CHAPTER – II

Review of Literature and Research Methodology
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In this chapter an attempt was made to review the literature on (1) Bio-Medical Waste Management in Hospitals (2) Treatment technologies and (3) Disposal practices. This is followed by a description of the research objectives and methodology adopted in the present study.

II.1. Common Bio Medical Waste Treatment Facilities (CBMWTF)

A Common Bio Medical Waste Treatment Facility (CBMWTF) is an infrastructure developed by private management under the supervision of Government of India, where biomedical waste, generated from a number of healthcare units, will be treated to reduce adverse effects that this waste may pose. The treated waste may finally be sent for disposal in a landfill or for recycling purposes. These facilities are present for each district in all the States. The number of CBMWTF depends on the number of Health care facilities. As per the Bio Medical Waste Handling Rules, it is mandatory, for each individual, small, and medium Health care facility, to send biomedical waste to CBMWTF. If not so, HCFs have to establish in-house treatment facility.

Chang (1995) has reported that rapid advances of medical activities in Taiwan have caused an environmental problem in managing the waste generated by hospitals or clinics. Government regulations, public concern and an increased commitment to a clean environment have also brought more attention to the handling problems of medical waste. A project to plan and manage the first centralized incineration plant for infectious hospital waste has been carried out in Taiwan. Public concern against incineration was considered to be the most important criterion to address during establishment of the incinerator, as well as good operational performance.

It is well known that biomedical waste generated is not permitted to be mixed with municipal waste and stored beyond a period of 48 hours. If for any reason it becomes necessary to store the waste beyond such period, the authorized person must take
permission of the prescribed authority and take measures to ensure that the waste does not adversely affect human health and the environment. Every occupier of an institution is required to set up in accordance with the time schedule prescribed in the rules, requisite biomedical waste treatment facilities like incinerator, autoclave, microwave system for the treatment of waste, or ensure requisite treatment of waste at a Common Bio Medical Waste Treatment Facility (CBMWTF).

One of the options which are most common in India for the treatment of health care waste is the incinerator. There is growing interest in alternative technologies for treatment of biomedical waste due to concerns of air pollution from biomedical waste incineration. Therefore, some of the advanced technologies alternatives to incineration such as microwave, hydroclave, pyrolysis, ozonation, alkaline hydrolysis etc., are being critically examined for economical and safe handling. Common treatment facilities are necessary because it is not feasible for smaller health care establishments to set up a complete treatment and disposal system due to lack of space, trained manpower, minimum scale of operation and scale of economy. The main reasons for improper management of the biomedical waste are financial and technological constraints and difficulty in monitoring of scattered health care facilities. The central treatment facilities would be providing advantage of economies of scale, state-of- art technologies, air control devices and ease of monitoring the functioning of waste management facilities.

II.1.i. Process and Treatment Technologies for Bio Medical Waste

As per the Ministry of Environment and Forests, India, treatment of infectious medical waste on a daily basis is mandated. A number of BMW treatment methods are available yet the final choice of suitable treatment method is made carefully, on the source 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.
II.1.i.a. Incineration treatment

It is used to be the method of choice for most hazardous health-care wastes and is still widely used. Incineration has been recognized as the best method for the disposal of infectious hospital waste. Usually 64-93% treatment of regulated medical waste in US hospitals is accomplished by incineration and majority of the hospitals are using steam sterilize for Microbial waste disinfection (Rutala and Mayhall, 1992).

Incineration of BMW includes combustible materials such as polyvinyl chloride plastics, papers and discarded items of equipment that constitute biomedical waste, because it can significantly reduce the volume of waste material and can also destroy organic matter (Lee et al., 2003a,b). But the disadvantage of medical waste incineration is the emission of pollutants to the atmosphere, some of them are extremely toxic. Many gaseous and condensed organic and metallic compounds have known effects on human health and environment (Alvim-Ferraz et al., 2000, Alvim-Ferraz and Afonso, 2003a,b).

UNEP (2005), explained the standard method for safe destruction of pathogenic microbes in infectious waste.

According to Chen et al. (2003) the inventories of potential emissions of polycyclic aromatic hydrocarbons (PAHs) performed in a lot of countries in the recent past have shown that combustion is a major contributor to the environmental concentrations of these toxic pollutants. Up to now, the emissions of PAHs have become one of the most controversial issues related to different incinerators.

One of the major objectives of incinerators is to develop a sustainable waste management by reducing volume of non avoidable and non recyclable medical waste and to decrease its toxicity to the biotic and abiotic environment. Major pollutants are trace metals enriched in medical waste products. Since combustion will not destroy inorganic compounds present in healthcare waste, such as metals, it is possible that such compounds may end up in bottom ash at harmful concentrations. While some general information is available from recently published work, the behaviour of the metals in the bottom ash of medical waste incinerators is yet to be understood. Although the bottom ash
can be utilized for recovery from the conventional incinerators based on the grate system, a major portion of these residues are still landfilled (Racho and Jindal, 2004).

In Japan, reported Shimaoka and Hanashima (1996), landfilling or ocean dumping of fly ash is prohibited. To avoid the possibility of causing damage to environment and human health, fly ash must be subjected to intermediate treatment to be stabilized and made insoluble and non-unhygienic. Four methods can be used for the fly ash intermediate treatment; (1) cement solidification, (2) treatment by chemicals, (3) acid and other solvents and (4) melting and solidification.

All types of incinerators, if operated properly, eliminate pathogens from waste and reduce waste to ashes. However, certain types of health-care wastes, e.g., pharmaceutical or chemical wastes, require higher temperatures for complete destruction. Incinerators designed especially for treatment of health-care waste should operate at temperatures between 900 and 1200°C (Pruss et al., 1999).

Pandompatam et al. (1997) have successfully experimented a pilot-scale incinerator with a nominal capacity of 50 kg/h used to simulate PCDD (Polychlorinated Dibenzo-p-Dioxin) and PCDF (Polychlorinated Dibenzofurans) emissions from fuel processing NaCl contaminated bark. Biomedical waste incinerators in Ontario are available in a wide range of capacities. Ozvacic et al. (1990) reported testing and evaluation program carried out at Ontario in small, batch or semi-continuously fed two-chamber type incinerators. All these incinerators are equipped with either afterburners or secondary stage burners to keep the combustion gas at 1000 °C for one half second.

The Ontario Ministry of the Environment (MOE) has initiated an extensive testing and evaluation program to generate the needed emission data. Except for data generated in this program, there are no other air emission data for toxic pollutants from biomedical waste incinerators in Ontario.

Nasserzadeh et al., (1995) reported that the use of incineration to dispose of clinical waste is increasing as clinical waste disposal regulations become more stringent. Every year in the UK more than one million tonnes of hospital wastes are generated. Most of this
is potentially infectious and must be incinerated. Liberti et al., (1996) reported in their second paper in a two-part series more detailed data on the physicochemical characteristics of normal and infectious hospital waste and determined experimentally in a large sanitary district that includes four hospitals, public and private, with 164 sanitary departments, 40 analytical laboratories and 2500 rehabilitation beds, near the town of Bari (Southern Italy).

In all cases, Infectious Hospital Waste was shown to be classified as non-toxic deserving 950°C rather than 1200°C incineration temperature according to Italian Legislation.

Waclawiak (2002) studied a cylindrical pyrolyzer used in hospital waste incineration and reported that crucial factors are length and width of the reactor in terms of optimization of gas yield. Both experimental and modeling studies of the pyrolysis process inside the unit were carried out. It was shown how velocity, pressure and density of gas change in the reactor. The reactor used was 1 meter long and 24 cm in diameter, filled with municipal waste. Although widely used, incinerators pose serious environmental problem.

Marrack (1988) established the hydrochloric acid, dioxins and furans generated during the burning of chlorinated plastic (PVC) in red bag waste are important air pollutants. In this waste, PVC provides much of the organic chloride for the dioxins and furans generated.

II.1.i.b. Non-incineration Treatment

Non-incineration treatment contains four steps for effective treatment which are (i) Thermal (ii) Chemical (iii) Irradiative and (iv) Biological processes. But 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.

II.1.i.c. Thermal Treatment

Autoclaving is an efficient wet thermal disinfection process. Typically, autoclaves are used in labs and hospitals for 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) requires a 60-minute cycle at 121°C (minimum) and 1 bar (100kPa); 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). Chitnis et al., (2005) audited biomedical waste in pathology, microbiology, blood bank and other diagnostic laboratories. Needle sharps are collected in puncture proof containers and needles autoclaved before sending to needle pit. All microbiology waste along with containers/plates/tubes is autoclaved before recycling/disposal. The discarded/infected blood units in blood bank need to be autoclaved before disposal since chemical treatments are difficult or inefficient.

Lauer et al. (1982) examined the temperature profile of infectious laboratory waste being autoclaved relative to the type of containers used in the process. A standardized waste load (1,750 ± 4 g) placed in the container was evaluated by using a direct readout thermocouple.

Blood bank regulations and biomedical waste rules of India advocate disinfection of contaminated blood units. Incineration is not recommended due to polyvinyl chloride (PVC) content of blood bags. This study was designed to evaluate the efficacy of chemical disinfection of blood units deliberately contaminated with Staphylococcus aureus and E.coli with 1 and 6% hypochlorite, 10% formalin and 33% formaldehyde and autoclaving of blood units contaminated with the above mentioned vegetative forms and B. stearothermophilus spores. Only 33% formaldehyde could bring about 5 Log reduction of bacteria but it is highly irritating and toxic. Autoclaving at 15 lbs pressure for 2 hours uniformly inactivated the vegetative forms and B. stearothermophilus spores. Thus, autoclaving of PVC blood bags is a safer and reliable method compared to chemical disinfection (Chitnis et al., 2003).
II.1.i.d. Chemical Treatment

Chemical treatment includes disinfectants such as dissolved chlorine dioxide, bleach (sodium hypochlorite), peracetic acid, or dry inorganic chemicals. These disinfectants will be used to treat liquid waste that was drained to separate disinfection canals in the hospital campus. Addition of these chemicals kill all the native and transient microbial flora. After disinfection the liquid waste will be released to sewers. To enhance exposure of the waste to the chemical agent, chemical processes often involve shredding, grinding, or mixing. In liquid systems, the waste may go through a dewatering section to remove and recycle the disinfectant. Besides chemical disinfectants, there are also encapsulating compounds that can solidify sharps, blood, or other body fluids within a solid matrix prior to disposal (HCWH, 2001).

Pruss et al. (1999) described that chemical disinfection is usually carried out on hospital premises. Recently, however, commercial, self-contained, and fully automatic systems have been developed for health care waste treatment and are being operated in industrial zones. The disinfected waste may be disposed of as non-risk health care waste, but the chemical disinfectants may create serious environmental problems in case of leakage or after disposal.

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.

Barek et al. (1998) have tested three chemical methods viz. oxidation with sodium hypochlorite (NaClO, 5%) hydrogen peroxide (H2O2, 30%), and Fenton reagent (FeCl2.2H2O; 0.3 g in 10 ml H2O2, 30%), for the degradation of four anticancer drugs: Amsacrine, Azathioprine, Asparaginase and Thiotepa. The efficiency of the degradation
was monitored by high-performance liquid chromatography. In all cases where a high degree of degradation was achieved, the residues obtained were non mutagenic.

II.1.i.e. Irradiative Treatment

Gamma irradiation (e.g., Cobalt-60) has been used for many years as a means of inactivating potential pathogens on the surfaces of many different medical products. Since the appropriate dose of radiation can be precisely calculated, it has been found to be an extremely reliable treatment system. A newer form of irradiation system employs an electron beam generated by an accelerator to sterilize medical products and, potentially, clinical waste. Irradiation systems require extensive shielding to protect the workers, can only treat relatively small quantities of waste and do not alter the physical appearance of the material (EA, 2003). HCWH (2001) recorded that these technologies require shielding to prevent occupational exposures. Irradiation does not alter the waste physically and would require a grinder or shredder to render the waste unrecognizable.

II.1.i.f. Microwave Irradiation

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 molecules contained within the waves and the infectious components are destroyed by heat conduction. In the USA, a routine bacteriological test using Bacillus subtilis is recommended to demonstrate a 99.99% reduction of viable spores (Pruss et al., 1999).

Hoffman and Hanley (1994) assessed a clinical waste decontamination unit that used microwave-generated heat for operator safety and efficacy. Tests with loads artificially contaminated with aerosol-forming particles showed that no particles were detected outside provided the seals and covers were correctly sealed. Thermometric measurement of a self-generated steam decontamination cycle was used to determine the parameters needed to ensure heat disinfection of the waste reception hopper, prior to entry for maintenance or repair. Bacterial and thermometric test pieces were passed through the machine within a full load of clinical waste. These test pieces, designed to represent a
worst-case situation, were enclosed in aluminum foil to shield them from direct microwave energy. None of the 100 bacterial test pieces yielded growth on culture and all 100 thermal test pieces achieved temperatures in excess of 99 °C during their passage through the decontamination unit. It was concluded that this method might be used to render safe the bulk of ward generated clinical waste.

II.1.i.g. Advanced Treatment Technologies: Pyrolysis Treatment and Plasma Technology

Plasma Pyrolysis is a state-of-the-art technology for safe disposal of medical waste. It is an environment-friendly technology, which converts organic waste into commercially useful by-products. The intense heat generated by the plasma enables it to dispose all types of waste including municipal solid waste, biomedical waste and hazardous waste in a safe and reliable manner. Pyrolysis involves the high temperature (545 to 1000 °C) combustion of waste in the absence of oxygen. In generating these high temperatures, the systems treat, destroy, and reduce the volume of clinical waste (EA, 2003). Medical waste is pyrolysed into CO, H2, and hydrocarbons when it comes in contact with the plasma-arc. These gases are burned and produce a high temperature (around 1200°C). In the plasma pyrolysis process, the hot gases are quenched from 500°C to 70°C to avoid recombination reactions of gaseous molecules that inhibit the formation of dioxin and furans. The gas analysis results reveal that toxic gases found after the combustion are well within the limit of the Central Pollution Control Board emission standards. The plasma pyrolysis technology has been indigenously developed at the Facilitation Centre for Industrial Plasma Technologies, Institute for Plasma Research, Gandhinagar (Nema and Ganeshprasad, 2002).

Inaba and Iwao (2000) reported that plasma treatment is being developed and tested for incinerator ash, low level radioactive wastes, industrial and biomedical wastes, etc., by industrial companies and municipalities worldwide.

II.1.i.h. Plasma Technology

In plasma system, an electric current is discharged through an inert gas (e.g., argon) to ionize it and in turn cause an electric arc to create temperatures as high as 6000 °C. The
clinical waste within the system is brought to temperatures between 1300 to 1700 °C, destroying potentially pathogenic microbes and converting the waste into a glassy rock or slag, ferrous metal, and inert gases (EA, 2003). In a plasma torch, an arc is established between two electrodes. A carrier gas, which may be inert or have some heating value, passes between the electrodes and transfers the energy to the waste material. In a non-transferred system, the anode and cathode are both part of the plasma torch. Another design is to use a DC (Direct Current) plasma arc, wherein the arc forms between a graphite electrode directly to the metal in a molten bath formed from the waste in the treatment chamber (HCWH, 2001).

II.1.ii. Selection of Suitable Treatment Technology

Certain treatment options may effectively reduce the infectious hazards of health care waste and prevent scavenging but, at the same time, give rise to other health and environmental hazards. Walker (1990) studied the current technology used to manage infectious and hazardous wastes in hospitals. Infectious waste is either incinerated or it is sterilized and landfilled (a few states permit landfilling without pretreatment). Most hospital based waste incinerators are adequate to dispose of syringe needles and body parts. Chlorinated plastics require state-of-art commercial incinerators that can remove the hydrochloric acid, dioxins, and furans from the stack gas. Chemotherapy waste is mostly gloves and gowns and if not properly sorted can represent a large volume. A potential problem is the discharge of small concentrations of formaldehyde into the sewer. Yufeng et al., (2003) reported that based on the conventional pyrolysis principle, a new apparatus has been developed for waste disposal in China. It is especially useful in China, as the waste is not sorted. The experiment shows that the concentration of dioxins meets the emission standard of 0.1 ng TEQ/NmN by controlling the residence time and temperature. The expulsive solid weight is as low as 5-7% of the whole refuse. At the same time, a great deal of fire gas was generated at the treatment process. The final choice of treatment
II.1.iii. Residue Treatment

After incineration, leftover byproducts are called residues (bottom ash, grate sifting, heat recovery ash, fly ash, and air pollution control residue). These are generated at different points in the process of waste incineration. Chemical analyses of solid waste residue, bottom ash, air pollution control residue, and combined ash, have often been published. Lombardi et al. (1998) reported that a fly ash coming from a hospital solid waste incineration plant was solidified/stabilized in cementitious matrices. Owing to the high chloride, sulphate and alkali content and the low Si, Al and Fe values, this fly ash cannot be used in the formulation of blended cement. Idris and Saed, (2002) mentioned the ash produced from a hospital waste incinerator was treated using a high temperature melting process at 1200°C. The quality of the produced slag was characterized by X-ray diffraction (XRD), X-ray fluorescence (XRF), leaching tests and sequential chemical extraction of metals. The slag contained large amounts of SO2, CaO, Al2O3, Sn, Ni, Cu, Ba and B.

II.1.iv. Effluent Treatment

Hospital effluents are the most dangerous waste to contaminate our natural environment. Hence, these are to be treated to detoxify before released into the drains. Several scientists worked on the ill effects of effluents. For example, Giuliani et al., (1996) evaluated the genotoxic potential of the wastewater of a hospital. Within 2 years over 800 native wastewater samples were analyzed. Genotoxic activity was found in 13% of the samples. The highest genotoxic activity occurred in the morning hours, but the genotoxic samples were detected also during the day and night. Nearly 96% of the genotoxic wastewater samples revealed a genotoxic potential without growth inhibition of test bacteria monitored as OD-600, in the same way as antineoplastic drugs like mitomycin C or cisplatin. Four percent of the genotoxic wastewater samples showed combined cytotoxic and genotoxic activities as seen in control experiments using glutaraldehyde containing disinfectants and certain antibiotics.

The sludge from hospital waste treatment facilities is a potential source of infectious organisms. The average numbers of microorganisms in the sludge of hospital
wastewater in Taiwan were as follows: total count 8.1x10^7 cfu g^-1 (dry weight of sludge), and 1.4x10^6, 3.6x10^5, 1.6x10^5, 2.2x10^5 and 5.5x10^4 cfu g^-1 (dry weight of sludge) for total coliforms, faecal coliforms, faecal streptococci, Pseudomonas aeruginosa and Salmonella spp., respectively. Salmonella spp. were detected in 37% (10 of 27) of the sludges from hospital wastewaters. Therefore, the treatment of such sludge to reduce pathogenic microorganisms should be considered (Tsai et al., 1998). In the treatment of hospital waste sludge, which contains high concentrations of organic components, the amount of hypochlorite has a pseudo-first-order relationship to the formation of organic halides. Ethanol is a common and safe solvent that is used for the extraction of organic halides from sludge. However, the high partitioning coefficient of sludge for microorganisms retards the extraction effectiveness of ethanol (Tsai et al., 1999).

Tsai and Lin (1999) have reported that hypochlorite and chlorine dioxide were used to disinfect hospital wastewater sludge.

Kiffmeyer et al. (1998) discussed a trace analytical procedure for the cytostatic drugs carmustine, chlorambucil, cisplatin, cyclophosphamide, cytarabine, etoposide, 5-fluorouracil, melphalan, methotrexate, and vinblastine was developed in order to evaluate the environmental hazards of these drugs in clinical wastewater and sewage treatment plants. The analysis was performed using solid phase extraction with subsequent HPLC separation and quantitative determination by gradient elution techniques with DAD and fluorescence detection. Detection limits after the clean up and enrichment procedure vary from 0.002 to 0.2 mg/L. A simulation of the degradation processes under conditions as close as possible to those in a real sewage plant showed that cisplatin and cyclophosphamide are not biodegradable, but cytarabine and 5-fluorouracil are biodegradable in different magnitudes. Maurya et al. (2002, 2003a, 2003b) have optimized a best-suited condition by considering the concentration of substrate, reaction time, amount of catalyst, oxidant and solvent for maximum transformation of phenol. All encapsulated complexes serve as catalyst for the decomposition of H2O2 and for the oxidation of phenol to a mixture of catechol and hydroquinone using H2O2 as an oxidant. However,
selectivity towards the formation of catechol and hydroquinone vary from catalyst to catalyst.

Rai et al. (2007) investigated in a laboratory scale the decolorization of a simulated dye waste containing three different triphenylmethane dyes using two-stage anaerobic high rate reactor. It has been shown that the influent dye concentration had little effect on overall COD and color removal.

II.1.v. Environmental Emissions

Incinerators during burning of waste, release lot of gaseous effluents as well as solids in the form of ash. Wastewater from gas washing and quenching of ashes should undergo a chemical neutralization treatment before discharged into a sewer; the treatment includes neutralization of acids and flocculation and precipitation of insoluble salts. Sludges from wastewater treatment and from cooling of fly ash should be considered as hazardous waste.

They may either be evacuated to a waste disposal facility for hazardous chemicals, or be treated on-site by drying followed by encapsulation in drums which are then filled up with cement mortar and may be disposed of in a landfill. The solid ashes in the incineration residue are far less hazardous than fly ash, and in the past have been reused in civil engineering works. Incineration produces between 25 and 30 kg of dust per tonne of waste (Pruss et al., 1999). These facilities which have equipment with design throughput capacities of greater than 500 lbs/h are considered to be large application and are thereby required to meet much more restrictive levels of emissions (Remmen, 1998). The stack gas samples from municipal solid waste incinerators (MSWIs), small size incinerators (SIs), a hospital waste incinerator (HWI) and an industrial waste incinerator (IWI) were collected and analysed for polychlorinated dibenzo-p-dioxins and polychlorinated dibenzofurans (PCDD/Fs). This study shows that PCDD/Fs emission is related to the age of incinerators, CO, and flue gas dust. The PCDD/Fs emission of the small size incinerators is considered as the major point source of PCDD/Fs emission in Korea (Oh et al., 1999).
Murnyak and Guzewich (1982) quantified chloride/chlorine emissions from a hospitals medical waste incinerator in conjunction with a particulate emission stack test. Lindner et al., (1990) detected dioxins and furans in emissions from eight medical waste incinerators tested in California. Total uncontrolled emissions ranged from 363 to 11,811 nanograms per dry standard cubic meter. The most effective of three wet scrubbers achieved an emissions control efficiency of 95 percent for total PCDD and PCDF. A baghouse was less than 30 percent efficient in removing PCDD and PCDF from the incinerator emissions.

Manscher et al. (1990) conducted an extensive series of dioxin measurements on Danish municipal and hospital solid waste incinerators during the last two years. The study was directed toward finding the total annual dioxin emissions from MSWI in Denmark, now estimated to be 3 kg of dioxins and furans.

Nasserzadeh et al. (1995) carried out emission monitoring on the high temperature clinical waste incinerator plant with a burning capacity of 12 ton/day (4MW) at Sheffield, UK. The emissions including the measurement of CO, CO2, O2, NOx, SO2, HCl/HF, volatile organic compounds, particulates, heavy metals and dioxins/furans in the flue gas. Scrubber liquor, filter cake and ash were also analyzed for heavy metals, dioxins/furans and unburnt carbon content.

Shy et al. (1995) studied the residents of three communities having, respectively, a biomedical and a municipal incinerator, and a liquid hazardous waste-burning industrial furnace. The results were compared with three matched-comparison communities. They did not detect differences in concentrations of particulate matter among any of the three pairs of study communities. Average fine particulate (PM2.5) concentrations measured for 35 days varied across study communities from 16 to 32 micro g/m3.

Wang et al. (2002) conducted laboratory experiments in a two-stage horizontal muffle furnace in order to monitor emissions from batch combustion of polystyrene (PS) and identify conditions that minimize them. PS is a dominant component of municipal and hospital streams. Bench-scale combustion of small samples (0.5g) of shredded Styrofoam
cups was conducted in air, using an electrically heated horizontal muffle furnace, kept at Tgas = 1000°C. Upon devolatilization, combustion of the polymer took place in a diffusion flame over the sample. At the exits of the primary and the secondary furnace the emissions of CO, CO2, O2, NOx, particulates as well as volatile and semi volatile hydrocarbons, such as polycyclic aromatic hydrocarbons (PAH), were monitored. Online analyzers, gravimetric techniques, and gas chromatography coupled to mass spectrometry (GC-MS) were used.

Lee et al., (2002) conducted a study on two batch-type medical waste incinerators (MWIs), including the one with a mechanical grate (MG-MWI) and the other with a fixed grate (FG-MWI) for the disposal of general medical waste and special medical waste, respectively. Both incinerators shared the same air pollution control devices, which were installed in series, including one electrostatic precipitator (ESP) and wet scrubber (WSB). In this study, the GC/MS technique was used to analyze the concentrations of 21 PAH species contained in the stack flue gas, ESP fly ash, WSB effluent, and incinerating ash. Results show that total PAHs (i.e., the sum of 21 PAH species) in stack flue gas were dominated by LM-PAHs (i.e., two to three ringed PAHs), but in incinerating ash, ESP fly ash and WSB effluent it is found that they were dominated by MM-PAHs (i.e., four-ringed PAHs) and HM-PAHs (i.e., five to seven ringed PAHs) for both types of MWIs. The above results due to air pollution control devices used in both types of MWIs had much higher efficiencies on both MM-PAHs and HM-PAHs (>78%) than on LM-PAHs (<5%). The emission factors of total PAHs for MG-MWI (=252,000 g/kg-waste) were lower than FG-MWI (=856,000 g/kg-waste), which was probably due to more complete combustion involved in the combustion process of the former than the latter. Nevertheless, the above two emission factors were found consistently higher than the above results, warrant the need for seeking better technologies for disposing medical waste in future.

II.1.vi. Management of Bio Medical Waste

A study on evaluation of medical waste management systems was conducted by Manyele and Lyasenga (2010), in the low-level health facilities (LLHFs) in Dares Salaam by comparing Ilala and Kinondoni municipalities of Tanzania. The study has revealed that
most of the facilities have no specific disposal sites. In Ilala, 70% of the health facilities burn wastes in poorly designed incinerators which are not in working condition. 83% of the facilities bury wastes in the pits. More than 50% of the disposal sites surveyed are not fenced. Also, 9% and 47% of the healthcare facilities in Ilala and Kinondoni, respectively, do not have the Standard Operating Procedures. Nearly 71% of the facilities in Kinondoni carry the wastes on hands to the disposal sites while in Ilala, 40% of LLHFs use wheelbarrows. Waste segregation and colour coding are poorly adhered to while most of the storage areas are too small. It was concluded that, the medical waste management in LLHFs is still poor. Awareness should be raised among LLHFs workers on proper management of the medical wastes.

A review was undertaken by Nasima Akter (2000) to understand various waste handling and disposal procedures in different countries. It was found that Medical wastes pose a significant impact on health and the environment. Waste handling safety measures, waste disposal and laboratory analysis of infectious waste is inadequate and said that there is need to create awareness and education on medical waste.

According to Hem Chandra (1999), in an article on ‘Hospital Waste: An Environmental Hazard and its Environment’ examined about the hospital waste, classification of waste and stated that 1.5 kg/bed/day waste is being generated, among that only 10% is hazardous waste. Importance of safety measures and imparting training to the personnel involved in waste handling is also mentioned in the study.

An attempt was made on Bio-medical Waste Management: A Case study of YCM Hospital Pimpri-Chinchwad, Pune by giving a detailed background on the standard process of bio-medical waste management and provision of relevant law by Amar Dhre (2011) and found that the quantity of bio-medical waste produced in YCM Hospital is estimated to be about 500KG/day. Of this the waste sharps such as tubings, catheter etc is about 100kg/day and BMW generated in the form of soiled plaster casts, linens etc is also about 50 kg/day. Remaining quantity of the BMW is heterogeneous masses. Majority of waste is treated by using of incinerator, autoclaving, microwaving, shredding and chemical treatment.
A study was conducted in Sharada hospital, Greater Noida with the aim to find out bacteriological profile of BMW with study of practices being followed in management and disposal of this waste with standard procedure by Vichal Rastogiet al., (2011), on Bacteriological Profile of Bio-Medical Waste: Management Guidelines. Bacteria isolated from BMW also included resistant strains of variety of bacteria’s. It is concluded that bacteria isolated should be disposed off properly to prevent spread of infection in other patients and community.

According to the study conducted by Insa et al. (2010) it has been observed that there is no specific national law that has been passed to regulate medical waste management, but 13 of its regional Governments have adopted regulations for health and environment protection. In their study, certain differences were detected regarding the procedures for sorting, collecting, storage, transport, treatment and disposal practices. They have also proposed a set of general criteria for effective medical waste management.

According to Praveen Mathur et al., (2012) on the need for ‘Biomedical Waste Management System in Hospitals – An Emerging issue – A Review’, explained that everyday relatively large amount of potentially infectious and hazardous wastes are generated in the health care facilities and also indiscriminate disposal of BMW or hospital waste and exposure to such waste possess serious threat to environment and to human health that requires specific treatment and management prior to its final disposal.

Yasunori Ohtsu et al., (2011) conducted a study on medical plastic waste treatment with the sample of five plastic syringes with a volume of 20ML by giving three types of treatment like microwave, irradiation, electric heat and combination of both. In their study, they have observed that only with the treatment of combined heating the plastic syringes were completely treated.

Surjit (2007) discussed on Biomedical Waste Classification and Prevailing Management Strategies. He identified that there is a growing interest in technologies for treatment of biomedical waste due to concerns of air pollution from waste incineration. He
has presented a case study on common biomedical waste treatment facility to predict waste incineration in Shimla by considering five major health care facilities.

II.1.vii. Biomedical Waste Segregation

In a study made by Chitnis et al., (2005) on ‘Biomedical Waste in Laboratory Medicine: Audit and Management’, have expressed that needle sharps are to be collected in puncture proof containers and the needles are to be autoclaved before sending to needle pit. The discarded/infected blood units in blood bank need to be autoclaved before disposal since chemical treatments are difficult or inefficient. They found that segregation of waste at source is the key step and reduction, reuse and recycling should be considered in proper perspectives.

Lalji et al., (2008) quotes in a study on biomedical waste management in nursing homes and smaller hospitals in Delhi. A systematic analysis of current biomedical waste management practices in smaller nursing homes and hospitals in Delhi was carried out. They identified that there is a marked improvement in the segregation practices of biomedical waste in small private hospitals and nursing homes but awareness and training programs should be given not only to target doctors, nurses, and paramedics but also to waste handlers.

In various studies conducted by Das et al., (2010) it is discussed that there was a Total Quality Management (TQM) Approach for implementation of handling and management of hospital waste in Tata main hospital by following the Govt. of India, Biomedical Waste (Management & Handling) Rules 1998. A task force was constituted in Sept. 1999 consisting of representatives from doctors, nurses, administration and housing departments to approach the problem through TQM.

Diaz et al., (2008 & 2005) examined in their study on Characteristics of healthcare wastes, examined that there is limited reliable information available in the open literature on the quantities and characteristics of the wastes that are generated in healthcare facilities. They identified that the range of hospital waste generation varies from 0.016 to 3.23 kg/bed-day. Also the reported amount of infectious waste varied from 0.01 to 0.65
kg/bed/day. They observed that the characteristics of the components of healthcare wastes, such as the bulk density and calorific value, have substantial variability. They observed that the most common method of land disposal of solid wastes used in developing countries is the open dumping. This method is a severe threat to public and it may cause serious health effects to environment.

According to Dohare et al., (2013) in a study on Hospital Waste Management status in Health facilities of an urban area quotes that only 42.2% HCFs were registered with State Pollution Control Board for biomedical waste management. Only 46.4% HCFs were aware of existence of Central Pollution Control Board rules on Biomedical waste Management and only 4.2% HCFs had trained staff, 39.4% HCFs are maintaining records. It was concluded from the analysis that there were gross inadequacies in most of the health facilities.

Patil et al., (2001& 2005), observed that the waste generation rate ranges between 0.5 and 2.0 kg bed/day. It was estimated that annually about 0.33 million tons of waste is generated in India. 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%). When compared to municipal wastes, hospital wastes have greater potential to damage the health profile of human beings as they contain much infectious material.

A study was conducted by Virendra Misra et al., (2005) on Hazardous waste, impact on health and environment for development of better waste management strategies in India - they outlined the nature of the wastes, waste generation industries, waste characterization, health and environmental implications of wastes management practices and they have attempted a better cost-effective strategies of waste management be evolved in future.

According to the study conducted by Blenkharn et al., (2007) the arrangements of bulk clinical waste handling were audited in 16 UK hospitals. The standard performance in clinical waste management in UK hospitals remain poor due to neglect of basic hygiene,
housekeeping and safety standards and the reality of clinical waste management in some National Health Service (NHS) hospitals continues to be largely inadequate.

Cheng et al., (2009) in their study on Medical waste production at hospitals and associated factors, conducted in Taiwan, evaluated the quantities of medical waste generated and the factors associated with the generation rate at medical establishments in Taiwan. The average waste generation rates ranged from 2.41 to 3.26 kg/bed/day for general medical wastes and 0.19 -0.88 kg/bed/day for infectious waste. They observed that large hospitals are the major source of medical waste in Taiwan.

A cross sectional study was conducted by Vanesh Mathur et al., (2011) on Attitude and Practices about Biomedical Waste Management among Healthcare Personnel and their objective was to assess knowledge, attitude and practices of doctors, nurses, laboratory technicians and sanitary staff regarding biomedical waste management. The study was conducted among hospitals which are having more than 100 beds capacity at Allahabad city. They observed that except sanitary staff all are having better knowledge regarding biomedical waste management and injury report is also very low across all groups of health care workers.

The findings of the study by Praveen Mathur et al., (2012) on proper biomedical waste management represents a real problem of living in the nature. Everyday large amount of potentially infectious wastes are generated in health care facilities and indiscriminate disposal of this waste possess serious threat to environment.

Pokhrel, (2004) conducted a study in KLE Society’s 1000 bed hospital and Medical Research Centre, Belgaum. Their objective was to assess the operating procedures and quantitative determination of waste and final disposal of waste. The study centre conformed to the bio-medical Solid Waste Rules (Management and Handling), 1998. The total amount of infectious and non-infectious waste generated is approximately 2310 and 385 kg/day respectively. In their study it was observed that the personnel working under the occupier were trained to take adequate precautionary measures in handling these bio-hazardous waste materials.
Surjit (2007), observed that the segregation of waste at source is the key step and reduction, reuse and recycling should be considered in proper perspectives. They opined that segregation at source is vital to prevent hospital borne infections.

Rao et al, (2004) conducted an infrastructural survey of hospitals at various sectors like Government, Private, Charitable institutions to assess the infrastructural requirement for BMW Management. They found that capital cost incurred by benchmarked hospital of 1047 beds was Rs.3 lakh 50 thousand excluding cost of incinerator. The hospital is incurring Rs.656/- per day as recurring expenditure. Pune city has CBMWTF for final disposal of BMW where it is charging Rs.20 per kg of infectious waste. So they felt that there is a need to standardize the infrastructural requirement.

Prasanth et al., (2011) carried out a study on ‘Biomedical Waste Management: An Update’, identified that lack of concern, motivation, awareness and cost factor are some problems faced in the proper waste management. Appropriate education, training and the commitment of healthcare staff, management and healthcare managers within effective policy and legislative framework is required for effective hospital waste management.

A case study from the Southwestern region by Veronica et al., (2011) on Health care Waste management in Cameroon among five health care facilities in Southwestern Region of Cameroon to seek information on the existing procedures and practices in handling and treatment of wastes was carried. Interviews and structured questionnaires were used to collect data on waste practices from waste handling workers. The study concluded that there is a need to formulate sustainable health care waste management plan and legislation.

A survey was conducted by Masum Patwary et al., (2010) on ‘Assessment of Occupational and Environmental Safety associated with medical waste disposal in developing countries: A qualitative approach in Dhaka’, the capital city of Bangladesh from health care establishments and other waste disposal operatives. Data was collected through observation, formal structured interview. Formal representative sampling for fixed population and adaptive sampling for roaming populations was used to select the sample of
188 respondents. The findings of the study revealed that the operatives are found to be untrained and the protective equipment was inadequate. The storage facilities for hazardous waste were found to be inadequate and scavengers repackaged and resold some items such as syringes and expired medicines. The segregation of waste is also not up to the mark which indicates lack of education and management.

According to Ramesh Chandra Sahoo et al., (2013) on ‘Biomedical Waste Management in the District of Balasore, Odisha: A Critical Survey’, quotes that infectious and non-infectious wastes were dumped together within the hospital premises then disposed of with municipal waste. Laboratory waste materials were also disposed into the municipal sewer without disinfection of pathogens. The results of the study demonstrates need for strict enforcement of legal provision and a better environmental management system for the disposal of biomedical waste in hospitals in Balasore, Odisha. This study was conducted on eight hospitals both Government as well as private hospitals using random sampling technique to analyze awareness, management, handling, transportation, treatment and disposal about BMW.

II.1.viii. Treatment and Disposal Facilities

A case study of a rural medical hospital starting from the source of segregation to disposal of hospital waste was undertaken by Vyas et al., during the time period between August 2010 to October 2010 at Bangalore. It was suggested to use “plasma pyrolysis” instead of incineration which is the latest environment friendly and economical method. The study reveals that all wastes i.e., pathogenic, sharps and infectious except general waste can go for plasma pyrolysis.

In a study on ‘Management of Infectious Bio-Medical Waste of Ujjain City’ by Parag Dalal (2013), an attempt was made to assess the structure and amount of Bio-medical Waste generated and its management. Findings of the study reveal that there is no proper management of Bio-medical waste. Incinerator was also installed but it was situated at the densely populated area of the city, causing air pollution in main Government Hospital. Only 15-20% of the total generated waste is taken by various companies of
Indore and rest is been pumped into municipal waste or direct open burning. It is concluded from the analysis that there is an urgent need for Bio-medical waste disposal facilities in Ujjain City.

II.1.ix. Studies on Health Care Employees

A cross-sectional study was conducted on ‘Awareness of Biomedical Waste Management Among Healthcare Personnel in Jaipur’, India by Alok Sharma et al., (2013) with an aim to find awareness regarding BMW policy and practices, needle stick injuries, attitude towards BMW among healthcare providers of different categories. The study reveals that there was poor level of awareness on BMW hazards, legislation and 36% of nurses had poor knowledge of BMW generation and legislation whereas Class IV employees had an excellent awareness of BMW management practices. It is suggested from the analysis that there should be regular monitoring and training required at all levels.

According to Shalini Sharma (2010), in her study on ‘awareness about Bio-Medical Waste management among Health Care Personnel of some important medical centres in Agra’, quotes that there is lack of knowledge and awareness towards legislation on Bio—Medical Waste management event among qualified hospital personnel and also she suggested that there is need of standard operative procedures (SOP) and defined management techniques like TQM and timely training programmes explicitly for BMW handling and disposal.

A study was conducted among 20 doctors and 20 nurses by Dipakar Chattopadhyay et al., (2010) to assess the attitude of doctors and nurses working in the in-patient departments, operation theatres and emergency ward of the Institute of Post-Graduate Medical Education and research, Kolkata. A multistage sampling design was adopted. Two doctors and two nurses were selected by stratified random sampling methods. Data were collected through a Questionnaire consisting of six questions related to measurement of attitude by using five-point Likert Scale. Mean scores were summed up to calculate summated attitude scores. The result showed that the attitude of doctors and nurses of the Institute with respect to health care waste management is good.
A cross-sectional study was conducted by Yamini et al., (2012) by using a pretested semi-structured proforma, by interview cum observational technique. Convenient sampling methods was adopted and selected 120 health care workers includes nurses, technicians at two Government District hospitals and 50-final year MBBS students to assess the perception and practice of infection control measures amongst the health care workers in Mangalore. Results showed that majority (85.8%) were aware of disposing used needles and syringes, not recapping the needles after use but only 55.7% were actually practicing it. The study concluded that there is a need for improvement in the perception and practice of infection control measures among health care workers.

An interventional study was performed to investigate whether training has significant impact on knowledge levels of healthcare managers regarding bio-medical waste management by Aclan Ozder et al., (2013). Statistically significant difference was found among those who received medical waste management training and among others who had not received training.

A study was conducted in Primary Health Centres (PHCS) of Bagepalli Taluk to assess the knowledge and practice on bio-medical waste management among the health care providers among 120 respondents representing the Senior Health Workers, Junior Health Workers, Laboratory Technicians and Pharmacists by Nagaraju et al., (2013). The results of the Chi-square analysis showed that there was no significant association for any of the socio-demographic variables, whereas there was significant association between practice and total years of experience.

II.1.x. Hospital Waste Management in Developed and Developing Countries.

A study was performed by Nasima Akter (2000), to understand the various handling and disposal procedures in different countries. Knowledge and awareness of individuals involved in medical waste generation, handling and disposal, the potential impacts of the waste stream on both human health and the natural environment were reviewed.
A study was undertaken with an aim to document the handling, practices of waste along with the types and amount of wastes generated by Health Care Establishments (HCE) by Manzurul Hassan et al., (2008) on the Pattern of medical waste management: existing scenario in Dhaka City, Bangladesh. The results indicate that HCE generate a total of 5,562 kg/day of waste of which 77.4% are non-infectious and about 22.6% are infectious. The average waste generation rate for the surveyed HCE is 1.9 kg/bed/day and the study revealed that there was no proper management of medical waste except in a few private HCE’s where segregation of infectious waste from non-infectious waste is done carefully. This study concludes that lack of awareness on policies, laws are responsible for improper management of medical waste in Dhaka City.

An attempt was made to represent the systematic management of Bio-Medical Waste and to deal with proper handling, segregation according to the colour coding, mutilation, disinfection, storage, transportation and final disposal of bio-medical waste by Tanksali (2013) on Management of Bio Medical Waste. It was found that in Karnataka there are 12,365 Health Care Establishments, among them 7,109 are Government units and 5,256 are private units and approximately these HCEs generate 62 tons of health care waste per day and to manage this amount of waste, there are only 14 Common Biomedical Waste Treatment facilities and there is an urgent need to establish further treatment facilities. Most of the health care systems are disposing indiscriminately, which leads to adverse effect both on life and environment.

A cross-sectional study was undertaken on Hospital Waste Disposal: A Review carried out in five teaching hospitals of Lahore through convenience sampling by Nosheen Arshad et al., (2011) to analyze the present situation of medical waste management system. This was performed to understand various handling and disposal procedures and impact of waste on human health and environment. It was found that different methods were used in disposing waste includes burning, burial, entombing, selling and dumping. Awareness of medical waste issues to the concerned personnel is insufficient and incineration is the most preferred disposal method and suggested that proper waste management strategy is needed to ensure health and environmental safety.
To evaluate the current practices of segregation procedures, storage arrangements, collection and disposal systems in the teaching hospitals of Karachi, a cross-sectional survey was conducted by Shahida Rasheed et al., (2005) on Hospital Waste Management in the Teaching Hospitals of Karachi. From the results of the study, it was known that only two hospitals had well documented guidelines according to the law. There should be proper training and management regarding awareness and practices of waste disposal. The hospital waste management guidelines enacted on 7th June 2004 should be followed and regulated by law enforcement agencies.

Ramesh Babu et al., (2009) in a study on ‘Management of Biomedical Waste in India and Other Countries : A Review’, investigated to summarize the rules for management and handling of biomedical waste, to give the definition, categories of biomedical waste, suggested storage containers and treatment options, to highlight the effects of biomedical waste in the environment such as air, land, radioactive pollution and disposal of wastes, regulation and recommendations. The results revealed that the waste generation rate ranges between 0.5 to 2.0 kg/bed/day. It is concluded from the study that there is a need for education as the hazards associated with improper waste disposal of BMW.

Dwivedi et al., (2009) discusses in a study on fate of hospital waste in India, provides an exhaustive survey and detailed investigation of the waste generated, recycled and their disposal procedures adopted in the leading hospitals in Terai belt of Uttar Pradesh in India. It has been reported through a self assessment audit that consists of 122 parameters divided into 33 broad categories. It has been found that the amount of the infectious components in the waste is very little and this needs careful handling. There is no efficient management of hospital waste both in private and Government health institutions and also management and disposal of wastes is not in accordance to the environmental rules.

Susan Q. Wilburn and Gerry Eijkemans (2004), identified effective measures that are needed to prevent blood borne infections, needle stick injuries among health care workers.
A case study was undertaken by Vijjaya Kumar Goddu et al., (2007) entitled “A Critical analysis of Healthcare Waste Management in Developed and Developing Countries: Case Studies from India and England”, with an objective to examine healthcare waste management practices in King George Hospital in Vizag, Andhra Pradesh State in India and National Health Service Hospital in Cornwall in England. The results from the above study suggest that there is a need of training and creating awareness for staff with respect to healthcare waste and the implications involved in incorrect handling at King George Hospital. It was found that there was difficulty in segregating the healthcare waste and even segregation of waste into colour coded bins namely Yellow and Red. The personnel engaged in handling and segregation of waste were untrained and unsupervised. It is suggested by the authors that greater measures are to be put in place according to the rules and regulations laid down by Central Pollution Control Board (CPCB).

II.1.xi. BMW Disposal in Landfills for Eco Management

BMW disposal is becoming a problem of increasing importance in almost all developed and developing countries. Engineered landfills have been accepted for disposal of clinical waste, except for the biological waste to be incinerated for ethical reasons and infectious waste contaminated by microbes (Ponka et al.,1996). As by a recent Italian law a meaningful percentage of hospital waste (50 to 60%), corresponding to food residuals, plastics, paper, various organic materials, etc., could be landfilled as municipal refuses, if this is a preliminary submission to a suitable sterilization treatment (Tata and Beone, 1995). Residues of incinerator after burning are being landfilled. If the model landfills were kept nearly anaerobic almost no mineralization occurred in all kind of refuse disposed of (Filip and Trost, 1985). Refuse from medical consulting rooms, a mixture of those refuse with municipal refuse (1:10), and municipal refuse were disposed aerobically and roughly anaerobically for over six months in a model landfill. Survival, proliferation, and transportation of microorganisms were estimated at different periods of time. Concentrations of aerobic bacteria and hypomycetes decreased during the first weeks of deposition but remained later unchanged. Concentrations of nonsporeforming indicator bacteria (Escherichia coli, fecal streptococci) decreased more strongly, and
E. coli could not be found at latest after 23 weeks. In municipal refuse alone and mixed with refuse from medical consulting rooms, Pseudomonas aeruginosa proliferated temporarily. Leaching of microorganisms from the model landfill was observed in the whole course of the disposal period (Trost and Filip, 1985).

II.1.xii. Developing Strategy for Minimization of BMW

There are no fully satisfactory guidelines for BMW management, nor are there methods in general use that are safe and environmentally acceptable for the storage, transport and final disposal of the ever increasing volume of such waste that is generated by the health services. Presence of harmful, toxic and infectious waste in beaches and domestic refuse landfill sites is common, causing public uneasiness and ill health. Land filling of contagious and infectious BMW is dejected in almost all locations of the globe. Instead incinerator must be used to minimize the eco hazards posed by BMW. Technologically advanced incinerators are expensive hence some of the small Health Care Facilities and clinical labs need to establish simple and inexpensive incinerators (Collins, 1991).

For proper management of BMW, a management plan must be established to ensure protection of public health and the environment. The Plan should include standard operating procedures (SOPs) to address: the generation of wastes, segregation of wastes, containerization and storage of wastes, waste treatment, waste handling and transportation, waste disposal, and contingency planning (Meaney and Cheremisihoff, 1989).

Liberti et al., (1994) have reported that a two-year R&D project dealing with the study, design, prototype plant development and operation of an integrated management system of infectious hospital wastes (IHW) was performed by CO.PR.AM., an Italian industrial consortium. The project was concerned with the characterization, handling (collection, storage, transportation) and incineration of IHW produced by a large sanitary district (three hospitals, 191 different clinics, 40 laboratories, and a total of 2500 bedspaces) and permitted researchers to analyze in
detail each major aspect of IHW disposal such as production handling and treatment in order to devise an optimal solution to their overall management.

Boutacoff (2000) discussed the ability of hospitals and other health care facilities to maintain the quality of patient care with cost control. Partnerships with health care organizations, energy service providers, equipment vendors and industry associations were established as the way to optimize energy use and reduce costs (Zanoni, 1998). Shih and Lin (1999) have studied that most small to medium sized hospitals and clinics in Taiwan do not have on-site treatment facilities for their medical and infectious wastes and must rely on outside agencies for its collection and treatment. The problem of optimally planning and scheduling the collection of medical wastes from a disperse group of facilities is formulated as a periodic vehicle routing problem.

In Helsinki, Finland, new guidelines have been adopted for the management of wastes from healthcare facilities. The purpose has been to rationalize waste management, reducing the amount of waste needing special treatment and lowering costs, while at the same time maintaining occupational safety and preventing environmental hazards (Ponka et al., 1996).

There is currently no form of biological monitoring or health assessment technique that is sensitive or specific enough to adequately predicts the effects of chronic long-term exposure to cytotoxic drugs (OSHS, 1997).

Clark (1997) reviewed the present and future provision for clinical waste treatment and disposal in Scotland. Data was obtained using open structured interviews and a simple questionnaire. The results of the study show that the more number of facilities are to be constructed and commissioned then the current situation of over capacity will be considerably exacerbated.

Role of nurses and other staff members in minimizing BMW has been emphasized in some of the hospitals of Isfahan by Maroufi, et al. (2012). In this context it is clear that the advanced technology for treatment, proper segregation and disposal methods are essential for protection of public health and eco aesthetics.
For the present study the author made an attempt to see the present BMW generation scenario in India on the whole and Chittoor district of Andhra Pradesh, in detail, as a part of applied study.

Some of the important contributions referred in the review of literature are listed in table II.2. so that they point a direction towards the availability in nature of literature paving a path towards the present need for the study.

Table No. II.1: Summary of key Contributions to BMW Management by Various Researchers

<table>
<thead>
<tr>
<th>Sl.No.</th>
<th>Subject</th>
<th>Author</th>
<th>Year</th>
<th>Place</th>
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<tr>
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</tr>
<tr>
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<td>1992</td>
<td>USA</td>
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<td>Lee et al.,</td>
<td>2003</td>
<td>USA</td>
</tr>
<tr>
<td>7.</td>
<td>Fly Ash Treatment</td>
<td>Shimaoka and Hanashima</td>
<td>1996</td>
<td>Japan</td>
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<td>Incinerators</td>
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<td>Nasserzadeh et al.,</td>
<td>1995</td>
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<td>Physicochemical Characteristics</td>
<td>Liberti et al.,</td>
<td>1996</td>
<td>Bari, Italy</td>
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<tr>
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<td>Amar Dhre</td>
<td>2011</td>
<td>Pune</td>
</tr>
<tr>
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<td>Bacteriological profile</td>
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<td>2011</td>
<td>Noida</td>
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<td>17.</td>
<td>BMW Classification</td>
<td>Surjit</td>
<td>2007</td>
<td>Shimla</td>
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<td>18.</td>
<td>BMW in Nursing homes and smaller Hospitals</td>
<td>Lalji et al.,</td>
<td>2008</td>
<td>Delhi</td>
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<td>Waste Generation Rate</td>
<td>Patil et al.,</td>
<td>2001 &amp; 2005</td>
<td>India</td>
</tr>
<tr>
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<td>Hazardous Waste</td>
<td>Virendra Misra et al.,</td>
<td>2005</td>
<td>India</td>
</tr>
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<td>22.</td>
<td>Medical Waste Production</td>
<td>Cheng et al.,</td>
<td>2009</td>
<td>Taiwan</td>
</tr>
<tr>
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<td>Vanesh Mathur et al.,</td>
<td>2011</td>
<td>Allahabad, India</td>
</tr>
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<td>Healthcare Waste Management</td>
<td>Veronica et al.,</td>
<td>2011</td>
<td>Cameroon</td>
</tr>
<tr>
<td>26</td>
<td>Assessment of Occupational and Environmental Safety</td>
<td>Masum Patwary et al.,</td>
<td>2010</td>
<td>Dhaka, Bangladesh</td>
</tr>
<tr>
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<td>Ramesh Chandra Sahoo et al.,</td>
<td>2013</td>
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</tr>
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<td>Vyas et al.,</td>
<td>2010</td>
<td>Bangalore, India</td>
</tr>
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<td>29</td>
<td>Management of Infectious Biomedical Waste</td>
<td>Parag Dalal</td>
<td>2013</td>
<td>Ujjain</td>
</tr>
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<td>Awareness on BMW Management</td>
<td>Alok Sharma et al.,</td>
<td>2013</td>
<td>Jaipur, India</td>
</tr>
<tr>
<td>31</td>
<td>Awareness on BMW Management</td>
<td>Shalini Sharma</td>
<td>2010</td>
<td>Agra</td>
</tr>
<tr>
<td>32</td>
<td>Attitude of Medical Personnel</td>
<td>Dipaka Chattopadhyay et al.,</td>
<td>2010</td>
<td>Kolkota</td>
</tr>
<tr>
<td>33</td>
<td>Infection Control Measures</td>
<td>Yamini et al.,</td>
<td>2012</td>
<td>Mangalore</td>
</tr>
<tr>
<td>34</td>
<td>Impact on Knowledge levels of BMW</td>
<td>Aclan Ozder et al.,</td>
<td>2013</td>
<td></td>
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<td>Assessment of Knowledge and Practice of BMW Management</td>
<td>Nagaraju et al.,</td>
<td>2013</td>
<td>Begapalli</td>
</tr>
<tr>
<td>36</td>
<td>Documentation of Waste Handling Practices</td>
<td>Manzurul Hassan et al.,</td>
<td>2008</td>
<td>Dhaka, Bangladesh</td>
</tr>
<tr>
<td>37</td>
<td>Handling, Segregation of BMW</td>
<td>Tankasali</td>
<td>2013</td>
<td>Karnataka</td>
</tr>
<tr>
<td>38</td>
<td>Hospital Waste Disposal</td>
<td>Nosheen Arshad et al.,</td>
<td>2011</td>
<td>Lahore, Pakistan</td>
</tr>
<tr>
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<td>Hospital Waste Management</td>
<td>Shahida Rasheed et al.,</td>
<td>2005</td>
<td>Karachi</td>
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<td>HCWM in Developed and Developing Countries</td>
<td>Vijaya Kumar Goddu et al.,</td>
<td>2007</td>
<td>India &amp; England</td>
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<td>Management of BMW</td>
<td>Ramesh Babu et al.,</td>
<td>2009</td>
<td>India</td>
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<tr>
<td>42</td>
<td>Hospital Waste</td>
<td>Dwivedi et al.,</td>
<td>2009</td>
<td>Uttarpradesh, India</td>
</tr>
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<td>Treatment Facilities</td>
<td>Shih and Lin</td>
<td>1999</td>
<td>Taiwan</td>
</tr>
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<td>44</td>
<td>Occupational Safety</td>
<td>Ponka et al.,</td>
<td>1996</td>
<td></td>
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<td>Minimizing BMW</td>
<td>Maroufi et al.,</td>
<td>2012</td>
<td>Isfahan</td>
</tr>
<tr>
<td>46</td>
<td>Clinical Waste Treatment</td>
<td>Clark</td>
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II.2. Research Methodology

The study has adopted the following procedure to carry out the study.

II.2.i. Need and Significance of the study

In India, improper Bio-Medical waste disposal methods have been recognized by several researchers, consequently Ministry of Environment and Forest, Govt. of India, under the supervision of Central Pollution Control Board, has framed rules and regulations to systematize the biomedical waste disposal and management. A number of difficulties are being faced at many places for implementation of these requirements in practice. In order to estimate and to evaluate the present waste generation scenario in India as a whole and Chittoor district of Andhra Pradesh as a part, the present study analyses the waste disposal methods and waste handling practices. Bio-Medical waste is hazardous to the living organisms, hence, proper waste management methods are of dire necessity. In this context, a comprehensive study was carried out on waste generation and disposal in India as well as in Andhra Pradesh and also waste handling practices in Chittoor District of Andhra Pradesh.

The present study is helpful to the Government authorities to take appropriate remedial measures to protect the occupational health of employees as well as public. Also, the analysis of secondary data gives growth rate of biomedical waste per annum. This helps to establish more number of Common Bio Medical Waste Treatment Facilities in appropriate places so as to minimize the mixing of BMW with municipal waste. The study also helps to observe segregation methods, treatment methods, waste handling and safety measures employed at different hospitals in Chittoor District.

In this regard, the study may stimulate and provide an insight into the approaches required by the hospital waste management to the HCFs and Government to think about improper treatment and disposal methods and to introspect their ways of dealing with it at workplace.
II.2.ii. Research Gap

From the survey of literature, it is clear that there are some studies on treatment technologies, treatment methods and segregation practices. Few studies were identified on CBMWTFs in India. Besides, it is clear that the studies on BMW generation and growth rate in India are meager. Hence the study was focused in this direction. The studies on BMW segregation, treatment, handling and disposal practices in South India are scanty and no reports were observed. For any State or District level, it is envisioned to consider and study BMW generation in the Country, and in detail one State and for an applied study to go into the field details of one District to be chosen. At State level Andhra Pradesh State was chosen, and for District study, Chittoor District in Andhra Pradesh was chosen for filed exploration. Integrating the perspective and analysis at the National level, State level and District level the following objectives were formulated.

II.2.iii. Objectives

The prominent objectives of the study can be specified as:

1. To cognise at the macro level in India the occurrence of Bio Medical Waste and the trends in the industry
2. To account for the Bio Medical Waste generation in the State of Andhra Pradesh and the management practices in vogue
3. To thoroughly examine the nature and the quantum of Bio Medical Waste Generated at district level in the district of Chittoor in A.P.
4. To evaluate the techniques and management practices involved in the process of Bio Medical Waste movement in the District
5. To highlight the problems faced in Bio Medical Waste Management in the District
6. To render policy implications for better Bio Medical Waste Management in the wellbeing of the institutions, environment and society.

The approach to the study can be traced in four stages. The first stage deals with the National perspective of HCFs, the bed capacities in the country, region wise and the waste generated.
In the second stage the focus is on the State of Andhra Pradesh highlighting the HCFs, bed capacity, and waste generation in the State and in the Districts.

The third and fourth stages deal with Chittoor District in Andhra Pradesh. The establishment and operation of CBMWTF in the District are studied. A survey of the HCFs in the District was carried to cognize the various Management Practices by the HCFs, with an evaluative outlook for better management.
Figure II.1: Schematic representation of work plan

I Stage

HCFs and beds in India (Region wise) and Waste generation

Data Source
CPCB, New Delhi

II Stage

HCFs and beds in Andhra Pradesh (District wise), Waste generation

Data Source
APPCB, Hyderabad

III Stage

Case Study of CBMWTF, Pacchikapalam, Chittoor District

Data Source
Personal enquiries

IV Stage

Survey on Waste Management Practices in HCFs of Chittoor District

Data Source
Questionnaire and Personal observation
II.2.iv. Hypothesis

The survey of HCFs in the District envisages the formulation of various hypothesis. Eleven hypothesis have been stipulated relating to waste management practices to the type of hospitals, category of hospitals, bed capacity, bed occupancy, quantity of waste generated and waste handling human resources. The eleven hypothesis can also be classified into four groups of waste management practices as segregation practices, treatment and disposal practices, waste handling safety measures and waste administration.

H1 : There is no significant association between the type of hospital and Waste Management Practices

H2 : There is no significant association between the category of hospital and Waste Management Practices

H3 : There is no significant association between the bed capacity and Waste Management Practices

H4 : There is no significant association between the bed occupancy and Waste Management Practices

H5 : There is no significant association between the amount of waste generated and Waste Management Practices

H6 : There is no significant association between the number of waste handling workers and Waste Management Practices

H7 : There is no significant impact of the type of hospital on Waste Management Practices

H8 : There is no significant impact of bed capacity on Waste Management Practices
H9  :  There is no significant impact of bed occupancy on Waste Management Practices

H10 :  There is no significant impact of amount of waste generated on Waste Management Practices

H11 :  There is a significant impact of number of waste handling workers on Waste Management Practices

**Figure II.2: Formulated Research Hypothesis**
II.2.v. Data Sources and Collection

The supportive data to observe the waste generation rate in India was collected from Central Pollution Control Board (CPCB), New Delhi, India. Number of Hospitals, beds and BMW generated from each hospital per bed was collected among different States of India. This was analyzed to know the rate of waste generation, the amount of waste that is being disposed in to the eco system and waste that was being mixed with municipal waste.

Similarly, comprehensive data was taken for Andhra Pradesh to see the waste generation rate and treatment scenario. The data was obtained from A.P. Pollution Control Board. Conclusions were drawn.

Data on number of hospitals and waste generated from each hospital was maintained by respective State Pollution Control Boards. This data is more authenticated, verified and registered with respective State Pollution Control Boards. All the states periodically send the data to the CPCB, New Delhi. Waste generation data was collected on hospitals in India for 3 years i.e., 2009 - 2010 to 2011-2012.

Comprehensive data on Common Biomedical Waste Treatment Facilities (CBMWTF) in A.P which were established and maintained as per the Ministry of Environment and Forest rules and regulations was collected from A.P. Pollution Control Board (APPCB), Hyderabad. Number of hospitals, waste generation among Government hospitals as well as the hospitals (private) which were registered with CBMWTF was also collected. The data was verified with the registered private hospitals under District Medical & Health Offices (DM&HO) located at each district headquarters. Comparisons were made to see the waste that is being generated from the entire state and the waste which is being treated by CBMWTF’s in the entire state. The entire study is dependent on both primary and secondary data. To derive conclusions on the rate of waste generation in India, secondary data plays a vital role. The primary data which was collected based on questionnaire is supportive to know the biomedical waste management in HCFs of Chittoor District. Both primary and secondary data collection was unexpectedly a difficult task than expected. It is expected that the Pollution Control Board authorities will respond
freely to provide secondary data. However, it became a mammoth task for getting done the work from concerned authorities. The primary data was also expected to collect assuming individual hospital as a respondent. Therefore, the questionnaire was designed in such a way to obtain the information from hospital authorities. However, the individual hospital authorities did not give the expected information thinking that the information may be disclosed or used for any other purpose. As a result, different approaches were adopted to obtain data from concerned HCFs.

To evaluate the proper biomedical waste segregation, treatment, disposal and safe handling methods among hospitals in Chittoor District of Andhra Pradesh was surveyed by using descriptive research method. For which a questionnaire was designed based on the standards given by World Health Organization (WHO). A pilot study was conducted by distributing the questionnaire to 10 HCFs in Tirupati. Based on the difficulty expressed by them, in understanding and responding questions, the wording of questionnaire was modified. The modified questionnaire consists of two parts:

1. The first part consists profile (Type, Location, Category, Bed Capacity etc.) of the HCFs in Chittoor District
2. The second part covers questions related to hospital waste management practices (Segregation, Treatment, Safety measures and Administrative aspects).

II.2.vi. Population

The Study was conducted in Chittoor District of Andhra Pradesh. The population of the study is 271 HCFs, among them 20 are Government and 251 are private Healthcare Facilities.

II.2.vii. Sampling Technique

The technique adopted is one of convenience sampling but based on some rationale. The spread of the 271 HCFs in the District was classified into four clusters. It was intended to analyse 50 per cent of the HCFs in each cluster for responses. There was a purposive bias of including most of the Government HCFs into the survey. The Government hospitals only constitute 6.5% of the total HCFs but the bed capacity is considerably higher.
II.2.viii. Sample Size

Out of 271 HCFs, 134 HCFs were selected for the investigation.

Table II.2. HCFs Population and Respondents in Chittoor District

<table>
<thead>
<tr>
<th></th>
<th>HCFs Population</th>
<th>No. of Questionnaires Administered</th>
<th>Sample Validated</th>
<th>% of Response</th>
</tr>
</thead>
<tbody>
<tr>
<td>Government</td>
<td>20</td>
<td>18</td>
<td>16</td>
<td>88.8</td>
</tr>
<tr>
<td>Private</td>
<td>251</td>
<td>122</td>
<td>118</td>
<td>96.7</td>
</tr>
<tr>
<td>Total</td>
<td>271</td>
<td>140</td>
<td>134</td>
<td>95.7</td>
</tr>
</tbody>
</table>

Table No.II.3: Population and Sample Size of HCFs in Chittoor District

<table>
<thead>
<tr>
<th>Sl.No.</th>
<th>Cluster</th>
<th>Population (No. of HCFs)</th>
<th>Sample</th>
</tr>
</thead>
<tbody>
<tr>
<td>1.</td>
<td>Tirupati</td>
<td>154</td>
<td>74</td>
</tr>
<tr>
<td>2.</td>
<td>Srikalahasti</td>
<td>30</td>
<td>16</td>
</tr>
<tr>
<td>3.</td>
<td>Madanapalli</td>
<td>55</td>
<td>28</td>
</tr>
<tr>
<td>4.</td>
<td>Chittoor</td>
<td>32</td>
<td>16</td>
</tr>
<tr>
<td>5.</td>
<td>Total</td>
<td>271</td>
<td>134</td>
</tr>
</tbody>
</table>

The structure questionnaire was administered to 140 HCFs. Of these, 122 are private HCFs and 18 are Govt. HCFs. Out of these, 118 questionnaires of the Private HCFs and 16 from Govt. HCFs are validated. The response rate comes to 96.70% and 88.8% for private and Government HCFs respectively.
FIG.II.3. LOCATION MAP OF STUDY AREA

CHITTOOR DISTRICT
II.2.ix. Data Analysis

The data was processed by using M.S Excel and SPSS version 19.0. Descriptive statistical tools like percentages, means and standard deviation were carried out to test the hypothesis by using various analytical tools like t-test, $X^2$, Regression analysis, ANOVA, Correlation.

ANOVA test

One-way ANOVA (Analysis of Variance) is used to observed significant difference among three or more independent groups with regard to the variables under study.

t-tests

To observe variation between two independent groups viz., Type of Hospital, Category; Bed capacity, Bed occupancy etc., with respect to variables under the study t-tests are done.

Karl Pearson’s Co-efficient of Correlation.

Karl Pearson's Co-efficient of correlations are calculated for the variables in study to know the degree of interrelationship among them.

Chi-square test

Chi- square test of independence of attributes is also used to know the association between two attributes (qualitative variables).

II.2.x. Scope and Limitations of the study

In addressing the problem of BMW management, the scope would vary at different levels.

1. BMW generation in India and in the regions and in the State was considered only for three years depending on the availability of data. The study of trend is only for a limited period

2. In A.P. the applied study was limited to one district i.e, Chittoor in view of the strain involved in the research. What is depicted for a District may have semblances for many districts in State or the country, if not for all the districts.
3. The sample has purposive bias as more of Government supported HCFs are taken in to the sample survey.

4. The accuracy of the responses in the survey is questionable with a margin of doubt typical to a social survey.

5. There is a small margin of non-respondents on some issues. But they do not affect or imbalance the overall observation.
II.3. References


54. Nagaraju B, Padmavathi GC, Puranik DS, Shantharaja MP. Sampulatha SP. ‘A study to assess the Knowledge and Practice of Biomedical Waste Management among Healthcare providers working in PHCs of Begaplli Taluk, with the view to


75. Remmen TV. ‘Evaluation of the available air pollution control technologies for achievement of the MACT requirements in the newly implemented new source


