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BIOMEDICAL WASTE MANAGEMENT IN INDIA: A REVIEW

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ABSTRACT

Biomedical waste is defined as the waste generated during the diagnosis, treatment or immunization of human beings or animals or in research activities or testing of biological, and including categories mentioned in schedule of the biomedical waste management rules 2016. Proper waste management strategy is needed to ensure health and environmental safety. Hospitals generate an enormous amount of dangerous waste. Biomedical waste management is mainly to reduce waste generation, efficient collection, handling and disposal in such a way that it controls infection and provides safety for working in the system. Increasing concern for community health standards and pollution control requirements demand that the huge mass of infectious waste be rendered as harmless as possible before it is disposed. This Paper also suggests a few measures for the effective management of waste disposal.

Keywords: Biomedical Wastes, Healthcare Establishment, Regulations, Treatment, Waste Disposal.

I INTRODUCTION

Biomedical waste is the waste generated in the diagnosis, treatment or immunization of human beings or animals, in research or in the production of testing of biological products including all categories of infected and toxic waste that is a potential threat to human beings and the environment (Dohare et al., 2013). Health-care waste or medical waste (MW) includes all the waste generated by hospitals, other large health care establishments, diagnostic centers, relevant research facilities, laboratories and small health care facilities (e.g., physicians' offices and dental clinics; Anastasios et. al.,2010). Medical and health-care wastes have sharply increased in recent decades due to the increased population, number, and size of health care facilities, as well as the use of disposable medical products (Amal et al., 2014). Unwanted materials generated during diagnosis, treatment, operation, immunization or in research activities including production of biologicals is termed as biomedical waste (Nagaraju et al.,2013).They generate "wastes" day in and day out which may be the potential health hazards to health workers. While hospitals claim to dispose off their wastes as per the stipulated norms, it is shocking to note that much of the infectious waste including needles, syringes, catheters, etc. are being recycled only to find its way back into the market (Vijayamma and Jayalkshmi, 2016).

In India, collection, segregation, storage, transportation and disposal of hospital waste also called the biomedical waste is unscientific and chaotic. The waste produced in the course of healthcare activities carries a higher potential for infection and injury than any other type of waste. The usual methods for disposal such as burning, land filling or burial, which were in conformity with the then existing public health knowledge and epidemiology were practiced by hospitals or most of the times, the waste thrown out of the hospitals was to be taken care of by the local municipalities(Sarvjeet Kaur,2011).The health care sector includes a diverse range of health care facilities which have a size assortment from large general and specialist hospitals to small municipal dispensaries and D-type centers. All these facilities are an integral part of our society with an endeavor to reduce health problems and to eliminate imminent jeopardy to people's health. In the course of curing health problems the health care sector produce huge amount of bio-medical waste which may be hazardous to all those who come in contact with this waste. Hazardous waste management is a concern for every health care organization (Shalini Sharma,2010).

Biomedical waste forms 1 to 2% of the total municipal waste. Less than 10% of this waste is infectious while another 5% is non-infectious but hazardous. The greatest risk is from the infectious and sharp component of the waste because people associated with handling of the waste are at risk of getting injuries from infected sharps or needle prick injury and can contract HIV, Hepatitis B and C (Dohare et al.,2013). Awareness of biomedical waste management among health care workers and public is necessary and it is the responsibility of the health care facility and health care providers to safeguard the health of workers who are involved in handling, transportation and disposal of biomedical waste (Ananthachari and Divya, 2016).

II SOURCES OF BIOMEDICAL WASTE

While urban solid waste has attracted the attention of town planners, environmental activists and civic administrators, there is yet lack of concern for some special sources of waste and its management. One such waste is bio-medical waste generated primarily from health care establishments, including hospitals, nursing homes, veterinary hospitals, clinics and general practitioners, dispensaries, blood banks, animal houses and research institutes. The other sources of biomedical waste are the following: households, industries, education institutes, and research centers, blood banks and clinical laboratories, health care establishments for humans and animals (Babu et al.,2009).

III CLASSIFICATION OF BIOMEDICAL WASTE

Non-hazardous waste constitutes about 85% of the waste generated in most healthcare set-ups. This includes waste comprising of food remnants, fruit peels, wash water, paper cartons, packaging material etc.

3.1 Hazardous waste

3.1.1 Potentially infectious waste

Over the years different terms for infectious waste have been used in the scientific literature, in regulation and in the guidance manuals and standards. These include infectious, infective, medical, biomedical, hazardous, red bag, contaminated, medical infectious, regulated and regulated medical waste. All these terms indicate basically the same type of waste, although the terms used in regulations are usually defined more specifically. It constitutes 10% of the

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total waste which includes dressings and swabs contaminated with blood, pus and body fluids, laboratory waste including laboratory culture stocks of infectious agents. Potentially infected material such as excised tumours and organs, placenta removed during surgery, extracted teeth etc., potentially infected animals used in diagnostic and research studies, sharps, which include needle, syringes, blades etc., blood and blood products.

3.1.2. Potentially toxic waste (Radioactive waste)

It includes waste contaminated with radionuclide; it may be solid, liquid or gaseous waste. These are generated from *in vitro* analysis of body fluids and tissue, *in vitro* imaging and therapeutic procedures, Chemical waste: It includes disinfectants (hypochlorite, gluteraldehyde, iodophors, phenolic derivatives and alcohol based preparations), X-ray processing solutions, monomers and associated reagents, base metal debris (dental amalgam in extracted teeth), Pharmaceutical waste: It includes anesthetics, sedatives, antibiotics, analgesics etc (Hegde et al., 2007).

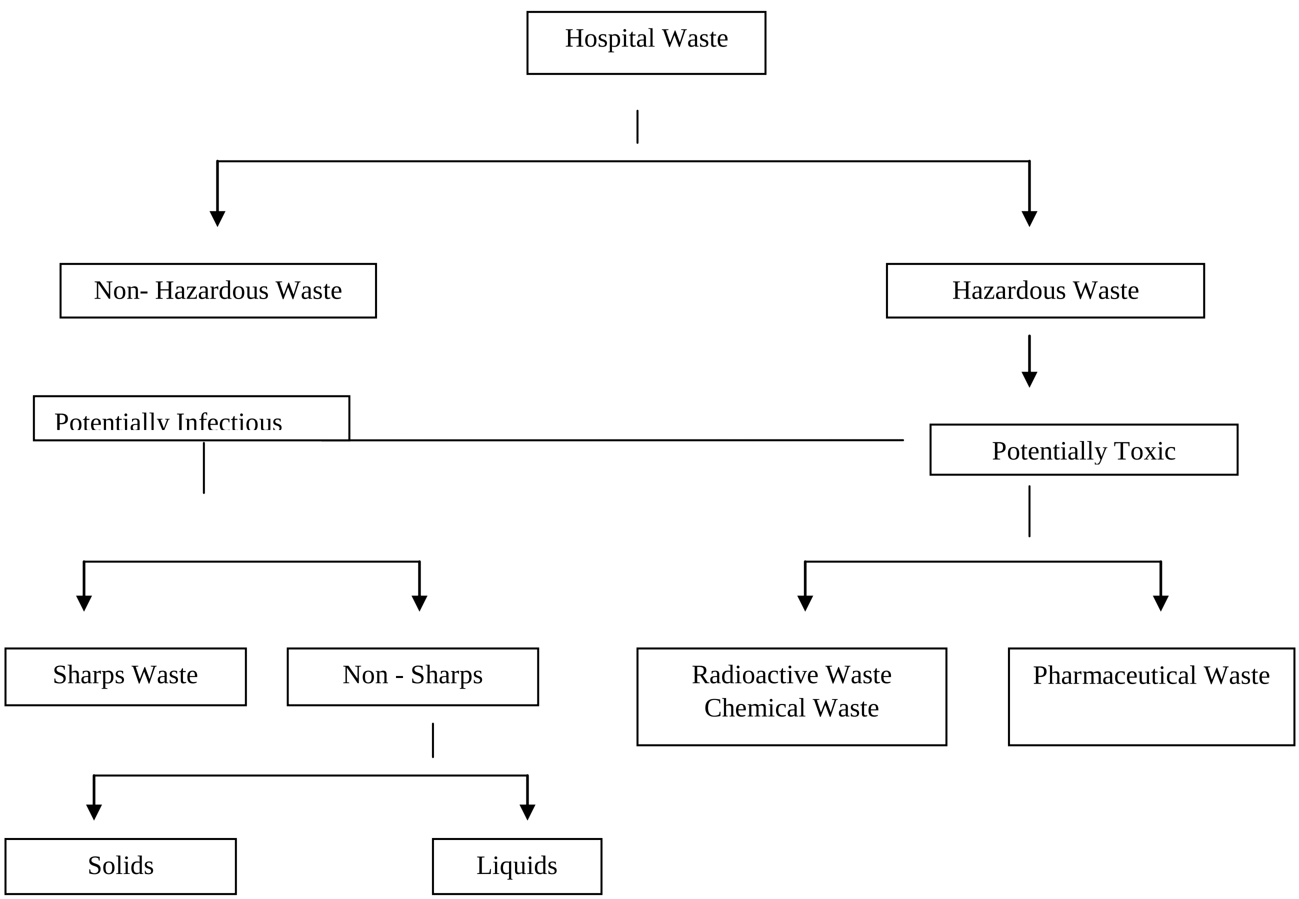

Fig.1. Classification of bio-medical waste (Source: Hegde et al.,2007)

IV BIOMEDICAL GENERATION RATE

Studies carried out in India, shows generation of bio-medical waste in the range of 0.3 to 1.0 kg/bed/day of which around 50% of the wastes is collected as infectious wastes (human anatomical wastes and animal wastes). However, effective segregation of these human & anatomical wastes in HCFs would reduce the quantity of infectious waste needing incineration/deep burial. Based on the literature, the quantity of hospital waste generated in some developed countries are given in table (Envis Newsletter, 2014).Based on the literature, the quantity of hospital waste generated in some developed countries are given in table below.

Table 1: Quantity of bio-medical waste generated in few countries (Envis Newsletter, 2014)

Country	Netherlands	France	USA	Latin America	India
Biomedical Waste Generation (kg/bed/day)	2.7	2.5	4.5	2.63 to 3.8	0.3 to 1.0

There are around 48,000 beds in health care facilities in Delhi. The average number of beds per 1000 inhabitants in Delhi is 2.58. This average is increasing in Delhi day by day due to rapid development in the health care facilities which has put Delhi among cities with advanced facilities in the country. Since, Delhi provides better health care facilities, patients from all over India comes here for treatment. The average occupancy of hospitals is around 75%-80% throughout the year. The BMW generation also has an increasing trend with respect to population of Delhi. The sane is depicted in figure 2 (Siddhartha Gautam, 2017).

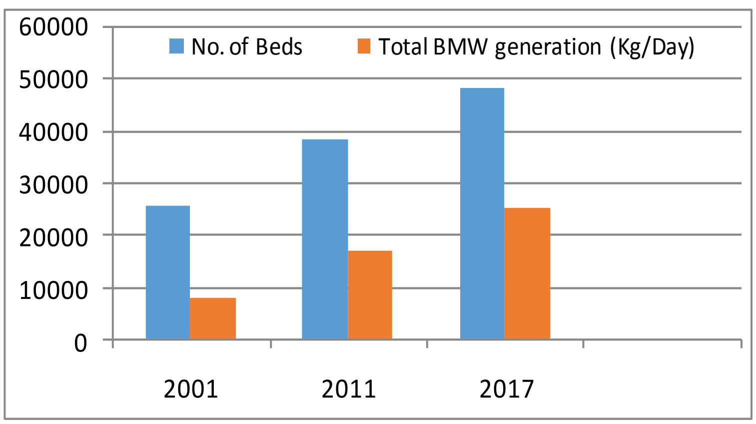

Fig 2.Trend of BMW Generation (Envis handbook, 2017)

V BIOMEDICAL WASTE MANAGEMENT RULES, 2016

The ambit of the rules has been expanded to include vaccination camps, blood donation camps, surgical camps or any other healthcare activity. Phase-out the use of chlorinated plastic bags, gloves and blood bags within two years. Pre-treatment of the laboratory waste, microbiological waste, blood samples and blood bags through disinfection or sterilization on-site in the manner as prescribed by WHO (World Health Organization) or NACO (National AIDS

Control Organization). Provide training to all its health care workers and immunize all health workers regularly. Establish a bar-code system for bags or containers containing bio-medical waste for disposal. Report major accidents. Existing incinerators to achieve the standards for retention time in secondary chamber and dioxin and furans within two years. Bio-medical waste has been classified in to 4 categories instead 10 to improve the segregation of waste at source. Procedure to get authorization simplified.

Automatic authorization for bedded hospitals. The validity of authorization synchronized with validity of consent orders for bedded HCFs. One time authorization for non-bedded HCFs. The new rules prescribe more stringent standards for incinerator to reduce the emission of pollutants in environment. Inclusion of emissions limits for dioxin and furans. State government to provide land for setting up common bio-medical waste treatment and disposal facility. No occupier shall establish on-site treatment and disposal facility, if a service of common bio-medical waste treatment facility is available at a distance of seventy-five kilometer. Operator of a common bio-medical waste treatment and disposal facility to ensure the timely collection of bio-medical waste from the HCFs and assist the HCFs in conduct of training.

In cases where service of the common bio-medical waste treatment facility is not available, the occupiers shall set up requisite bio medical waste treatment equipment like incinerator, autoclave or microwave, shredder prior to commencement of its operation, as per the authorization given by the prescribed authority. Untreated human anatomical waste, animal anatomical waste, soiled waste and, biotechnology waste shall not be stored beyond a period of forty–eight hours. In case for any reason it becomes necessary to store such waste beyond such a period, the occupier shall take appropriate measures to ensure that the waste does not adversely affect human health and the environment and inform the SPCB (State Pollution Control Board) along with the reasons (Bio-Medical Waste Management Rules, 2016).

VI CATEGORIES OF BIOMEDICAL WASTE

Table 2: Biomedical wastes categories and their segregation, collection, treatment, processing and disposal options (Bio-Medical Waste Management Rules, 2016)

Color Coding	Type of Container	Waste Category	Treatment	Disposal
Yellow	non-chlorinated plastic bags/ containers	Human anatomical waste/ animal anatomical waste/ soiled waste/ expired or discarded medicines/ chemical waste/ chemical liquid waste/ discarded linen, mattresses, beddings contaminated with blood or body	Incineration/ Plasma pyrolysis /deep burial	Treated waste to be sent for energy recovery

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		fluid/ microbiology, biotechnology and other clinical laboratory waste		
Red	non-chlorinated plastic bags or containers	Contaminated Waste (Recyclable)	Autoclaving / micro-waving/ hydroclaving / shredding / mutilation or combination of sterilization and shredding	sent to registered or authorized recyclers or for energy recovery or plastics to diesel or fuel oil or for road making
White	Puncture proof, Leak proof, tamper proof containers	Waste sharps including metals	Autoclaving / Dry Heat Sterilization/ shredding / mutilation / encapsulation in metal container or cement concrete/ combination of shredding cum autoclaving	sent to iron foundries or sanitary landfill or designated concrete waste sharp pit.
Blue	Cardboard boxes with blue colored marking	Glassware/ metallic body Implants	Disinfection (by soaking the washed glass waste after cleaning with detergent and Sodium Hypochlorite treatment) or through autoclaving or microwaving or hydroclaving	sent for recycling

VII EFFECTS OF BIOMEDICAL WASTE

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

7.1 Air pollution

Air pollution can be caused in both indoors and outdoors atmosphere. Biomedical waste that generated by air pollution are been classified in three types namely-Biological, Chemical and radioactive. In-door air pollution is pathogens present in the waste can enter and remain in the air for a long period in the form of spores or as pathogens Segregation of waste, pre-treatment at source etc., can also reduce this problem to a great extent. Sterilizing the rooms will also help in checking the indoor air pollution due to biological .The indoor air pollution caused due to the above chemicals from poor ventilation can cause diseases like Sick Building Syndrome (SBS). Proper building design and well-maintained air conditioners can reduce the SBS. Chemicals should be utilized as per prescribed norms. Over use of chemicals should be avoided. Outdoor air pollution can be caused by pathogens. The biomedical waste without pre treatment if transported outside the institution, or if it is dumped in open areas, pathogens can enter into the atmosphere. Chemical pollutants that cause outdoor air pollution have two major sources-open burning and incinerators. Open burning of bio-medical waste is the most harmful practice. When inhaled can cause respiratory diseases. Certain organic gases such as dioxins and furans are carcinogenic. The design parameters and maintenance of such treatment and disposal technology should be as per the prescribed standards.

7.2 Radioactive emissions

Research and radio-immunoassay activities may generate small quantities of radioactive gas. Gaseous radioactive material should be evacuated directly to the outside. The use of such device requires maintenance of the trap and monitoring of the off-gas. Radioactive waste in liquid form can come from chemical or biological research, from body organ imaging, from decontamination of radioactive spills, from patient’s urine and from scintillation liquids used in radioimmunoassay. Under normal circumstances, urine and faeces can be handled as no radioactive waste so long as the patient’s room is routinely monitored for radioactive contamination.

7.3 Water and land pollution

The liquid waste generated when let into sewers can also lead to water pollution if not treated properly. Water pollution can alter parameters such as pH, BOD (Biochemical Oxygen Demand), DO (Dissolved Oxygen), COD(Chemical Oxygen Demand), etc. There are instances where dioxins are reported from water bodies near incinerator plants. Dioxins enter the water body from the air. Soil pollution from bio-medical waste is caused due to infectious waste, discarded medicines, chemicals used in treatment and ash and other waste generated during treatment processes. Heavy metals such as cadmium, lead, mercury etc., which are present in the waste will get absorbed by plants and can then enter the food chain. Nitrates and phosphates present in leachates from landfills are also pollutants. Excessive amounts of trace nutrient elements and other elements including heavy metals in soil are harmful to crops and are also harmful to animals and human beings (Babu et al,2009).

VIII PROBLEMS RELATING TO BIOMEDICAL WASTE

A major issue related to current Bio-Medical waste management is lack of knowledge in segregation practices that result in mixing of hospital wastes with general waste making the whole waste stream hazardous. Inappropriate segregation ultimately results in an incorrect method of waste disposal. Inadequate Bio-Medical waste management thus will cause environmental pollution, unpleasant smell, growth and multiplication of vectors like insects, rodents and worms leads to the transmission of diseases like typhoid, cholera, hepatitis and AIDS through injuries from syringes and needle contaminated with human. Various communicable diseases, which spread through water, sweat, blood, body fluids and contaminated organs, are important to be prevented.

The problem of bio-medical waste disposal in the hospitals and other healthcare establishments has become an issue of increasing concern, prompting hospital administration to seek new ways of scientific, safe and cost effective management of the waste, and keeping their personnel informed about the advances in this area. The need of proper hospital waste management system is of importance and is an essential component of quality assurance in hospitals as well as the knowledge of the workers in effective waste disposal also prime importance (J. Mano Ranjini, 2014).

Waste managers are distressed by diverse types of the health effect because of pathogenic organisms of medical waste. One assessment shows that a number of such that 5.2 million people (comprising 4 million children) die each year in the sphere from waste-related diseases. By survey it was detected those respondents were suffering from vomiting and headache in higher percentage 35% and 32% respectively. Some of the respondents met heart pain (18%) for the period of the waste handling particularly the anatomical waste during the first time of the services (Som and Hossain, 2017).

Table 3. Types of infectious caused by biomedical waste (Nikos et al,2011)

Infection Type	Pathogen Agents	Transmission Path
Gastrointestinal infections	Enterobacteria: Salmonell, Shigellaspp. Vibrio cholera Helminths	Faeces or/and vomiting liquid
Respiratory infections	Mycobacterium tuberculosis Measles virus Streptococcus pneumonae	Respiratory secretions, saliva
Eye infections	Herpes virus	Eye secretions
Genital infections	Neisseria gonorrhoeae Herpes virus	Genital secretions
Skin infections	Streptococcus spp.	Purulent secretions
Anthrax	Bacillus anthracis	Secretions of skin lesions
Meningitis	Neisseria meningitides	LCR
AIDS	HIV	Blood, semen, vaginal secretions
Haemorrhagic fevers	Junin Viruses, Lassa, Ebola Marburg	Biological fluids and secretions
Septicemia	Staphylococcus ssp	Blood
Viral Hepatitis type A	VHA	Faeces

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Viral Hepatitis type B and C	VHB, VHC	Blood, biological Fluids

IX STATUS OF COMMON BIO-MEDICAL WASTE TREATMENT FACILITIES (CBWTFS) IN INDIA

There has been increase in number of CBWTFs over the years and at present there are 226 CBWTFs (i.e. 198 CBWTFs are in operation and 28 CBWTFs are under installation) so as to facilitate proper treatment and disposal of bio-medical waste in India. A state wise study has been done on CBWTFs shows that Maharashtra has the maximum number of operational CBWTFs whereas D & D & DNH, Kerala, Meghalaya, Puducherry, Tripura has least number of CBWTFs. There are 198 operational and 28 under construction CBWTFs in India. However in some states like Maharashtra, Karnataka, Gujarat are found to be aware about the CBWTFs, whereas other states like D & D & DNH, Kerala, Meghalaya, Puducherry, Tripura have only one CBWTF or are not much aware about that facility (Envis Newsletter, 2014).

Vishwanath and Anuradha,2015 conducted a similar study and inferred that the proper biomedical waste management will help to control nosocomial diseases, reduces HIV/AIDS, sepsis and hepatitis transmission from dirty needles and other improperly cleaned/ disposed medical items, control zoonoses. It will also help to prevent illegal repackaging and resale of contaminated needles, cut cycles of infection and avoid negative long term health effects like cancer, from the environmental release of toxic substances such as dioxin, mercury and others.

As per the details summarized in Table.5 , total number of health care facilities (HCFs) in India have been reported as 1,68,869 (this may also contain number of HCFs which do not come under the purview of authorization as required under BMW Rules) and 1,06,805 number of healthcare facilities applied for authorization. This certainly indicates that number of HCFs is in operation without obtaining authorization from the respective SPCB/PCC. The number of HCFs (authorized/ unauthorized) as well as unregistered HCFs are on large number which may be involved in improper bio-medical waste management in the country.

Table 4: Bio-Medical Waste Management Scenario in India (Siddhartha Gautam, 2017)

Items	**Number/Quantity**
Number of Health Care Facilities (HCFs)	1,68,869
Number of beds	17,13,816
Number of Common Bio-medical Waste Treatment Facilities (CBWTFs)	198 + 28
Number of HCFs using CBWTFs	1,31,837
Number of HCFs having treatment & disposal facilities	22,245
Number of HCFs applied for authorization	1,06,805
Number of HCFs granted authorization	1,05,270

Total number of on-site/captive treatment equipment installed (excluding CBWTFs) by the HCFs:-	
Number of incinerators	
i). With Air Pollution Control Device	331
ii). Without Air Pollution Control Device	217
Number of autoclaves	3,112
Number of microwaves	250
Number of Hydroclaves	15
Number of Shredders	5,179
Total number of treatment equipment installed by the CBWTFs:-	
Number of Incinerators	198
Number of autoclaves	189
Number of microwaves	06
Number of hydroclaves	03
Number of Shredders	202
Quantity of bio-medical waste generated in tons/day	484
Quantity of bio-medical waste treated in tons /day	447
Number of HCFs violated BMW Rules	7,894
Number of Show-cause notice/Directions issued to defaulter HCFs	4,391

It can be inferred from Table 4 that approximately 92.3% of bio-medical waste generated is being treated and disposed of either through 198 number of common bio-medical waste treatment facilities or captive treatment equipment installed by the HCFs. However it can also be observed that HCFs has installed 548 number of incinerators, 3112 autoclaves, 250 microwaves, 15 hydroclaves and 5179 shredders as captive treatment equipment in India. Also 198 numbers of incinerators are operated by the CBWTFs. However out of total around 60.4% of captive biomedical waste Incinerators operated by HCFs are provided with air pollution control devices.

X LABELLING FOR IDENTIFICATION OF BIOMEDICAL WASTES

Labelling is essential for the correct identification and safe management of medical wastes. Labeling makes the identification and handling of different types of medical waste, easier. It will also warn the workers, patients, and the public about the existence of the wastes and their potential health hazards. All labelling and sign posting should follow the international symbols and colour coding. All the infected, soiled, pathological, human and sharp wastes, should be marked with biohazard symbol in black colour, representing cytotoxic wastes.

Labelling of the wastes at the generation point should be in the form of tag or adhesive label, attached to the collection bag or container, prior to it being collected by the cleaning staff. This waste tagging system will allow waste audits conducted at the treatment/ disposal site, to identify those areas that are in compliance or non-compliance with the required hospital waste management practices. If needed, a corrective action can then be easily initiated. If would be better, if the bags and bins provided are already labeled with the appropriate hazard symbol (S.K. Garg, 2009).

XI TRANSPORTATION OF BIOMEDICAL WASTES TO THE TREATMENT AND DISPOSAL SITES

Wastes in hospitals should be frequently lifted from well marked designated collection points in hospital wards or rooms. Open trolleys are often used to collect wastes from individual bins. In all such cases, each bin and each trolley must be thoroughly cleaned and disinfected with 1% solution of bleaching powder (hypochlorite) at least once a week. The movement of the sanitation staff should be prevented or minimized through the designated clean areas of the hospital. Automated waste handling and transported system is much better than the manual ones. The vehicles used for waste transport to the disposal sites should not be used for any other purpose. Such vehicles should be labeled and designated for the purpose by the authorities (S.K. Garg, 2009).

XII BIOMEDICAL WASTE MANAGEMENT TECHNIQUES

12.1 Chemical Methods

In this method, the waste is disinfected by using chemicals like chlorine compounds, such as bleaching powder, etc. Other chemicals like iodine, alcohols, phenolic compounds, hexachlorophene, formaldehydes, etc. may also sometimes be used. However, 1% solution of hypochlorite (bleaching powder) is most commonly used. All such chemicals shall be used in aqueous solutions, in which the waste items shall be kept submerged. Many of the waste items may even need shredding before disinfection, as to help in providing sufficient contact between the waste and the disinfectant. The disinfected waste will usually be shredded. In this method, the shredded wet wastes containing disinfectant chemicals will need final disposal. The method can hence be used for disposing solid waste items like tubes, catheters, blood or urine bags, globes and sharps like needles, syringes etc. which can be buried after disinfection and shredding; or for disposing certain types of liquid wastes which can be discharged into the sewers after disinfection(S.K. Garg, 2009).

12.2 Incineration Technology

The numerous advantages of incineration have led to its world-wide use as the preferred means of treating and disposing clinical solid waste. Incineration is a high-temperature dry oxidation process that converts the waste into residual ash and gases. It is particularly useful in the treatment of pathological waste and sharps, as these components of waste stream are rendered unrecognizable. This process is usually selected to treat wastes that cannot be recycled, reused, or disposed of in a landfill site. Incineration emits lots of harmful pollutants including particular concern carbon monoxide (as a result incomplete combustion), hydrogen chloride, metals (e.g. mercury, lead, arsenic, cadmium), dioxins and furans. Many of these pollutants, dioxins in particular, can be carried long distance from their emissions source and accumulate in soil, water, food source, `and pollute them. It is reported that a properly designed incinerator can completely burn waste and leave minimum residual in the form of ashes (Hossain et al., 2011). It imposes a great risk of environmental and health hazard due to wide varieties of pollutants released from the burning of biomedical waste such as dioxins, furans, etc. Further, incineration has been concluded as the most expensive treatment for biomedical waste management in developing countries (Vasistha et al., 2018).

This is a high temperature thermal process employing combustion of the waste under controlled condition for converting them into inert material and gases. Incinerators can be oil fired or electrically powered or a combination thereof. Broadly, three types of incinerators are used for hospital waste: multiple hearth type, rotary kiln and controlled air types. All the types can have primary and secondary combustion chambers to ensure optimal combustion. These are refractory lined (Mathur et al.,2012).

12.3 Non Incineration Technology

Non-incineration treatment includes 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.

12.4 Plasma Pyrolysis

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 byproducts. 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. Medical waste is pyrolysed into CO, H_2, and hydrocarbons when it comes in contact with the plasma-arc. These gases are burned and produce a high temperature (around 1200^{o}C).

12.5 Autoclaving

The autoclave operates on the principle of the standard pressure cooker. The process involves using steam at high temperatures. The steam generated at high temperature penetrates waste material and kills all the micro organism. These are also of three types: Gravity type, Pre-vacuum type and Retort type. In the first type (gravity type), air is evacuated with the help of gravity alone. The system operates with temperature of 121° C. and steam pressure of 15 psi. for 60-90 minutes. Vacuum pumps are used to evacuate air from the pre vacuum autoclave system so that the time cycle is reduced to 30-60 minutes. It operates at about 132° C. Retort type autoclaves are designed much higher steam temperature and pressure. Autoclave treatment has been recommended for microbiology and biotechnology waste, waste sharps, soiled and solid wastes. This technology renders certain categories (mentioned in the rules) of bio-medical waste innocuous and unrecognizable so that the treated residue can be land filled.

12.6 Microwave Irradiation

The microwave is based on the principle of generation of high frequency waves. These waves cause the particles within the waste material to vibrate, generating heat. This heat generated from within kills all pathogens.

This process involves pre-shredding the waste, injection it with steam, and heating it for 25 minutes at 25^0 C, under a series of microwave units. Microwave radiation is designated as that portion of the electromagnetic radiation spectrum lying between the frequencies of 300 and 3, 00,000 MHz, and the microbial inactivation occurs as a result of thermal effect of radiation, and not from any intrinsic non-thermal property(S.K.Garg, 2009).

Table 5. Comparison of treatment technologies for medical wastes (Babu et al., 2009)

S.No.	Treatment Systems	Autoclave	Hydroclave	Microwave	Incinerator	Chemical
1	Description	Steam sterilization (direct heating)	Steam sterilization (indirect heating) simultaneous shredding and dehydration	Microwave heating of pre-shredded waste	High temperature waste incineration	Mixing pre-ground waste with chemicals, such as chemicals
2	Sterilization efficiency	Medium	Medium	Medium	High total destruction of micro-organisms	Dependent on chlorine strength and dispersment through the waste
3	Capital cost	Low	Low	High	High	Moderate
4	Operational cost	Low	Low	High	High	Low
5	Operator maintenance skills	Low skill level required	Low skill level required	Automated but highly complex and high level maintenance skill required	High level operator and maintenance skills required	High level required for chemical control and grinder
6	Air emissions	Odorous but non-toxic	Somewhat odorous but non-toxic	Somewhat odorous but non-toxic	Can be highly toxic	Some chlorine emissions
7	Water emissions	Odorous may contain live micro-	Odorous but sterile	Negligible	None	None

		organisms				
8	Treated waste characteristics	Wet waste, all material recognizable	Dehydrated, shredded waste, unrecognizable material	Shredded but wet waste	Mostly ash, may contain toxic substances	Shredded wet waste, containing chemicals used as disinfectant

Also it can be inferred that amongst the various methods recommended for the disposal of the disposal of infectious waste, i.e. incineration, autoclaving, microwave, deep burial, etc., microwave offers many advantages. Microwave energy penetrates and heats the entire material at nearly the same rate and converts the infectious waste into municipal waste which can be handled by human beings and disposed of along with other waste.

Table 6. Comparison of Microwave vs. Autoclave (Siddhartha Gautam, 2017)

Microwave	Autoclave
Fully Mobile	Static
45- minutes cycle	120- minute cycle
Hub Connectivity	NO Hub Connectivity
Absolutely Safe – Works indoor	Unsafe – Works like large pressure
3KW with 1Ø	12 KW with 3Ø
Saving of 9 kw/hr/unit	Mucky Waste +ETP Cost
Negligible Running Cost	Very high double the cost in 5 years
Higher Level of disinfection to the order of log10^5 - 10^7	High Level of disinfection to the order of log 10^3 - 10^5
Zero Emission	Excessive emission of effluent, stream & Heat
State of Art Technology	Legacy Technology
Can disinfect “ Super Bug” MRSA infected biological waste	Infected Biological Waste

XIII CONCLUSION

Biomedical waste management is an integral part of health-care facility, and creating harm through inadequate waste management reduces the overall benefits of healthcare. In new Biomedical Waste Management Rules, there are only 4 categories and more focus is on testing of dioxins and furans .However, it is also compulsory that in incineration the residence time of particle in secondary chamber should be of 2 seconds. Development of bar coding to track waste generation and its disposal and trolley washing area should be connected with sewage treatment plant. Isolated storage sites should have designated compartments for the various categories of waste and it should not be in open access. Among the various methods recommended for the disposal of infectious waste, microwave offers many advantages as energy penetrates and heats the entire material uniformly at the same rate. Therefore, it converts the infectious waste into municipal waste which can be handled by human beings and disposed off along with other wastes.

REFERENCES

[1] Dohare S., Garg V. K. and Sarkar B. K. ,A Study of Hospital Waste Management Status In Health Facilities of An Urban Area, International Journal of Pharma and Bio Sciences, 4(1),2013,(B) 1107 - 1112

[2] Anastasios G., Evangelos V., Athanasios P., Nikolaos I., and Maria K., 2010, Composition and Production Rate of Medical Waste from a Small Producer In Greece, International Journal of Integrated Waste Management, Science and Technology, 2010, 1683-1689

[3] Amal S., Aaeid A., Ihab L., Abdelnaser O., Isam S., Assessment of Medical Waste Management within Selected Hospitals in Gaza Strip Palestine: A Pilot Study, International Journal of Scientific Research in Environmental Sciences, 2 (5), 2014,164-173

[4] Nagaraju B, Padmavathi GV, Puranik DS, Shantharaj MP, Sampulatha SP, A Study to Assess The Knowledge and Practice on Bio-Medical Waste Management among The Health Care Providers Working in Phcs of Bagepalli Taluk with the view to prepare Informational Booklet, International Journal of Medicine and Biomedical Research,2(1),2013,28-35

[5] Vijayamma Ajmera, Jayalkshmi L. S., A Study to Assess the Knowledge Regarding Biomedical Waste Management among B.Sc Nursing Students of Selected Nursing Colleges of Udaipur (Raj), International Journal of Science and Research, 5(4),2016,1734-1738

[6] Sarvjeet Kaur, A Comparative Study on Knowledge and Practices of Nurses Regarding Biomedical Waste Management in select Government Hospitals, Nursing and Midwifery Research Journal, 7(3),2011,130-140

[7] Shalini Sharma, Awareness about Biomedical Waste Management among Health Care Personnel of Some Important Medical Centers in Agra, International Journal of Environmental Science and Development, 1(3),2010, 251-255

[8] Ananthachari K.R., Divya C.V., A Study on Assessment of Knowledge on Biomedical Waste Management among Health Care Workers Of Malabar Medical College Teaching Hospital, Calicut, Kerala, India, International Journal of Community Medicine and Public Health, 3(9),2016,2409-2413

[9] B. Ramesh Babu, A.K. Parande, R. Rajalakshmi, P.Suriyakala, M.Volga, Management of Biomedical Waste in India and Other Countries: A Review, J. Int. Environmental Application & Science,4(1),2009,65-78

[10] Hegde V., Kulkarni RD, Ajantha GS, Biomedical Waste Management, Journal of Oral and Maxillo Facial Pathology, 11(1),2007,5-9

[11] Envis Newsletter, Biomedical Waste Management- An Overview, 2014

[12] Siddhartha Gautam, Environmental Handbook on Bio-Medical Waste Management And Wastewater Treatment Technologies, 2017

[13] Bio-Medical Waste Management Rules, 2016

[14] J. Mano Ranjini, A Study to assess The Knowledge on Biomedical Waste Disposal among The Group D Health Workers in Sri Ramakrishna Hospital, Coimbatore, Asian Pacific Journal of Health Sciences, 1(4),2014, 465-470

[15] U. Som and Md. S. Hossain, Management of Medical Waste as a Key for Innocuous City Development: A Case Study In Jessore City, Bangladesh, International Conference on Mechanical Engineering and Renewable Energy,2017

[16] Nikos E. M., Carmen A. B., Tatiana A. O., Cornelia A.B., Philippe D., Holistic Approach Of Biomedical Waste Management System With Regard to Health and Environmental Risks, International Journal Of Energy And Environment, 5(3),2011,309-318

[17] Vishwanath S. B. & Anuradha M., The Effectiveness of Awareness Program on the Practices of Bio-medical Waste Management among Nurses: A Review article, International Journal of Current Medical and Applied Sciences,8(3),2015,81-87

[18] S.K. Garg, Sewage Disposal and Air Pollution Engineering, Environmental Engineering (Vol. II), 2009, Khanna Publications, New Delhi, India

[19] Md. S. Hossain, A. Santhanam, N.A. Nik Norulaini, A.K. Md. Omar, Clinical Solid Waste Management Practices and Its Impact on Human Health And Environment- A Review, International Journal of Integrated Waste Management, Science and Technology,2011,754-766

[20] P. Vasistha, R.Ganguly and A. K. Gupta, Biomedical Waste Generation and Management in Public Sector Hospital in Shimla City, Environmental Pollution, Water Science and Technology Library,2018,225-232

[21] P. Mathur, S. Patan and A. S. Shobhawat, Need of Biomedical Waste Management System in Hospitals - An Emerging issue - A Review, Current World Environment, 7(1),2012, 117-124