J. Int. Environmental Application & Science, Vol. 4 (1): 65-78 (2009)

Management of Biomedical Waste in India and Other Countries: A Review

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Received July 29, 2008; Accepted March 16, 2009

Abstract: The objective of this study is (i) to summarize the rules for management and handling of biomedical wastes, (ii) to give the definition, categories of biomedical wastes, suggested storage containers including colour-coding and treatment options, (iii) mainly to highlight the effects of biomedical waste in the environment such as air, land, radioactive pollution and (iv) disposal of wastes, regulation and recommendations. Health-care waste management in several countries including India is receiving greater attention due to stringent regulations. The waste generation rate ranges between 0.5 and 2.0 kg $bed^{-1}day^{-1}$. The solid waste from the hospitals consists of bandages, linen and other infectious waste (30-35%), plastics (7-10%), disposable syringes (0.3-0.5%), glass (3-5%) and other general wastes including food (40-45%). Several survey works carried out by various research organizations by (Government and Non government and private sectors) have been discussed and reviewed in this paper.

Keywords: *Data management, emissions, biomedical wastes, hazardous waste, health-care establishment, regulations, waste-management plan, waste disposal.*

Introduction

'Bio-medical waste' means any waste generated during diagnosis, treatment or immunization of human beings or animals. Management of healthcare waste is an integral part of infection control and hygiene programs in healthcare settings. These settings are a major contributor to community-acquired infection, as they produce large amounts of biomedical waste. Biomedical waste can be categorized based on the risk of causing injury and/or infection during handling and disposal. Wastes targeted for precautions during handling and disposal include sharps (needles or scalpel blades), pathological wastes (anatomical body parts, microbiology cultures and blood samples) and infectious wastes (items contaminated with body fluids and discharges such as dressing, catheters and I.V. lines). Other wastes generated in healthcare settings include radioactive wastes, mercury containing instruments and polyvinyl chloride (PVC) plastics. These are among the most environmentally sensitive by-products of healthcare (Askarain *et al.,* 2004; Remy, 2001). WHO stated that 85% of hospital wastes are actually non-hazardous, around 10% are infectious and around 5% are non-infectious but hazardous wastes. In the USA, about 15% of hospital waste is regulated as infectious waste. In India this could range from 15% to 35% depending on the total amount of waste generated (Glenn & Garwal, 1999; Anonymous, 1998; Chitnis et al., 2005)

The management of bio-medical waste is still in its infancy all over the world. There is a lot of confusion with the problems among the generators, operators, decision-makers and the general community about the safe management of bio-medical waste. The reason may be a lack of awareness. Hence resource material on the environment for hospital administrators, surgeons, doctors, nurses, paramedical staff and waste retrievers, is the need of the hour (Almuneef & Memish, 2003; Acharya & Meeta, 2000).

Sources of Bio-Medical Waste

While urban solid waste has attracted the attention of town planners, environmental activists and civic administrators, there is yet lack of concern for some special sources of waste and its management. One such waste is bio-medical waste generated primarily from health care establishments, including hospitals, nursing homes, veterinary hospitals, clinics and general

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practitioners, dispensaries, blood banks, animal houses and research institutes. The other sources of biomedical waste are the following:

Households,
Industries, education institutes and research centres,
Blood banks and clinical laboratories,
Health care establishments (for humans and animals): (Anonymous, 2000; Chitnis et al., 2000).

The sector generates all the types of waste listed under the bio-medical waste are shown in Figure 1.

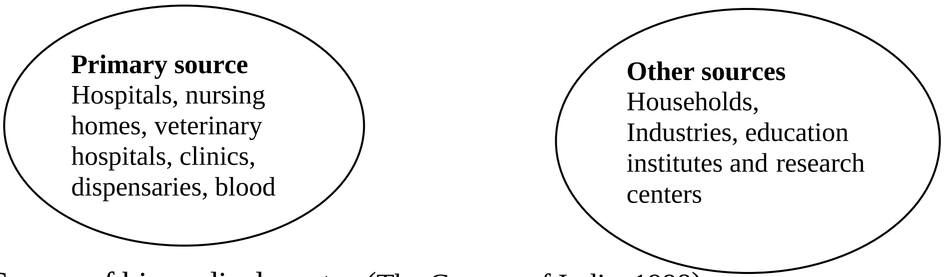


Figure 1. Source of biomedical wastes (The Gazette of India, 1998)

Categories of biomedical wastes

Categories of biomedical wastes are given in Table 1.

Table 1. Categories of biomedical wastes

Category	Source of waste	Treatment and Disposal
1	Human Anatomical Waste (human tissues, organs, body parts)	Incineration /deep burial
2	Animal Waste (animal tissues, organs, body parts, carcasses, bleeding parts, fluid, blood and experimental animals used in research, waste generated by veterinary hospitals, colleges, discharge from hospitals, animal houses)	Incineration /deep burial
3	Microbiology & Biotechnology Waste (wastes from laboratory cultures, stocks or specimens of micro-organisms live or attenuated vaccines, human and animal cell culture used in research and industrial laboratories, wastes from production of biological, toxins, dishes and devices used for transfer of cultures)	Local autoclaving / microwaving incineration
4	Waste Sharps(needles, syringes, scalpels, blades, glass, etc. that may cause puncture and unused sharps)	Disinfection (chemical treatment /autoclaving/ microwaving and mutilation/ shredding”
5	Discarded Medicines & Cytotoxic drugs (wastes comprising of outdated, contaminated and discarded medicines)	Incineration /destruction and drugs disposal in secured landfills
6	Soiled Waste (items contaminated with blood and body fluids including cotton, dressings, soiled plaster casts, lines, beddings, other material contaminated with blood.	Incineration autoclaving/ microwaving
7	Solid Waste (wastes generated from disposable items other than waste sharps such as tabbing, catheters, intravenous sets etc.)	Disinfection by chemical treatment autoclaving/ microwaving and mutilation/ shredding”
8	Liquid Waste(waste generated from laboratory and washing, cleaning, house-keeping and disinfecting activities)	Disinfection by chemical treatment and discharge into drains
9	Incineration Ash (ash from incineration of any bio-medical waste)	Disposal in municipal landfill
10	Chemical Waste (chemicals used in production of biological, chemicals used in disinfection, as insecticides, etc.)	Chemical treatment and discharge into drains for liquids and secured landfill for solids.

Source: Biomedical wastes (Management and Handling Rules, 1998)

Effects of biomedical waste

The improper management in bio-medical waste causes stern environmental problems that causes to air, water and land pollution. The pollutants that cause damage can be classified into biological, chemical and radioactive. There are several legislations and guidelines in India concerning environmental problems, which can be addressed. The classification of radioactive waste generated as part of bio-medical waste is covered. Some of the effects of pollution on air, radio activities, land, health and hazards are discussed (Sadhu and Singh 2003; www.ipaiindia.org/files/2007.pdf).

Air Pollution

Air pollution can be caused in both indoors and outdoors atmosphere. Biomedical waste that generated by air pollution are been classified in three types namely-Biological, Chemical and radioactive (http://kspcb. kar.nic.in/BMW).

In-door air pollution

Pathogens present in the waste can enter and remain in the air for a long period in the form of spores or as pathogens Segregation of waste, pre-treatment at source etc., can also reduce this problem to a great extent. Sterilizing the rooms will also help in checking the indoor air pollution due to biological (Askarian et al 2004b; Baveja et al 2000). The indoor air pollution caused due to the above chemicals from poor ventilation can cause diseases like Sick Building Syndrome (SBS). Proper building design and well-maintained air conditioners can reduce the SBS. Chemicals should be utilized as per prescribed norms. Over use of chemicals should be avoided (Bdour 2004, Saurabh & Ram 2006).

Out-door air pollution

Outdoor air pollution can be caused by pathogens. The biomedical waste without pre-treatment if transported outside the institution, or if it is dumped in open areas, pathogens can enter into the atmosphere. Chemical pollutants that cause outdoor air pollution have two major sources-open burning and incinerators. Open burning of bio-medical waste is the most harmful practice. When inhaled can cause respiratory diseases. Certain organic gases such as dioxins and furans are carcinogenic (Burd 2005). The design parameters and maintenance of such treatment and disposal technology should be as per the prescribed standards (Bdour 2004).

Radioactive emissions

Research and radio-immunoassay activities may generate small quantities of radioactive gas. Gaseous radioactive material should be evacuated directly to the outside. The use of such device requires maintenance of the trap and monitoring of the off-gas (Malviga 1999).

Water Pollution

The liquid waste generated when let into sewers can also lead to water pollution if not treated properly (Rao, 1995; Rao & Garg, 1994). Water pollution can alter parameters such as pH, BOD, DO, COD, *etc*. There are instances where dioxins are reported from water bodies near incinerator plants. Dioxins enter the water body from the air (Chitins *et al*, 2000; Ravikant *et al*, 2002; Saini & Dadhwal 1995)

Radioactive effluent

Radioactive waste in liquid form can come from chemical or biological research, from body organ imaging, from decontamination of radioactive spills, from patient’s urine and from scintillation liquids used in radioimmunoassay. Under normal circumstances, urine and faeces can be handled as no radioactive waste so long as the patient’s room is routinely monitored for radioactive contamination (Patil & Pokhrel, 2004; Shah *et al*, 2001).

Land Pollution

Soil pollution from bio-medical waste is caused due to infectious waste, discarded medicines, chemicals used in treatment and ash and other waste generated during treatment processes. Heavy metals such as cadmium, lead, mercury etc., which are present in the waste will get absorbed by plants and can then enter the food chain. Nitrates and phosphates present in leachates from landfills are also pollutants. Excessive amounts of trace nutrient elements and other elements including heavy metals in soil are harmful to crops and are also harmful to animals and human beings (Mehta 1998). The permissible limits of some elements in soil for plants are presented in the Table 2. Minimizing the waste and proper treatment before disposal on land are the only ways of reducing this kind of pollution (Silva et al 2005). The waste generated from various countries is given in Table 3.

Table 2. Comparison of treatment technologies for medical wastes

Treatment Systems	Autoclave	Hydroclave	Microwave	Incinerator	Chemical
Description	Steam sterilisation (Direct heating)	Steam sterilization, (indirect heating) simultaneous shredding and dehydration	Microwave heating of pre-shredded waste	High temperature waste incineration	Mixing pre-ground waste with chemicals, such as chlorine
Sterilization efficacy	Medium	Medium	Medium	High (total destruction of micro-organisms)	Dependent on chlorine strength and dispersment through the waste
Capital cost	Low	Low	High	High	Moderate
Operating cost	Low	Low	High	High	Low
Operator maintenance skills	Low skill level required	Low skill level required	Automated, but highly complex and high level maintenance skill required	High level operator and maintenance skills required	High level required for chemical control and grinder
Air emissions	Odorous but non-toxic	Somewhat odorous but non-toxic	Somewhat odorous but non-toxic	Can be highly toxic	Some chlorine emissions
Water emissions	Odorous, may contain live micro-organisms	Odorous but sterile	Negligible	None	None
Treated waste characteristics	Wet waste, all material recognizable	Dehydrated, shredded waste, unrecognizable material	Shredded but wet waste	Mostly ash, may contain toxic substances	Shredded wet waste, containing chemicals used as disinfectants

Table 3 Amount and composition of hospital waste generated

(a) Amount

Country	Quantity (kg/bed/day)
U. K.	2.5
U.S.A.	4.5
France	2.5
Spain	3.0
India	1.5

(b) Hazardous/non-hazardous

Hazardous	15%
a) Hazardous but non-infective	5%
b) Hazardous and infective	10%
Non-hazardous	85%

(c) Composition

By weight		
	Plastic	14%
Combustible		
	Dry cellublostic solid	45%
	Wet cellublostic solid	18%
Non-combustible		20%

Source*: http://isebindia.com/95_99/99-07-2.html*

Health hazards

According to the WHO, the global life expectancy is increasing year after year. However, deaths due to infectious disease are increasing. A study conducted by the WHO in 1996, reveals that more than 50,000 people die everyday from infectious diseases. One of major causes for the increase in infectious diseases is improper waste management. List of infections and diseases documented to have spread through bio-medical waste. Tuberculosis, pneumonia, diarrhoeal diseases, tetanus, whooping cough etc., are other common diseases spread due to improper waste management (Chitins *et al*, 2002; Chitins *et al*, 2003; Tudor *et al*, 2005; Marinkovic *et al*, 2005).

Occupational health hazards

Occupational health concerns exist for janitorial and laundry workers, nurses, emergency medical personnel, and refuse workers. Injuries from sharps and exposure to harmful chemical waste and radioactive waste also cause health hazards to employees in institutions generating bio-medical waste. Proper management of waste can solve the problem of occupational hazards to a large extent (Patil & Shekar, 2001).

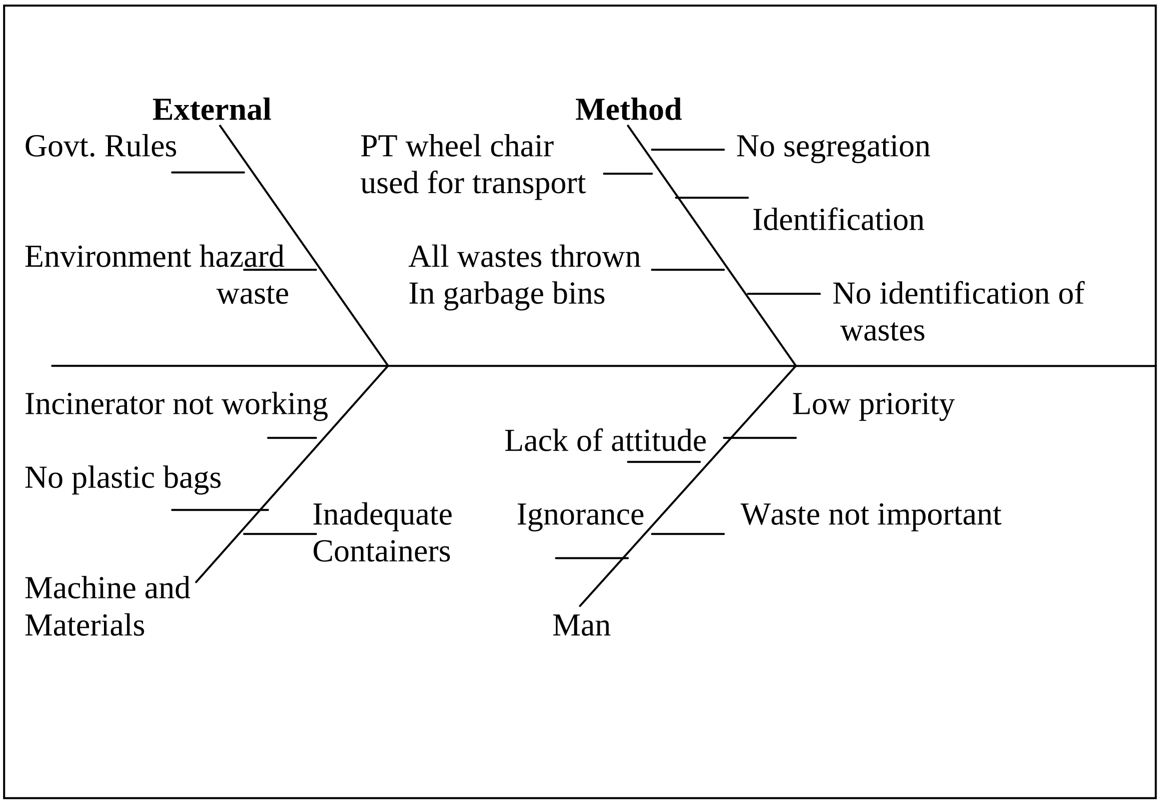
Hazards to the general public

The general public's health can also be adversely affected by bio-medical waste. Improper practices such as dumping of bio-medical waste in municipal dustbins, open spaces, water bodies etc., leads to the spread of diseases. Emissions from incinerators and open burning also lead to exposure to harmful gases which can cause cancer and respiratory diseases (Manohar *et al*, 1998; Da silva *et al*, 2005).

Plastic waste can choke animals, which scavenge on openly dumped waste. Injuries from sharps are common feature-affecting animals. Harmful chemicals such as dioxins and furans can cause serious health hazards to animals and birds. Certain heavy metals can affect the reproductive health of the animals (Code & Christic, 1999).

2. Environmental management system

The EMS is a broad framework aimed at providing effective direction for an institution in response to the changing external and internal factors. Waste system of the hospital was studied by (Das *et al*, 2001; CPHEE 1998; Kelkar, 1998; Kela *et al*, 2000). Figure 2 shows the waste management flow chart and process flow chart of the existing indicated the sequence from generation of waste to its final disposal. Figure 3 shows the interference of the points and data (Jaswal & Jaswal 2000). Colour coding and type of container for disposal of biomedical wastes is given in Table 4 Biomedical waste solutions specialize are in three categories namely:



*(Source: Das et al, 2001), Containment (Anonymous, 1998), Disposal (Ndiaye *et al*, 2003), Info nugget 2003)

Figure 2. Waste management flow chart*

Table 4. Type of container and colour code for collection of bio-medical waste

Category	Waste class	Type of container	Colour
1.	Human anatomical waste	Plastic	Yellow
2.	Animal waste	-do-	-do-
3.	Microbiology and Biotechnology waste	-do-	Yellow/Red
4.	Waste sharp	Plastic bag puncture proof containers	Blue/White Translucent
5.	Discarded medicines and Cytotoxic waste	Plastic bags	Black
6.	Solid (biomedical waste)	-do-	Yellow
7.	Solid (plastic)	Plastic bag puncture proof containers	Blue/White Translucent
8.	Incineration waste	Plastic bag	Black
9.	Chemical waste (solid)	-do-	-do-

Source: http://isebindia.com/95_99/99-07-2.html

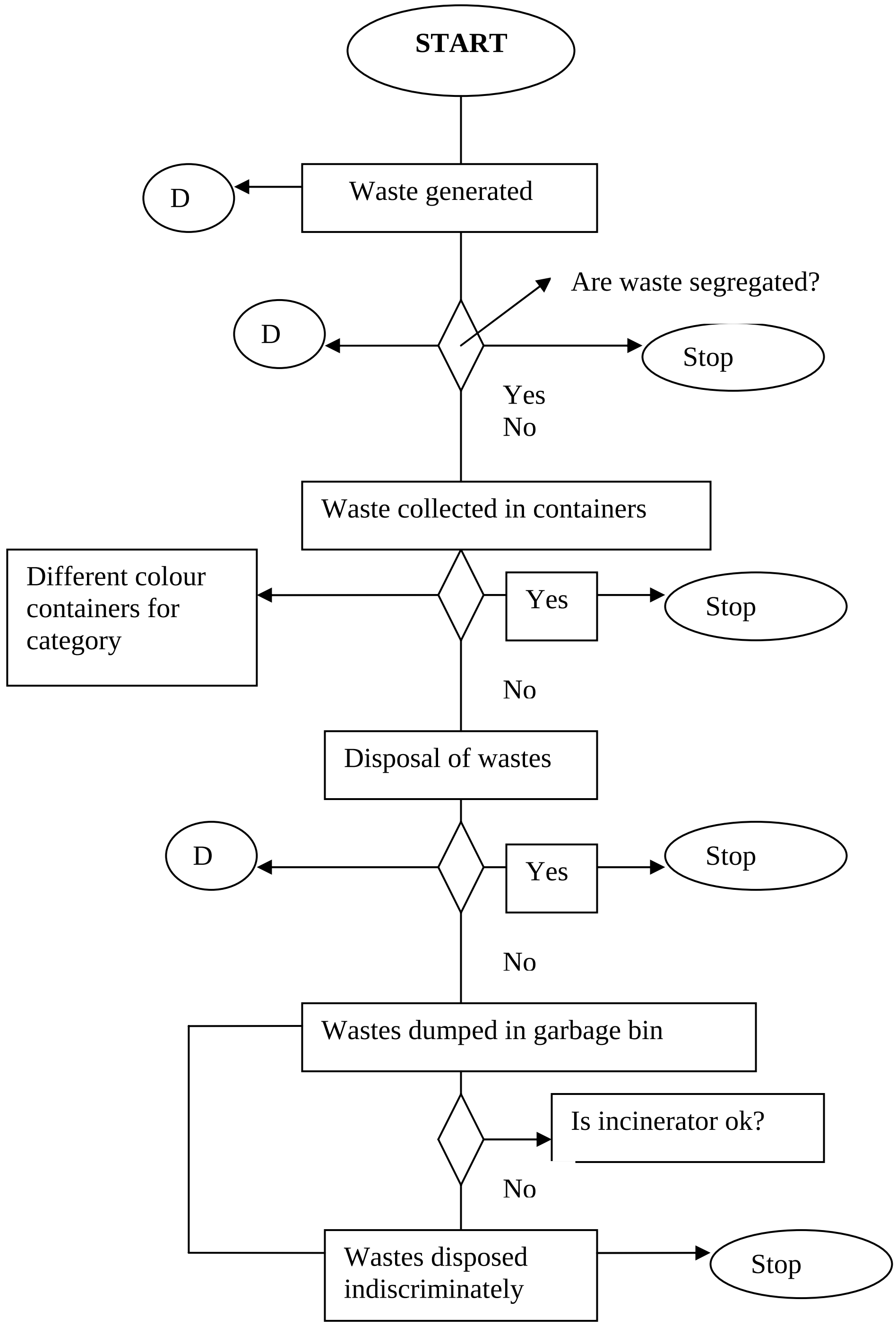


Figure 3. A process flow chart of the existing waste system of the hospital management of the infectious waste is crucial in today's health care arena (Saurabh, & Ram, 2006)

Disposal methods

Different methods are used for the disposal of bio medical waste and are discussed below:

Incineration:

It is a controlled combustion process where waste is completely oxidized and harmful microorganisms present in it are destroyed/denatured under high temperature. An article regarding plasma pyrolysis of medical waste was reported by Neema and Gareshprasad (2002). The authors stated that the operating cost of the system would be Indian Rupees 13 per kilogramme (kg), and the energy recovered would cost Indian Rupees 8 per kg; thus the net cost would be Rs 7 per kg. Amount and composition of hospital waste generated are in Table 5. Incineration is popular in countries such as Japan where land is a scarce resource, as they do not consume as much area as a landfill. Sweden has been a leader in using the energy generated from incineration over the past 20 years. Denmark also extensively uses waste-to-energy incineration in localised combined heat and power facilities supporting district heating schemes (Gupta, 1998).

Table 5. Machinery requirements for Common Waste Treatment Facility

1	Incinerators	2 numbers
2	Auto Claves	One
3	Microwave equipment	(Optional)
4	Shredders	2 nos
5	Chimney	30 M
6	Effluent Treatment Plant	1
7	Vehicle Washing Equipments	1
8	Water pumps, Storage, Air Compressors	1
9	Generator for Electricity	1

Source: http://mpcb.mah.nic.in

Autoclaving: Autoclaving is a low-heat thermal process where steam is brought into direct contact with waste in a controlled manner and for sufficient duration to disinfect the wastes. For ease and safety in operation, the system should be horizontal type and exclusively designed for the treatment of bio-medical waste. For optimum results, pre-vacuum based system be preferred against the gravity type system. It shall have tamper-proof control panel with efficient display and recording devices for critical parameters such as time, temperature, pressure, date and batch number etc (NEERI 1995, Bacini & Brunner, 1991; Pruss *et al*, 1999).

Microwaving, microbial inactivation occurs as a result of the thermal effect of electromagnetic radiation spectrum lying between the frequencies 300 and 300,000 MHz. Microwave heating is an inter-molecular heating process. The heating occurs inside the waste material in the presence of steam (Pruthvish *et al*, 1998).

Hydroclaving is similar to that of autoclaving except that the waste is subjected to indirect heating by applying steam in the outer jacket. The waste is continuously tumbled in the chamber during the process.

Shredder: Shredding is a process by which waste are deshaped or cut into smaller pieces so as to make the wastes unrecognizable. It helps in prevention of reuse of bio-medical waste and also acts as identifier that the wastes have been disinfected and are safe to dispose off. A shredder is to be used for shredding in bio-medical waste with minimum requirements (Singh & Sharma 1996; Shah *et al*, 2001; Rasheed *et al*, 2005).

Standards for treatment and disposal of bio-medical wastes

Standards for incinerators

All incinerators shall meet the following operating and emission standards

A. Operating Standards

1. Combustion efficiency (CE) shall be at least 99.00%.
2. The Combustion efficiency is computed as follows:

$$C.E = \frac{\%CO_2}{\%CO_2 + \%CO} \times 100$$

3. The temperature of the primary chamber shall be $800^o \pm 50^o$ C.
4. The secondary chamber gas residence time shall be at least I (one) second at $1050^o \pm 50^o$ C, with minimum 3% Oxygen in the stack gas.

B. Emission Standards

The emission standards are given in Table 6.

Table 6. EPA Emission limits for new hospital/medical/infectious waste incinerators

POLLUTANT	**EMISSION LIMITS**		
	Small	**Medium**	**Large**
Particulate Matter	69 mg/dscm	34 mg/dscm	34 mg/dscm
Carbon Monoxide	40 ppmv	40 ppmv	40 ppmv
Dioxins/Furans	125 ng/dscm total or 2.3 ng/dscm TEQ	25 ng/dscm total or 0.6 ng/dscm TEQ	25 ng/dscm total or 0.6 ng/dscm TEQ\
Hydrogen Chloride or 99% reduction or 99% reduction	15 ppmv or 99% reduction	15 ppmv or 99% reduction	15 ppmv or 99% reduction
Sulphur Dioxide	55 ppmv	55 ppmv	55 ppmv
Nitrogen Oxides	250 ppmv	250 ppmv	250 ppmv
Lead	1.2 mg/dscm or 70% reduction	0.07 mg/dscm or 98% reduction	0.07 mg/dscm or 98% reduction
Cadmium	0.16 mg/dscm or 65% reduction	0.04 mg/dscm or 90% reduction	0.04 mg/dscm or 90 % reduction
Mercury	0.55 mg/dscm or 85% reduction	0.55 mg/dscm or 85% reduction	0.55 mg/dscm or 85% reduction

mg = milligrams, dscm = dry standard cubic meter, ppmv = parts per million by volume ng = nanograms, TEQ = toxic equivalent; Capacities: small=less than or equal to 200 lbs/hr; medium=greater than 200 lbs/hr to 500 lbs/hr; large=greater than 500 lbs/hr.

***Standard for liquid waste**:*

Table 7. shows the effluent generated from the hospital should conform to the following limits

Table 7. Emission standards waste incinerators

S. No.	**Contaminant**	**Limit**
1	Total Particulate	20 mg/m^3
2	Carbon Monoxide	55 mg/m^3
3	Sulphur Dioxide	180 mg/m^3
4	Nitrogen Oxides (NOx as NO_2)	380 mg/m^3
5	Hydrogen Chloride	50 mg/m^3 or 90% removal
6	Hydrogen Fluoride	4 mg/m^3
7	Total Hydrocarbons (as Methane CH_4)	32 mg/m^3
8	Arsenic	4 µg/m^3
9	Cadmium	100 µg/m^3
10	Chromium	10 µg/m^3
11	Lead	50 µg/m^3
12	Mercury	200 µg/m^3
13	Chlorophenols	1 µg/m^3
14	Chlorobenzenes	1 µg/m^3
15	Polycyclicaromatic Hydrocarbons	5 µg/m^3
16	Polychlorinated Biphenyls	1 µg/m^3
17	Total PCDDs & PCDFs Opacity	0.5 ng/m^3 5%

Source: (Machala *et al*, 2007)

Common Biomedical treatment Facilities

Tables 8 and 9 show the machinery requirements for Common Waste Treatment Facility.

Table 8. Effluent generated from hospital

Parameters	Permissible limits
pH	6.3-9.0
Suspended solids	100 mg/L
Oil and grease	10 mg/L
BOD	30 mg/L
COD	250 mg/L

Source: Srivasta, 2000

Table 9. Design and Operation Requirements for Biomedical Waste Incinerators and Emission Control Systems

S.No.	Parameter	Incinerator Type Modular (Excess Air and Starved Air)	Incinerator Type Mass Burn
1	Incinerator		
2	Minimum Incineration Temperature	1000 degrees C at fully mixed height	1000 degrees C determined by an overall design review
3	Minimum Residence Time	1 second after final secondary air injection ports	1 second calculated from the point where most of the combustion has been completed and the incineration temperature fully developed
4	Primary Air (Underfire)	Utilize multi-port injection to minimize waste distribution difficulties	Use multiple plenums with individual air flow control
5	Secondary Air (Overfire)	Up to 80% of total air required (1)	At least 40% of total air required
6	Overfire Air Injector Design	That required for penetration and coverage of furnace cross-section	That required for penetration and coverage of furnace cross-section
7	Auxiliary Burner Capacity	Secondary burner 60% of total rated heat capacity, and that required to meet start-up and part-load temperatures	60% of total output, and that required to meet start-up and part-load temperatures
8	Oxygen Level at the Incinerator Outlet	6 to 12%	6 to 12%
9	Turndown Restrictions	80 to 110% of designed capacity	80 to 110% of designed capacity
10	Maximum CO Level	55 mg/m^3 @ 11% (4-h rolling average)	55 mg/m^3 @ 11% (4-h rolling average)
11	Combustion Efficiency	99.9% (8-h rolling average)	99.9% (8-h rolling average)
12	Emission Control Systems		
13	Flue Gas Temperature at Inlet or Outlet of Emission Control Device (2)	Not to exceed 140 degrees C	Not to exceed 140 degrees C
14	Opacity	Less than 5%	Less than 5%

Common Biomedical treatment Facilities are setup for the treatment and disposal of Biomedical Wastes generated in a number of health care facilities. They are likely to be more economical than individual waste treatment facilities. Resources can be utilized optimally in case of common Facilities (Anonymous, 1997; Ranyal, 2000; http://www.cpcb.nic.in).

Present Scenario:

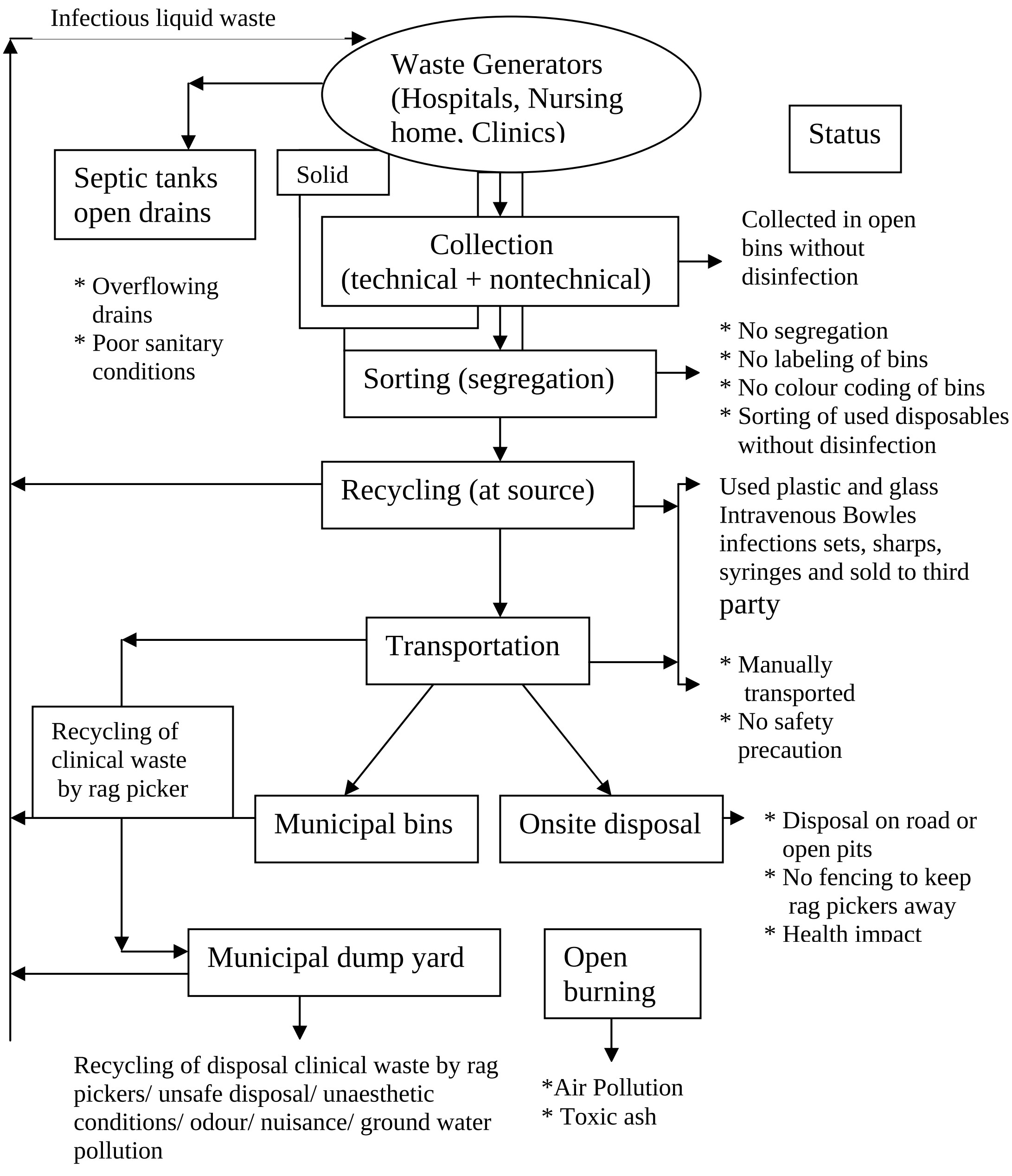
Waste management is one of the important public health measures. If we go into the historical background, before discovery of bacteria as cause of disease, the principle focus of preventive medicine and public health has been on sanitation. The provision of potable water, disposal of odor from sewage and refuse were considered the important factors in Prevention of epidemics. The current status of practice in India is given in Figure 4.

The vehicles transporting the wastes to the facility shall be designed exactly as per the standards of Bureau of Indian Standards (Anonymous, 2005). They should also be labelled with symbols meant for hazardous wastes. The common Treatment facilities should comply with all the emission and effluent standards of the pollution control Board (Anonymous, 2005).

Biomedical waste in Delhi, India

With increasing awareness in general populations regarding hazards of hospital waste, public interest, litigations were filed against erring officials. Some landmark decisions to streamline hospital waste management have been made in the recent time (http://health.delhigovt.nic.in/Health/files/bio.html)

All health care institutions are required to handle biomedical waste in a specified manner. Delhi is generating approximately 6500 metric tons of waste out of which 65 tons are Biomedical Waste. The Government hospitals and major private hospitals have their own arrangement for treatment of biomedical waste (Anonymous, 1998, Gayathri and Kamala P, 2005, Saurabh G, Ram B, 2006)



*(Source: Saurabh & Ram , 2006)

Figure 4. Current status of medical waste disposal in Lucknow, India

Conclusions

Proper management of Bio medical waste is a concern that has been recognized by both government agencies and the Non government organizations. Several hazards and toxic materials containing should be disposed off with proper take and care. Inadequate and inefficient segregation and transportation system may cause severe problem to the society hence implementing of protective measures, written policies all of these factors contribute to increased risk of exposure of staff, patients and the community to biomedical hazards. In order to accelerate the rate at which proper processing and management methods are designed, timely regulatory and legislative policies and procedures are needed. To properly separate, process and isolation of wastes, they must be well-characterized, which is challenging. Safe and effective management of bio medical waste is not only a legal necessity but also a social responsibility. Lack of concern in persons working in that area, less motivation, awareness and cost factor are some of the problems faced in the proper hospital waste management. Proper surveys of waste management procedures in various practices are needed. Clearly there is a need for education as to the hazards associated with improper waste disposal. An effective communication strategy is imperative keeping in view the low awareness level among different category of staff in the health care establishments regarding biomedical waste management. One important direction for future research would be to project the flows of bio medical waste worldwide and quantitatively and qualitatively assess.

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