with the Biomedical Waste Management and Handling Rules of 1998, established by the Ministry of Environment and Forests (MOEF). These rules provide guidelines and regulations for the proper handling and disposal of biomedical waste.

2. METHODOLOGY

The work primary aims at designing a medical waste incinerating system for the health care facility for Base Hospital, Manarkad, Kottayam, Kerala. The major component of the incineration system includes the combustion system, connecting ducts, filtration system and the air pollution control system.

3. DOUBLE CHAMBER INCINERATION SYSTEM

The double chamber incinerating system operates by feeding raw wastes into the primary chamber, where a fraction of the waste is oxidized, releasing heat and producing dense combustible smoke. Air flow is carefully increased to maintain high combustion temperature in the primary chamber for almost complete combustion. Smoke, flue gases, and fly ash pass from the primary chamber to the secondary chamber. The secondary chamber, equipped with an auxiliary burner and optional overfire air jet system, further increases combustion temperature and residence time. This design ensures complete combustion of flue gases and fly ash, resulting in nearly pollutant-free emissions. The fig 1 and fig 2 shows the study location.

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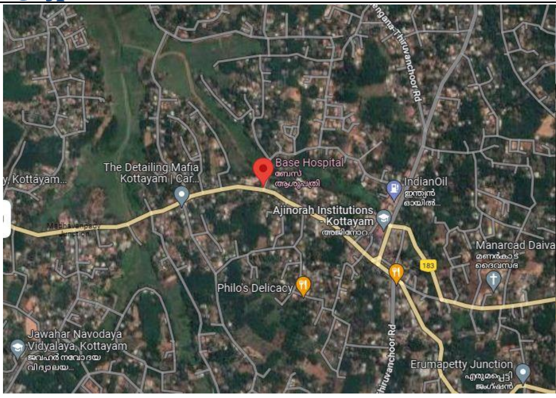

DESIGN OF INCINERATOR

Quantification of waste

From the study it can be concluded that average wastes quantification in Base hospital is about 60kg/day.

Design of Primary Chamber

For designing the primary chamber, Volume of the heap = $5m^3$

Assuming a suitable depth of 2.2m, area of the chamber Area = v/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

$2.3 = 1.5B*B = 1.5B^2$

B = 1m, L = 1.5m and H = 2m

Heat and Material Balance Sample Calculation

A heat and material balance are 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.

Assumptions: An incinerator is to be designed to incinerate a mixture of 30% red bag and 70% yellow bag (with a PVC contented 4%) biomedical waste.

Table 1: waste generation from base hospital

Sl no	Types of health care establishment	Quantity of waste generation /month	Quantity of waste generation /day
1	Wards	1116kg	37.2kg
2	Theaters and casuality	360kg	12kg
3	Laboratories	66kg	2.2kg

Total wastes generation per month = 1542Kg/month

Total wastes generation per day = 51.4 Kg/day

Throughput is to be 60 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 be 1100°C

Flue gas residence time at 1000°C

Table 2: waste category and measurements

Waste class	Component Description	Typical component weight percent	HHV dry basis (kg/kj)	Bulk density as fired (kg/m3)	Moister content of component	Weighted heat value range of waste component (kg)	Typical component heat value of waste (kj/kg)
A1 (Red Bag)	Human anatomical Plastics wabs	95-100 0-5 0-0.2	18600-1200 32500-46400 23500-32500	800-1200 32500-46400 25500-32500	70-90 0-1 0-0.2	177- 897 0 – 100 0-60	693.5 16.5 12

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	Disinfectance					0-23	8 730
A2(a) (yellow bag)	Animal anatomical Plastic Glass Beddings	80-100 0-15 1-5 1-10	20900-37100 32500-46400 0 18600-27900	500-1300 80-2300 2800-3600 320-730	60-90 0-1 0 0- 1880	630-4560 0-1000 0-100 0-100 0-100	1350 250 10 25 65 1700
A3 (a)yello w bag,lab waste	Paper Plastic pvc Sharps Needles Disinfectants Fluids	60-90 15-30 4-8 0-0.2 2-5	18600-27900 22500-46400 140 16200-32500 0-23200	80-1000 80-2300 7200-8000 800-1000 1000-1020	0-30 0-1 0-1 0- 5080- 100	890-5963 0-10 100-600 0-100 0-100 0-10	1384 0 226 70 50 0 1730
B1 (blue bag)	Non infected animals Anatomical Plastic glass Bedding Shavings	90-100 0-10 0-3 0-10	20900-37100 3250-4640 0 018600- 20900	500-1300 80-2300 2800-3600 320-730	60-9 0-1 0 10-50	233- 1500 177-1900 0-10 0-300	500 300 0 180 980

STEP 1: Assumptions

Calculations involving incineration of biomedical 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 biomedical waste have been taken as above.

1. Second Residual oxygen in flue gas: 6% minimum.
2. Input Temperature of waste, fuel and air is 15.5^0 C.
3. Air contains 23% by weight O_2 and 77% by weight N_2 .
4. Air contains 0.0132kg H_2O/kg dry air at 60% relative humidity and 26.7^0 C dry bulb temperature.
5. For any ideal gas 1kg mole is equal to 22.4m³ at 0^0 C and 101.3kpa.
6. Latent heat of vaporization of water at 15.5^0 C is 2460.3kJ/kg.

Step 2: Calculation of Material Input

Based on an input of 30% of 60 kg/h (i.e., 18 kg/h), the red bag was assumed to have the following composition.

- Tissue (dry) $C_6H_{10}O_3$ 0.15 x 18 = 2.7 kg/h
- Water H_2O 0.8 x 18 = 14.4 kg/h
- Ash - 0.05 x 18 = .9 kg/h

Total Red Bag = 18.0 kg/h

The yellow bag waste input is 70% of 60 kg/h (i.e. 42 kg/h) and was assumed to have the following composition:

- Polyethylene (C_2H_4) x 0.35 x 42 = 14.70 kg/h
- Polyvinylchloride (C_2H_3Cl) x0.04 x 42 = 1.68 kg/h
- Cellulose $C_6H_{10}O_5$ 0.51 x 42 = 21.42 kg/h
- Ash 0.1 x 42 = 4.2 kg/h

Total Yellow Bag = 42.00 kg/h

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

The HHV and heat input of each component are tabulated below.

Table 3: Heat calculation

Component	HHV kJ/kg	Input kg/h	Total heat in kJ/h
$C5H10\ O3$	20471	2.7	55271.7
H_2O	0	14.4	0.0
(C_2H_4)	46304	14.70	680668.8
(C_2H_3Cl)	22630	1.68	38018.4
$C6H10\ O5$	18568	21.42	397726.56
Ash	0	5.1	0.0
		60	1171685.46kJ/h

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 biomedical waste.

The stoichiometric oxygen required to burn the combustible components of the biomedical waste (44.1 kg/h) are 90.56kg/h oxygen (sum of 6.22, 49.64, 2.32 and 32.38).

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

From step 4, stoichiometric oxygen is 90.5 kg/h.

Therefore, stoichiometric air =90.5*100/23 =393.74kg/h air

Total air required for waste (at 150% excess) = (1.5*393.74) + 393.74 =984.35kg/h

Step 6: Material Balance

Total Mass in Waste = 100 kg/h

Dry air = 984.35 kg/h

Moisture in air= 12.99 kg/h = (984.35 x 0.0132) [step1]

Total Mass In = 1097.34 kg/h

Total Mass output (assuming complete combustion)

A. Dry Products From Waste

Air supplied for waste = 984.35kg/h

Less stoichiometric = 393.74 kg/h

Air for waste

Total excess air = 590.61 kg/h or 150%

Add nitrogen from stoichiometric air= 0.77X 393.74= 303.18 kg/h

Subtotal = 590.61+303.18 = 893.79 kg/h

Add total CO_2 from combustion:

CO_2 formed from $C_5H_{10}\ O_3$= 6.46 kg/h

CO_2 formed from C_2H_4 = 62.96 kg

$CO2$ formed from $C2H3\ Cl$= 2.8 kg/h

$CO2$ formed from $C6H10O$= 42.10 kg/h

Total Waste Dry Products = 893.79+114.32

= 1008.11 kg/h

B. Moisture

$H2\ O$ in the waste = 14.25 kg/h

$H2\ O$ from combustion reaction= 45.24 kg/h

$H2\ O$ in combustion air = 11.27 kg/h

Total moisture= 70.78 kg/h

C . Ash output

Ash output= 5.1 kg/h

D. HC1 formed from waste

HC1 formed from $C2H3\ Cl$= 1.26 kg/h

Total mass= Sum of above (A+B+C+D) = 1085.25 kg/h

Step 7: Heat balance

A. Total Heat in from Waste (Qi)

Qi= 1,171,685.46 kj/h (step3)

B. Total Heat out based on equilibrium Temperature of 1100℃(Qo)

i)Radiation loss = 5% of total heat available

= 0.05 x 1,171,685.46

= 58584.273 kJ/h

ii) Heat to as=mCp

= (5.1) (0.831) (1084.5

= 4596.22 kJ/h

Where, Weight of ash = 5.1 kg/h

Cp= Mean heat capacity of ash

= 0.831kJ/kg℃

(Assumed average value)

dT = Temperature difference

= (110-15.5) ℃

= 1084.5℃

iii) Heat to dry combustion

Products = mCpT

= (1008.11)*(1.086)*(1084.5

= 1187318.69Kj

Where 'm' is weight of combustion products

= 1498.22 kJ/

Cp= mean heat capacity of dry products

= 1.086kJ/kg℃(assumed average value)

dT= (1100-15.5)℃

= 1084.5℃

iv) Heat to moisture = (mCpDt)+((mHv)

= 70.78 x 2.347 x 1084.5 + 70.78 x 2460.3

=180157.86 + 174140.034

=354297.9kJ/h

Where m is Weight of Water= 70.78 Kg/h

Cp= mean heat capacity of water

= 2.347 kJ/kg℃

Dt = 1100℃-15.5℃

= 1084.5℃

Hv = heat of vaporization of water

= 2460.3 kJ/kg

Total heat out Qo

= sum of (i + ii + iii + iv)

=58584.273 +4596.22 +1187318.69 +354297.9

=1,604,797.1 kJ/h

Net balance= Qi - Qo

= 1,171,685.46 – 1,604,797.1

= 433111.623 kJ/h

Step 8: Required Auxiliary Fuel to Achieve 1100°C

i) Total heat required from fuel = 433111.623 + 5% radiation loss = 454767.2042 kJ/h

ii) Available heat (net) from natural gas at 1100°C and 20%

iii) Excess air = 15,805.2 kJ/m3 (assumption)

iv) Natural gas required = 454767.2042/15,805.2 m3/h = 28.77 m3/h

Step 9: Products of Combustion from Auxiliary Fuel

i) Dry Products from Fuel at 20%

ii) Excess Air = 16.0 kg x 28.77 m3 /h m3

iii) Fuel = 460.32 kg/h

iv) Moisture From Fuel = (1.59 kg/m3 fuel) x 28.77 m 3/h = 45.74kg/h

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

Total Dry Products

From waste + fuel= 1008.11 kg/h + 460.32 kg/h = 1468.43 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:

Vp = 1468.43 kg dp/h * (22.4 m3)/29kg dp) * (1273K / 273k)* (1 h/3600s) = 1.47 m3 /s

Total Moisture

From waste + fuel= 70.78 kg/h +45.74kg/h = 116.52 kg/h

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

Vm = (116.52 kg H2O/h) x (22.4 m3/18kg H2O) x (1273K/ 273k) x (lh/3600s) = 0.19 m3/s

Total Volumetric Flow Rate = sum of (i, ii) = 1.47 + 0.19 = 1.66 m3/s

Therefore, the active chamber volume required to achieve one second retention is 1.66 m3 ('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.

K = °C + 273

Step 11: Residual Oxygen in the Flue Gas

The residual oxygen (%02) can be determined using the following equation: EA (excess air) = % O2/ (23%-%02)

Therefore, (150 /100) = % O2/ (23%-%O2)

%02 = 22.6%

Efficiency of the Machine:

The efficiency of the machine is calculated using the relation: η = (Energy output / Energy input) * 100

= (1604797.1/1626452.664) x 100

= 98

4. RESULTS AND DISCUSSIONS

As per the data analysis, the estimated quantity of medical waste from surveyed health-care facilities was about 51.4kg/day, equivalent to 20.68 ton/year. The medical waste has higher calorific value, higher heating value and volatile matter, which can realize the sustained combustion of waste. The combustible component accounted for more than 60%, so it is entirely feasible to dispose medical waste by high temperature incineration. Daily increment of medical waste generation and the quest to safeguard the people and environment from outbreak of diseases, a cost effective and environmental-friendly incinerator was designed in present study to treat biomedical waste generated in surveyed HCFs with a capacity of 60 kg/h. From the material balance analysis by assuming complete combustion, total mass input (1097.34kg/h) is found to be equal to total mass output (1085.25kg/h) while the total energy input from the heat balance analysis is found to be 1,171,685.46 kJ/h and total energy output to be 1,605,797.1 kJ/h. From the design analysis, 28.77 m3/h of natural gas is required to achieve a design temperature of 1100^0 C. Also, from the design, the volume of secondary chamber is found to be 1.47 m3 with a detention time of 1 second. A Counter-current packed bed wet scrubber was designed by assuming a scrubbing efficiency of 99%.

5. CONCLUSIONS

The following main conclusions were drawn from the design of the incinerator system

1. The amount of waste generated is about 60kg/day

2. A Chamber Incinerator has been designed with an operating capacity of 60kg/hr.

3. The dimensions of the Primary Chamber of the incinerator were 1 x 1.5 x 2 m.

4. The material balance analysis assuming complete combustion shows that the total mass input (1097.34 kg/hr.) is almost equal to the total mass output (1085.25 kg/hr.)

5. The heat balance analysis showed that the total amount of heat generated from the input waste was 1,171,685.46kJ/hr, whereas the total heat requirement was 1,604,797.1kJ/hr for complete combustion. Hence, the deficient heat requirement of 433111.623kJ/hr was required to be supplied by auxiliary fuel to maintain a temperature of 1100°C.

6. From the design analysis it was determine that the flow rate of the natural gas was required to be maintained at 28.77m3/hr to neutralize the heat deficit and maintain the temperature at 1100°C.

7. The design volume of secondary chamber is found to be 1.47 m3 to maintain a retention time of 1 second.

8. A Counter-current packed bed wet scrubber with 99% scrubbing efficiency was designed with the incinerator to adsorb toxic (flue) gases that might be emitted in the course of burning the waste.

As these parameters are coming within specified range hence, the design is good for adoption.

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