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Monitoring of a Common Biomedical Waste Incineration Facility-A Case Study

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Abstract: Incineration is one of the options for the treatment and disposal of the biomedical wastes. The incineration process causes air as well as water pollution. Studies were conducted to assess the efficacy of a common biomedical waste incineration facility in achieving the prescribed limits for discharge of effluent and emissions in the environment. It was observed that with venturi as an air pollution control device, the concentrations of NO_x, HCl and the particulate matter in stack emissions were 17.8 mg/Nm^3, 75.8 mg/Nm^3 and 196.2 mg/Nm^3, respectively.The concentration of SO_2 was found below the detectable level. It was noticed that the emission levels of HCl and particulate matter exceed the prescribed limits. The oxides of nitrogen (NO_x) were found within the limit. The effluent discharge of venturiscrubber and other processes was treated using an activated carbon column. The analysis of treated effluentshown pH7.74, TSS of 12 mg/L, TDS of 1066 mg/L, BOD of 5 mg/L, COD of 21 mg/L and oil-grease of 2 mg/L that meet the prescribed effluent discharge limits. With pollution control measures, and proper operation and maintenance care, it is possible to contain the air and water pollution problems from the incinerator.
Key words: Biomedical waste, Incineration, Emission monitoring, Effluent treatment.

Introduction

Hospitals generate substantial quantity of wastes that has potential to cause health and the environmental hazards. Ramesh Babu et al.[1]reported the solid waste generation by the hospitals as 1.5-4.4 kg/bed/day consisting of syringes, bandages, plastics, human tissues, cathetersand other wastes. It has been noted that 10-25% of the hospital wastes is infectious or biomedical waste requiring safe disposal[2,3]. The literature shows that the waste management practices followed in several hospitals,particularly in developing countries, are far from satisfactory[4-8]. The studies also noted that awareness regarding handling and disposal of the wastes was limited to the doctors and nurses. There were inadequate efforts to train the sanitary staff involved in the waste management practices in the hospital studied[9-11]. The biomedical wastes, if disposed of without a proper treatment, can cause public nuisance by way of foul smell. Chaudhay and Dhakad[12]studied the health effects and observed lung deceases, dermal deceases and the eyeinfectionamong the human population exposed to the biomedical wastes. Gupta and Singhal[13]assessed the bacterial load in the liquid effluent of hospital and solid biomedical wastes as 6.0-6.5 log cfu/mL and 3.1-5.0 log cfu/g, respectively.A study by Malekahmadiet al.[14]reported that the wastes affect public health by possible diseases such as typhoid, cholera, hepatitis and other viral and bacterial infections. Hence, the importance of biomedical waste management hardly needs any emphasis.

The biomedical wastes are required to be properly disposed in an environmentally sound manner. There arewell established guidelines and regulations in India to contain the biomedical waste[15]. As per the guidelines, the biomedical wastes need to be properly segregated at source of its generation and colour coded for transportation, storage, appropriate treatment and disposal. The treatment technologies identified for the biomedical wastes include chemical treatment, autoclaving, microwaving and the incineration[16]. Shredding, deep burial and multilation are also related methods for the waste disposal as given in Table 1[15]. The selection of technology mainly depends on type of waste to be treated, its quantity and other aspects.

Table 1 Segregation and colour coding of different biomedical wastes with treatment options

Waste categories	Colour code of waste collection bag[#]	Treatment options
Human anatomical waste, animal waste, microbiology- biotechnology waste, soiled waste	Yellow plastic bag	Incineration/deep burial
Microbiology-biotechnology waste, soiled waste and solid waste[+]	Red disinfected container/plastic bag	autoclaving/microwaving/chemical treatment
Waste sharps, solid waste[+]	Blue/white translucent plastic bag/puncture proof container	Autoclaving/microwaving/chemical treatment and destruction/shredding
Discarded medicines-cytoxic drugs, incineration ash, chemical waste(Solid)	Black plastic bag	Disposal in secured landfill
Liquid waste, chemical waste(Liquid)	Not required	Disinfection by chemical treatment and discharge into drains

[#]Waste collection bag for the waste needing incineration should not be made of chlorinated plastics.
[+]Solid wastes other than sharp wastes such as tubing, catheter and intravenous set etc.

It is observed that smaller hospitals and related units (nursing homes, pathological laboratories, blood banks etc.) generate low quantity of biomedical wastes. With low quantityof the wastes, some of the treatment options mentioned in Table 1 may not viableat individual unit level primarily due to lack of technical knowhow, resources for operation and maintenance of the treatment facility and the financial crunch. In such cases, a common biomedical waste treatment facilityis set up to address the biomedical waste disposal problems. Presently, numbers of such common incineration facilities areoperating in India. The incineration gives effective and quick solution for disposing the wastes. It is to be noted that the incineration facility is also a source of pollution requiring appropriate control measures. The incinerator is predominantly characterised as the air polluting source[17,18].It also generates water pollution and solid wastes[19,20]. This paper covers monitoring study of a Maharashtra(India) based common biomedical waste incineration facility having 70 kg/hcapacity.

Objectives of Study

The common biomedical waste incineration facility generates effluent and air pollution (stack emissions). In addition, solid waste in the form of ash is generated due to combustion of the wastes. The objectivesinclude study of the process and assess the efficacy of the incineration facility in achieving the regulatory norms for discharge of effluent and emissions in the environment.

Materials and Methods

Information was collected from the common biomedical waste incineration facility including process,equipments available, sources of pollution (stack emission and effluent) and the control measures. The sampling and analysis of the particulate matter (PM), oxides of nitrogen (NO_x), sulphur dioxide (SO_2) and hydrogen chloride (HCl) was conducted as per the methodology for source emission monitoring[21]. Carbon dioxide (CO_2) and flue gas volume were measured using a potable flue gas analyzer (Testo-350, Testo India).

Effluent discharge quantity was estimated from pumping hours in a day. Effluent samples were collected from out let of the treatment plant in 1000 mL plastic bottles.The plastic bottles were well covered to avoid spillages and kept in an ice box for transporting from the field to laboratory. The samples were analyzed for main polluting parameters i.e. pH, total suspended solids (TSS), total dissolved solids (TDS), biochemical oxygen demand (BOD), chemical oxygen demand (COD)and oil-grease as per the standard methods[22].The results obtained from the monitoring were compared with the regulatory norms to assess the efficacy of the incineration facility.

Results and Discussions

A Maharashtra (India) based common biomedical waste incineration facility was chosen for monitoring of its effluent and emissions.The waste treatmentequipments available with the facility are incinerator (70 kg/h), autoclave (430 L), shredder (40 kg/h) and the effluent treatment plant (ETP). The details of main equipments i.e. the incineratorand venturi scrubber are given in Table 2.

Table 2 Details of incineration system

Particulars	Details/specification
Type of substrate (waste)	Biomedical wastes
Designated calorific value of the waste	2000 kcal/kg
Capacity	70 kg/h of waste
Operation hours	16-17 h/day
Mode of waste feed	DFDV mechanism
Type of auxiliary fuel and consumption	Light diesel oil, 7-10 kg/h
Primary chamber: Type, volume, temperature	Cylindrical vertical, 1.17 m^3, 800±50 °C
Secondary chamber: Type, volume, temperature, gas residence time	Cylindrical vertical, 0.65 m^3, 1050±50 °C, 1 second
Venturi scrubber: Type, pressure drop, Temperature, scrubbing media,	High pressure, 350 mm WC, 78-80 °C, Water with 1% caustic
Droplet separator	Cyclonic, mild steel rubber lined
Stack: Type, material, height, diameter	Self-supported, mild steel rubber lined, 30 m, 250 mm

The common biomedical waste incineration facility collects wastes from 700 of its member hospitals and related units (nursing homes, pathological laboratories, blood banks etc.) located in nearby areas and transport the same to the incineration site in covered trucks. After a random checks, the waste bags or containers are segregated as per the colour codes for appropriate treatment i.e. autoclaving, shredding or incineration. The waste designated for incineration is loaded on conveyor for feeding into the primary combustion chamber of incineration through a double flap damper valve (DFDV) mechanism. The DFDV mechanism prevents backfire and leakage of hot flue gases. It also prevents exposure of hot combustion chamber to the operators. All most all combustible waste material is burnt in the first chamber and the flue gases pass though the secondary combustion chamber of the incinerator.

The combustion chambers' temperatures are high enough to effect reactions between volatile components in the wastes and the gases in air (oxygen and nitrogen). The main reactions include carbon-oxygen producing carbon dioxide (CO_2) (or CO in case of incomplete combustion)and hydrogen-oxygen producing water vapour. Hydrogen also reacts with organically-bound chlorine to produce hydrogen chloride (HCl). Other reactions may produce sulphur oxide (SO_2) from sulphur compounds (or sulphur content of auxiliary fuel), oxides of nitrogen (NO_x) from nitrogen compounds (or atmospheric nitrogen), oxides of metals from wastes such as syringes.

The above reactions convert the wastes into ash that is removed from the bottom through a de-ashing door of the primary combustion chamber. The flue gases from the first chamber pass through secondary chamber of incinerator, where elevated temperature is maintained to destroy CO and other impurities. A high pressure veturi is installed at the out let of the secondary combustion chamber wherein water with 1% caustic (NaOH) solution is circulated. The venturi removes particulates and reduces flue gas temperature. Caustic solution removes sulphur dioxide by converting it into sodium sulphite (Na_2SO_3).The flue gases are further purified in droplet separator by way of arresting water droplets. The flue gases are finally let out through a stack (30 m height).

Stack emission monitoring

The flue gases from secondary chamber of the incinerator pass though venturi scrubber followed by droplet separator and the stack. The stack emissions were monitored for relevant parameters and the results are given in Table 3.

Table 3 Stack emission monitoring results

Parameters	Monitoring results	Permissible limits (at 12% CO_2 correction)[15]
Sulphur dioxide, mg/Nm^3	Below detectable limit	-
Oxides of nitrogen, mg/Nm^3	17.8	450
Hydrogen chloride, mg/Nm^3	75.8	50
Particulate matter, mg/Nm^3	196.2	150

During the monitoring, the incinerator was operated at desired temperatures in primary and secondary combustion chambers. The primary chamber was able to attain the desired temperature (≥800 °C). However, the temperature in the secondary chamber could not reach the desired level due to technical snag in the burner. The low temperature in the secondary chamber implies incomplete combustion. It was observed that with venturi as an air pollution control device, the concentration of NO_x, HCl and the particulate matter in stack emissions were measured as 17.8 mg/Nm^3, 75.8 mg/Nm^3 and 196.2 mg/Nm^3, respectively. The concentration of SO_2 was found below the detectable level (BDL). On comparing the monitoring results with the permissible limits, it was observed that the emission levels of HCl and particulate matter exceed the permissible limits, which may be due to inadequate temperature of the secondary combustion chamber of the incinerator as observed during the monitoring. The stack mission was found within permissible limit as far as oxides of nitrogen are concerned.

Effluent discharge monitoring

The effluentlet out by the venturi scrubber was measured as 1.5 m^3/daycontainingNa_2SO_3, unburnt carbon particles and ash. Low quantity of effluent is particularly due to the recycling of the water in the venturi. The containers washing activityalso generate 0.5 m^3/day of wastewater. The combined wastewater is treated in aneffluent treatment plant (ETP) consists of a collection tank, multi-grade filters (2 Nos. operating in series) and an activated carbon column.The details of effluent treatment plant are given in Table 4.

Table 4 Details of effluent treatment plant

Treatment units	Size
Collection tank	2 m Length X 2 m Width
Chemical dosing tank	0.3m Dia. X 0.6m Height
Multi-grade filter	0.3m Dia. X 0.6m Height (2 Nos.)
Activated carbon column	0.6 m Dia. X 1.5m Height

Effluent samples were collected for analysis from the out let of ETP and the results are given in Table 5.The analysis shown pH7.74, TSS of 12 mg/L, BOD of 5 mg/L, COD of 21 mg/L and oil-grease of 2 mg/L. It can be noticed that the treated effluent meets the permissible limits. The treated effluent is stored in a tank for use in plantation.

Table 5 Characteristics of effluent

Parameters	Analysis results of treated effluent	Permissible limits[15]
pH	7.74	6.5-9.0
Total suspended solids, mg/L	12	100
Total dissolved solids, mg/L	1066	-
Biochemical oxygen demand, mg/L	5	30
Chemical oxygen demand, mg/L	21	250
Oil and grease, mg/L	2	10

Solid waste disposal

The incinerator generates solid waste in the form of ash which is 5-10% of the waste by weight depending upon the composition of the waste. The ash after cooling is disposed in a landfill. The permissible limit of the volatile organic matter in the incineration ash is ≤0.01%[15]. The ash may contain heavy metals possibly due to inadequate segregation of syringes and broken thermometer from the wastes meant for incineration[23].

Other observations

The common biomedical incineration facility has installed shredder and autoclave. In shredding operation, waste (like syringes) is cut into pieces so as to make the wastes unsuitable for reuse. Autoclaving is a low-heat thermal process. Steam is brought into direct contact with the waste in a controlled manner for sufficient duration so as to disinfect the waste.

Conclusions

Incineration process is widely used for destruction of many wastes including the biomedical waste. Its operation is not free from environmental problems as it is the source of water and air pollution. With proper operation and maintenance of the control measures, it is possible to contain the water and air pollution problems. The forgoing studies have shown that the treated effluent meets the regulatory requirement. The sulphur dioxide level in the stack emissions was found below the detectable level and the concentration of nitrogen oxides was observed within permissible limit. The level of hydrogen chloride and particulate matter exceed the limits, which may be due to inadequate temperature of the secondary combustion chamber of the incinerator. Enhancing the operation and maintenance care of the incinerator and air pollution control device (venturi scrubber) can further improve the efficacy of the facility. The incinerator's ash may contain toxic constituents such as heavy metals and hence, requires safe disposal.

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