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Emerging Technologies in Biomedical Waste Treatment and Disposal

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The present study has been conducted at the district health care facility of a town in India to understand the characteristics of biomedical waste, category wise generation rate, segregation, labelling, handling, treatment and disposal methods for residue. The main focus has been on the development of an integrated low heat treatment system utilizing various available technologies like autoclaving, microwaving, and solar systems to economize the transportation cost to the zonal treatment facility. An attempt has also been made to minimizing the risk of infection and lowering the stress of the treatment on less green techniques like incineration. Owing to the recent developments the clinics, hospitals, medical colleges, nursing homes, medical laboratories and research centres have sprung not only in metros but even in small towns and villages. Since it is not feasible to build treatment facility in every hospital, biomedical wastes need to be transported to zonal treatment facility, which may be located far away from the health care facilities. Biomedical waste, however, can be rendered safe and unobjectionable, aesthetically and environmentally, if health care facility managers implement the requirements and recommendations of several codes of practice and technical advice, which are simple and inexpensive.

1. Introduction

Inadequate and inappropriate handling of health care waste may have serious public health consequences and a significant impact on the environment (Pruss et al., 1999). Dwivedi et al (2009) has studied that all the waste materials which is generated by hospitals are not hazardous in nature but only a part of these wastes are infectious which is laden with fatal microorganisms of many serious contagious diseases, which easily spread into water bodies and air. Proper management and handling of hazardous waste is of prime importance today. To minimize these problems many efforts have been done or are being done at the international level. For safe and scientific management of biomedical waste, handling, segregation, mutilation, disinfection, storage, transportation and finally disposal are vital steps for any health care institution. In developed countries all the institutions related to the health problem are adopting these vital steps. Katoch and Kumar (2008) have reported that a mathematical model can assist waste management planners to optimize existing waste management systems, to set guidelines and regulations, and to evaluate prevailing strategies for the handling of waste. The total process by which the medical waste is treated will influence the selection of biological and physical indicators used in the testing and validation processes and will influence the protocols in which they are used. The development of new medical waste treatment methods utilizing heat, chemicals, heat/chemicals, or irradiation has provided potential alternate solutions to the medical waste treatment/disposal problem (EPRI, 2000). The usual practice of disposal of health care waste in the different regions of the world is tabulated as follows (Table 1).

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Table 1: The most common disposal methods of health care waste of different countries

Country	Disposal methods	References
Mongolia	Open dumping or open burning, Incineration, Autoclaving	Shinee et al. (2008)
Bangladesh	Dumping	Hassan et al. (2008)
Libya	Dumping, Incineration	Sawalem et al. (2009)
Greece	Recycling- Reuse, Pyrolytic combustion, Landfill	Tsakona et al. (2007)
Malaysia	Landfill, Incineration, Recycling	Hossain et al. (2011)
India	Landfill, Incineration, Autoclaving, Recycling - reuse	Personal investigation

2. Disinfection efficacy of the treatment processes

The establishment of specific criteria that define medical waste treatment efficacy is required to consistently evaluate new or modified medical waste treatment technologies. There are four levels of treatment (EPRI, 2000 and HCWH, 2001):

Level 1 – Low Level Disinfection:
Inactivation of most vegetative bacteria, fungi, and some viruses but does not inactivate mycobacteria and bacterial spores and thus is inadequate for biomedical waste treatment.

Level 2 – Intermediate Level Disinfection:
Inactivation of all mycobacteria, viruses, fungi and vegetative bacteria but that of bacterial spores is not included. Tests for this level disinfection must show that a 6 log reduction of microorganism most resistant to the treatment is attained.

Level 3 – High Level Disinfection:
A minimum of 4 log reduction of spores of either *B. stearothermophilus* or *B. subtilis* is accepted as indicating high level disinfection. A 4 log 10 reduction is equivalent to a 99.99% reduction in spores.

Level 4 – Sterilization:
Sterilization is evidenced by a minimum 6 log reduction in spores of *B. stearothermophilus.*

The reduction levels required has been summarized as under (Table 2):

Table 2: Regulated Reduction Levels

Process Technology	Reduction of *B. stearothermophilus* spores (Sterilization – level 4)	Reduction of *B. stearothermophilus* or *B. subtilis* spores (High Level Disinfection – level 3)
Steam sterilization	6 log 10	-
Chemical	-	4 log 10
Microwave	-	4 log 10
Macrowave	-	4 log 10

3. Low heat treatment systems

The environmental regulations actually mandate the treatment of infectious medical waste on a daily basis if it is stored at room temperature. A number of treatment methods are available. The final choice of suitable treatment method is made carefully, on the basis of various factors, many of which depend on local conditions including the amount and composition of waste generated, available space, regulatory approval, public acceptance, cost etc. However, incineration used to be the method of choice for most hazardous health care wastes and still widely used. Low heat treatment systems popularly known as non-incineration treatment include four basic processes: thermal, chemical, irradiative, and biological. The majority of non-incineration technologies employ the thermal and chemical processes. The main purpose of the treatment technology is to decontaminate waste by destroying pathogens. Facilities should make certain that the technology could meet state criteria for disinfection.

3.1 Autoclaving

Autoclaving is a low-heat thermal process where steam is brought into direct contact with waste in a controlled manner for sufficient duration to disinfect the waste. 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 is 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, pressure, date and batch number etc. Typically, autoclaves are used in hospitals for the sterilization of reusable medical equipment. They allow for the treatment of only limited quantities of waste and are therefore commonly used only for highly infectious waste, such as microbial cultures or sharps. Research has shown that effective inactivation of all vegetative microorganisms and most bacterial spores in a small amount of waste (about 5-8 kg) require a 60 mine cycle at 121 °C (minimum) and 1 bar (100 kPa); this allows for full steam penetration of the waste material. About 99.9999 % inactivation of microorganisms is achievable with autoclave sterilization (Pruss et al., 1999).

3.2 Microwave Irradiation

In 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. Most microorganisms are destroyed by the action of microwaves of a frequency of about 2450 MHz and a wavelength of 12.24 cm. The microwaves rapidly heat the water contained within the waves and the infectious components are destroyed by heat conduction (Hoffman and Hanley, 1994).

3.3 Chemical Methods

Chemical disinfection, used routinely in health care to kill microorganisms on medical equipment and on floors and walls, is now being extended to the treatment of health-care waste. Chemicals are added to waste to kill or inactivate the pathogens it contains; this treatment usually results in disinfection rather than sterilization. Chemical disinfection is most suitable for treating liquid waste such as blood, urine, stools, or hospital sewage. Several self-contained waste treatment systems, based on chemical disinfection, have been developed specifically for health care waste and are available commercially. Most commonly used chemicals for disinfection of bio medical waste are sodium hypochlorite ($NaClO$, 5 %) hydrogen peroxide (H_2O_2, 30 %), and Fenton reagent ($FeCl_2.2H_2O$; 0.3 g in 10 ml H_2O_2, 30 %) (Chitnis et al., 2003 and HCWH, 2001).

3.4 Solar Disinfection

Solar heating as an alternative technology to cook up medical waste is being used in poor developing countries that cannot afford other expensive technologies. Chitnis et al in 2003 reported a 7 log reduction in the amount of viable bacteria when they used a box – type solar cooker to disinfect medical waste. A hybrid solar steam sterilizer with a capacity to run 76 L autoclave four times a day built in cooperation with Solar Bruke (Germany) and Solar Alternative (India) was at first installed in Holy Family Hospital in Mandar (150 beds) in winter 2004.

4. Case Study

The efficacy testing is only one factor in the safe and effective treatment of medical waste by conventional or new technologies. The facilities generating medical waste must evaluate their current waste streams in order to minimize the medical waste components of their solid wastes, more effectively manage the processing and transport of the medical waste within their facilities and insure that all medical waste is appropriately packaged for internal and/or external transport. The establishment of qualitative and quantitative parameters that ensure effective and safe medical waste treatment are required in defining treatment technology efficacy criteria and delineating the components necessary to establish an effective state medical waste treatment technology approval process (EPRI, 2000).The total amount of medical waste generated from a health care facility is associated with the type or the size of the institution (Cheng et al., 2009). Biomedical waste management rules were formulated in response to the worldwide public concern over medical waste. The practice of separation into different types of waste in health care institutes should be evaluated more scientifically. This study strongly suggests that waste should be removed from the hospital within 24 hours of its generation to prevent environmental contamination caused by any accidental spillage of waste. General waste generated in the hospital should be treated similar to infectious waste, as it can be equally hazardous (Saini et al., 2004).

Modeling of waste management system is rater less developed, perhaps due to the fact that the process invokes a large number of parameters having unknown behavior. However, need of some predictive tool is clearly visualized by many researchers (Katoch and Kumar 2008). MoEF, GoI (1998) had earlier described ten categories which are reduced to eight in the draft rule of 2011. Many regulatory definitions of regulated medical waste are based on ten broad categories defined in a 1986 EPA guide on infectious waste management. The ten categories are: Cultures and Stocks; Anatomical Wastes (or Human Pathological Wastes); Human Blood, Blood Products, and Other Bodily Fluids; Sharps; Animal Wastes; Isolation Wastes; Contaminated Medical Equipment; Surgery Wastes; Laboratory Wastes; and Dialysis Wastes (HCWH, 2001).

In compliance to Biomedical Waste (Management and Handling) Rules, Municipal Corporation Shimla had established zonal treatment facility for incineration of yellow bag waste since August 2002. In addition an autoclave facility within the campus of IGMCH which had been operating since September 2003 along with a shredder for the purpose of disinfection, recycling and resale of red bag waste. There are around one hundred clinics and health care facilities in the limits of Municipal Corporation. It was formerly the summer capital during the British Rule. Its altitude is about 2,100 m and surrounded by pine, deodar, oak, and rhododendron forests. The area of town is about 25 km^2. All the seasons of nature visit Shimla during the year. In the present study only five major health care facilities of a town Shimla, India which lies in between the longitude 77^o-0” to 78^o-19” E and latitude 30^o-45” to 31^o-44” N are considered (Table 3).

Table 3: Major Health Care Facilities (HCFs) at Shimla HP, India

Address of Health Care Facility	Specialty	Number of Beds
IGMC Hospital, Snowdon, Shimla.	State level general government hospital attached to medical college with state of art facility: Medicine, Surgery, Cardiology, Psychiatry, Orthopaedics, Paediatrics, ENT, Eye, Plastic Surgery, Urology, Radiotherapy etc.	872
KN Hospital, Marrina, Shimla.	Exclusively female care, gynaecology & obstetrics and attached to government medical college	136
DDU Hospital, Bus Stand, Shimla.	District level general male and female indoor and outdoor health care.	150
Indus Hospital, Jakhu, Shimla.	Private Hospital for general male and female health care with modern facilities and equipments.	100
Shimla Sanatorium, Chaura Maidan, Shimla.	TB Sanatorium	50

The data of biomedical waste incinerated at zonal treatment facility (ZTF) and autoclaved at Indira Gandhi Medical College and Hospital (IGMCH) of Shimla town on yearly basis under present study have been collected for five consecutive years (2007 to 2011). These waste data include both indoor and outdoor patients visiting health care facilities. The preliminary trends have been analysed (Figure1 and Figure 2). However, it appears that most of the biomedical waste is accumulated and sent for incineration. But after the year 2010 the autoclaving of biomedical waste has registered significant increase.

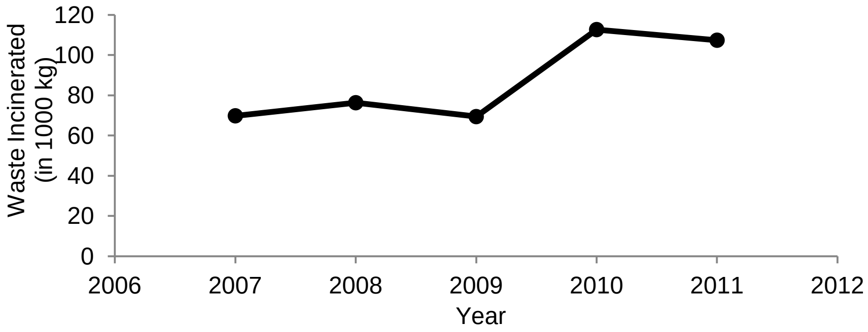

Figure1. Biomedical Waste Incinerated at ZTF Shimla (2007- 2011)

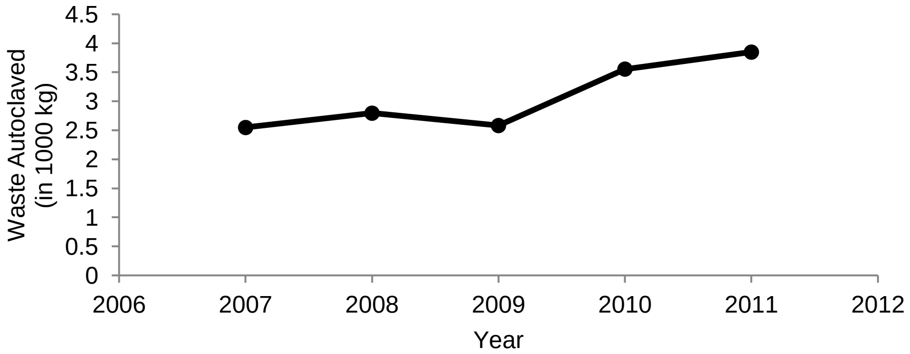

Figure 2. Biomedical Waste Autoclaved at IGMCH Shimla (2007- 2011)

5. Conclusions

Incineration still is the most favoured and widely used treatment technology. A Zonal Treatment Facility (ZTF) setup at Shimla, India where yellow bag biomedical waste, generated from a number of healthcare units, is imparted necessary treatment through incineration to reduce adverse effects that this waste may pose. The treated waste is sent for disposal in a secured landfill.

The autoclave unit running at the IGMCH Shimla has clearly shown a decline in the amount of waste incinerated and an increase in the quantity of the waste autoclaved in the recent past over a period of time. The autoclaved waste is being recycled and its resale is also going on since 2010.

Solar heating seems to be a cheap method to disinfect infectious medical waste in less economically developed countries. The alternative selected must provide adequate protection of public health, and be the most cost effective alternative to meet the limiting criteria. Recently developed alternative treatment methods are becoming increasingly popular. Sterilization/sanitation techniques represent now a technically and commercially viable alternative to biomedical waste thermal destruction that, besides, is more and more socially and politically less accepted.

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