CHAPTER II

THE CONCEPT OF BIO-MEDICAL WASTE, A NEW MENACE ON THE ENVIRONMENT: AN OVERVIEW

In order to cater to the needs of the expanding population and to achieve the goal of "Health for All" by 2000 A.D. adopted at the Alma Ata Conference in 1978, the last century witnessed rapid mushrooming of healthcare institutions in both government and in private sectors. Due to a combination of lack of know-how and enforcement, the wastes[1] generated in such establishments are being treated indiscriminately; consequently the same have been posing a constant threat to the environment. The entire operation and maintenance seems like a lost battle. In today's 'throw-away-society', it is a veritable hell-a city littered with garbage and filth[2].

There is no denying the fact that a modern hospital is a complex, multidisciplinary system which consumes thousands of items for delivery of medical care and is a part of physical environment. All these products consumed in the hospital leave some unusable leftovers i.e. Bio-Medical Waste[3]. The problem of Bio-Medical Waste has gained enormous proportions and complex dimensions in recent years. The emergence and acceptance of disposable hospital waste generation is an important factor in the current scenario. Being part of social organisation that aimed at meeting the medico-social needs of the community, hospital environments have undergone tremendous changes. In this process where, on the one hand, hospitals are providing for the best opportunities in the health care, on the other, it is affecting the health of the community as a whole including doctors, staffs, etc. due to the unscientific management and disposal of the Bio-Medical Waste spread through water, sweat, blood, body fluids and contaminated organs. Therefore, proper management of hospital waste is essential to maintain hygiene, aesthetics, cleanliness and control of environmental pollution. The hospital waste like body parts, organs, tissues, blood and body fluids along with soiled linen, cotton, bandage and plaster

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[1] Known as bio-medical waste in India and health care waste or clinical waste or medical waste in many other countries.

[2] Dr. Sushma Sahai, *Bio-Medical Waste Management* pg. 1 (A.P.H. Publishing Corporation, 1st Edn., 2009).

[3] Mohd Faisal Khan, *Hospital Waste Management*: *Principles and Guidelines* pg. 1 (Kanishka Publishers, 1st Edn., 2004).

casts from infected and contaminated areas are very essential to be properly collected, segregated, stored, transported, treated and disposed of in safe manner to prevent nosocomial or hospital acquired infection.

The inadequate, inappropriate and improper waste management not only leads to foul odour creating air pollution, it also causes water and land pollution, due to the propensity of mixing the such waste with air, water and land through disease carrying organisms like insects, rodents and worm etc. In addition to it the improper use of the infectious waste such as used sharps, needles etc. also causes accidental injuries. Owing to unsafe healthcare practices, half a million people all over the world die every year due to infections like hepatitis B, and C, HIV and hepato-cellular carcinoma[4]. The World Health Organisation[5] (WHO) has estimated that, in 2000, injections with contaminated syringes caused;

- 21 million hepatitis B virus (HBV) infections (32% of all new infections),
- Two million hepatitis C virus (HCV) infections (40% of all new infections),
- 260 000 HIV infections (5% of all new infections).

Epidemiological studies indicate that a person who experiences one needle-stick injury from a needle used on an infected source patient has risks of 30%, 1.8%, and 0.3% respectively to become infected with HBV, HCV and HIV. In 2002, the results of a WHO assessment conducted in 22 developing countries showed that the proportion of health-care facilities that do not use proper waste disposal methods ranges from 18% to 64%. According to WHO, category wise percentage of waste generation, non infectious waste is 80% , pathological and infectious waste 15% , sharps waste 1 % , chemical or pharmaceutical waste 3 % and others 1 %[6]. Thus, it can be said that between 75% and 90% of the waste produced by health-care providers is comparable to domestic waste and usually called “non-hazardous” or

[4] Anantpreet Singh and Sukhjit Kaur, *Biomedical Waste Disposal* pg.1 (Jaypee Brothers Medical Publishers (p) Ltd.1st Edn., 2012).
[5] Mohd Inayatulla Khan, M. C. Prasant, *et.al.*, “Bio Medical Waste Management- An Emerging Problem” 1 Global Journal of Medicine and Public Health pg. 51 (Jan-Feb 2012).
[6] Andhra Pradesh Environment Protection Training & Research Institute, *Bio-Medical Waste Management Self Learning Document For Nurses & Paramedical*, World Health Organization (WHO), (India Country Office, New Delhi), *Available at*: http://www.indiannursingcouncil.org/pdf/Bio-_medical_waste_management_self_learning_document_for_Nurses_and_Paramedica.pdf (Last visited on Sept. 12, 2016).

"general health-care waste". It comes mostly from the administrative, kitchen and housekeeping functions at health-care facilities and may also include packaging waste and waste generated during maintenance of health-care buildings. The remaining 10–25% of health-care waste is regarded as "hazardous" and may pose a variety of environmental and health risks.[7] Developed countries generate approximately 1 to 5 kg of hospital waste/bed/day, whereas developing countries 1-2 kg/bed/day. In developed countries like US and Canada, annual waste production in over 1 million hospital beds is about 2 tones per hospital bed, or about 2,000,000 tones in total.[8] The Table (Table 1) given below shows the quantity of waste produced by different countries every day.

Table 1

Quantity of BMW generated in different countries[9]

Country	**Quantity of waste generated (kg/bed/day)**
UK	2.5
USA	4.5
France	2.5
Spain	3.0
India	1.5

2.1 Meaning of Bio-medical Waste

The term biomedical waste means any solid or liquid waste that may pose the risk of infection to humans, including non-liquid tissue, body parts, blood, blood products, and body fluids of human beings including laboratory and veterinary wastes containing human pathogens and discarded sharps. It also includes blood absorbent and non absorbent substances, blood products, body fluids, secretions, secretions contaminated with blood and blood saturated or blood products. In other words, bio-medical waste includes all the waste generated within health-care facilities, research

[7] Yves Chartier, Jorge Emmanuel, *et. al.*, "Safe management of wastes from health-care activities" pg. 3 (WHO Press, World Health Organisation, 2nd Edn., 2014).
[8] Mohd Faisal Khan, *Hospital Waste Management*: *Principles and Guidelines* pg. 2 (Kanishka Publishers, 1st Edn., 2004).
[9] S Manasi , K S Umamani *et. al.*, "Bio-medical Waste Management: Issue and Concerns-A Ward Level Study of Bangalore City," pg. 3 The Institute of Social and Economic Change, (2014).

centres and laboratories related to medical procedures. In addition, it includes the same types of waste originating from minor and scattered sources, including waste produced in the course of health care undertaken in the home (e.g. home dialysis, self-administration of insulin, recuperative care).

According to D. A. Baldwin, Bio-Medical waste can be defined as "infectious waste, which is hazardous, as it is contaminated with disease causing pathogens. The human and animal wastes along with items saturated or dripping with, blood and body fluids, discarded medical equipments, soiled cotton, plasters and dressing, surgical and autopsy wastes, can all become a major health hazard, as they provide fertile environs for bacteria, virus and other micro-organisms to multiply."[10]

As per WHO, bio-medical waste "includes all the waste generated by health-care establishments, research facilities and laboratories. In addition, it includes the waste originating from "minor" or "scattered" sources-such as that produced in the course of health care undertaken in the home (dialysis, insulin injections, etc.)."[11]

In this context it is pertinent to mention the definition of bio-medical waste under the Indian Bio-Medical Waste Management Rules, 2016. Rule 3 (f) says, "bio-medical waste" means any waste, which is generated during the diagnosis, treatment or immunisation of human beings or animals or research activities pertaining thereto or in the production or testing of biological or in health camps, including the categories mentioned in Schedule I appended to these rules[12].

In United Kingdom bio-medical waste which is termed as clinical waste is defined in regulation 1(2) of The Controlled Waste Regulations 1992 (SI1992/588) of United Kingdom as follows:

1. any waste which consists wholly or partly of human or animal tissue, blood, other body fluids, excretion, drugs or other pharmaceutical products, swabs or

[10] Dr. Sushma Sahai, *Bio-Medical Waste Management* pg. 67 (A.P.H. Publishing Corporation, 1st Edn., 2009).
[11] *Ibid*.
[12] Government of India, Notification, Ministry of Environment, Forest and Climate Change, New Delhi, (March 28, 2016).

dressings, or syringes, needles or other sharp instruments, being waste which unless rendered safe may prove hazardous to any person coming into contact with it, and

2. any other waste arising from medical, nursing, dental, veterinary, pharmaceutical or similar practice, investigation treatment, care, teaching or research, or the collection of blood for transfusion, being waste which may cause infection to any person coming into contact with it[13].

2.2 Classification of Bio-Medical Waste

An extremely important aspect of managing the bio-medical waste is its classification. The classification is essential in order to adopt and follow the entire management process so that risk factor could possibly be avoided. It depends on type of waste and how it has to be treated and disposed of. As discussed above that majority of bio-medical wastes are non-hazardous and only a small amount of such wastes are hazardous. Although in small quantity of varying types, such hazardous wastes are regarded as most dangerous and harmful. Let us discuss various hazardous bio-medical wastes which are required to be identified for its proper management.

2.2.1 Hazardous Waste

Hazardous waste is an unwanted material and a specific class of refuse in the form of solid, liquid or gaseous if emitted to the nature can cause potential danger to living beings and the environment. It is explosive, flammable, oxidising, poisonous, radioactive, corrosive or toxic. The following are the different types of hazardous wastes:

2.2.1.1 Infectious Waste

Infectious waste is material suspected to contain pathogens (bacteria, viruses, parasites or fungi) in sufficient concentration or quantity to cause disease in susceptible hosts[14]. This category includes:

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[13] R. Chandrappa and D. B. Das, "Solid Waste Management" Environmental Science and Engineering pg. 148 (Springer-Verlag Berlin Heidelberg 2012).

[14] Dr. Sushma Sahai, *Bio-Medical Waste Management* pg. 69 (A.P.H. Publishing Corporation, 1st Edn., 2009).

a. Waste contaminated with blood or other body fluids

This includes free-flowing blood, blood components and other body fluids; dressings, bandages, swabs, gloves, masks, gowns, drapes and other material contaminated with blood or other body fluids; and waste that has been in contact with the blood of patients undergoing haemodialysis (e.g. dialysis equipment such as tubing and filters, disposable towels, gowns, aprons, gloves and laboratory coats).

b. Cultures and stocks of infectious agents from laboratory work

Laboratory cultures and stocks are highly infectious waste. Waste from autopsies, animal bodies, and other waste items that have been inoculated, infected, or in contact with highly infectious agents are highly infectious waste. Discarded instruments or materials that have been in contact with persons or animals infected with highly infectious agents are also to be considered infectious waste.

c. Waste from infected patients in isolation wards

Such waste includes excreta, dressings from infected or surgical wounds, and clothes heavily soiled with human blood or other body fluids. Waste from non-infective patients and that is not contaminated with blood or body fluids may be considered non-infectious.

2.2.1.2 Sharp Waste

Sharps are items that could cause cuts or puncture wounds, including needles, hypodermic needles, scalpels and other blades, knives, infusion sets, saws, broken glass and nails. Whether or not they are infected, such items are usually considered highly hazardous health-care waste and should be treated as if they were potentially infected[15].

2.2.1.3 Pathological Waste

Pathological waste could be considered a subcategory of infectious waste, but is often classified separately – especially when special methods of handling, treatment

[15] *Ibid* at pg. 72.

and disposal are used. Pathological waste consists of tissues, organs, body parts, blood, body fluids and other waste from surgery and autopsies on patients with infectious diseases. It also includes human fetuses and infected animal carcasses. Recognisable human or animal body parts are sometimes called anatomical waste. Pathological waste may include healthy body parts that have been removed during a medical procedure or produced during medical research[16].

2.2.1.4 Pharmaceutical waste, including Genotoxic Waste

Pharmaceutical waste includes expired, unused, spilt and contaminated pharmaceutical products, prescribed and proprietary drugs, vaccines and sera that are no longer required. The category also includes discarded items heavily contaminated during the handling of pharmaceuticals, such as bottles, vials and boxes containing pharmaceutical residues, gloves, masks and connecting tubing.

Genotoxic waste is highly hazardous and may have mutagenic (capable of inducing a genetic mutation), teratogenic (capable of causing defects in an embryo or fetus) or carcinogenic (cancer-causing) properties. Genotoxic waste may include certain cytostatic drugs, vomit, urine or faeces from patients treated with cytostatic drugs, chemicals and radioactive material[17].

2.2.1.5 Chemical waste

Chemical waste consists of discarded solid, liquid and gaseous chemicals, i.e. those generated from diagnostic and experimental work and from cleaning, housekeeping and disinfecting procedures. Chemical waste from health care is considered to be hazardous if it has at least one of the following properties.

- Toxic (harmful)
- Corrosive (e.g. acids of pH 12)
- Flammable
- Reactive (explosive, water reactive, shock sensitive)

[16] Anantpreet Singh and Sukhjit Kaur, *Biomedical Waste Disposal* pg. 5 (Jaypee Brothers Medical Publishers (p) Ltd.1st Edn., 2012).
[17] *Ibid* at pg. 6.

• Oxidizing[18].

Non-hazardous chemical waste consists of chemicals with none of the above properties; for example, sugars, amino acids and certain organic and inorganic salts, which are widely used in transfusion liquids[19].

2.2.1.6 Radioactive Waste

Radioactive wastes are materials contaminated with radionuclides. They may take solid, liquid and gaseous all three forms. They are produced as a result of procedures such as in vitro analysis of body tissue and fluid, in vivo organ imaging and tumour localisation, and various investigative and therapeutic practices[20]. The waste produced by health-care and research activities involving radionuclides and related equipment maintenance and storage can be classified as sealed sources, spent radionuclide generators, low-level solid waste (e.g. absorbent paper, swabs, glassware, syringes, vials), residues from shipments of radioactive material and unwanted solutions of radionuclides intended for diagnostic or therapeutic use etc[21].

2.2.2 Non-hazardous General Waste

Non-hazardous or general waste is waste that has not been in contact with infectious agents, hazardous chemicals or radioactive substances and does not pose a sharps hazard. A significant proportion (about 85%) of all waste from health-care facilities is non-hazardous waste and is usually similar in characteristics to municipal solid waste. More than half of all non-hazardous waste from hospitals is paper, cardboard and plastics, while the rest comprises discarded food, metal, glass, textiles, plastics, wood etc[22].

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[18] Dr. Sushma Sahai, *Bio-Medical Waste Management* pg. 72 (A.P.H. Publishing Corporation, 1st Edn., 2009).
[19] Anantpreet Singh and Sukhjit Kaur, *Biomedical Waste Disposal* pg.8 (Jaypee Brothers Medical Publishers (p) Ltd.1st Edn., 2012).
[20] Dr. Sushma Sahai, *Bio-Medical Waste Management* pg. 76 (A.P.H. Publishing Corporation, 1st Edn., 2009).
[21] Anantpreet Singh and Sukhjit Kaur, *Biomedical Waste Disposal* pg. 8 (Jaypee Brothers Medical Publishers (p) Ltd.1st Edn., 2012).
[22] Yves Chartier, Jorge Emmanuel, *et. al.*, "Safe management of wastes from health-care activities" pg. 8 (WHO Press, World Health Organisation, 2nd Edn., 2014).

2.3 Sources of Bio-Medical Wastes

Knowing the types and quantity of waste produced in a health care institution is an important step and it is pertinent to identify different sources which produce such waste. It may be noted here that the health care institutions are not the only producer of bio-medical waste; there are other institutions of significant concern (referred below under the minor sources) that also generate waste. Detail knowledge with regard to the types and quantity would help the authority preparing the appropriate data on the basis of which estimate of required containers, storage areas, transportation and treatment technologies can be made. Waste-generation data can be used to establish baseline data on rates of production in different medical areas and for procurement specifications, planning, budgeting, calculating revenues from recycling, optimisation of waste-management systems and environmental impact assessments. Therefore, an important step towards the management of this waste is to identify its sources and for the same it can be categorised as major or minor sources according to the quantities produced. While minor and scattered sources may produce some health-care waste in categories similar to hospital waste, their composition will be different. The sources of bio-medical waste are as follows:

2.3.1 Major Sources

- Government hospitals/private hospitals/nursing homes/dispensaries.
- Primary health Centers.
- Medical Colleges and research centers/paramedic services.
- Veterinary colleges and animal research centers.
- Blood banks/mortuaries/autopsy centers.
- Biotechnology institutions.
- Production units.

Apart from the above sources, there are blood banks, autopsy centers etc. which also produces particular types of wastes. There are various wards in the health care centers that give rise to different types of wastes. For example, infectious waste such as dressings, bandages, used hypodermic needles, intravenous sets, gloves, disposable medical items, sticking plaster, body fluids

and excreta are generated in every medical wards. Anatomical waste, such as tissues, organs, body parts including fetuses can be found in operation theaters and surgical wards. Besides, there are immunisation wards which produce hypodermic needles and syringes, residual vaccine, cotton swabs and ampoules, etc. In laboratories, mainly pathological and highly infectious waste e.g. small pieces of tissue, infected animal carcasses, micro-biological cultures, stocks of infectious agents, blood and other body fluids plus sharps, some radioactive and chemical waste are generated. The list also included research centers, production units etc. which also generate huge quantity of bio-medical waste consisting of animal tissues, organs, body parts, carcasses, body fluids, blood of experimental animals. Microbiological and bio-technological wastes are also generated in these institutions.

2.3.2 Minor Sources

- Physicians/ dentists' clinics
- Animal houses/slaughter houses.
- Blood donation camps.
- Vaccination centers.
- Acupuncturists/psychiatric clinics/cosmetic piercing.
- Funeral services.
- Institutions for disabled persons.

Nowadays there are large numbers of clinics that are in existence to deal with particular species of health problem. In addition to this the invention of new medical treatment technology and the raising concern in health awareness demanded the setting up of many vaccination centers, blood donation camps and in turn they also produces different types of bio-medical waste. The generation of bio-medical waste from such sources varies in composition and quantities. The above mentioned minor sources typically have some common features:

- They rarely produce radioactive or cytostatic waste.

- Human body parts are not normally produced.

- The quantity of chemical waste is very low.
- Sharps consist mainly of hypodermic needles[23].

Majority of bio-medical waste generated from such minor sources are infectious and sharps wastes. Although the quantity of waste is low but due to its infectious nature the risk factor involved in it cannot be avoided.

2.4 Health Impact from Hazardous Bio-Medical Waste

It is now clear that bio-medical waste includes a large component of general waste and a smaller proportion of hazardous waste. Although less in number, such waste is the cause of concern not only from the environmental point of view in general, it also has an ill effect to the health of people involved in it such as doctors, nurses, hospital maintenance personnel, patients, visitors, workers including those workers involve in waste disposal. The exposure of such wastes is the result of various diseases as referred in Table 2.

Table 2[24]

Different disease relating to Bio-medical waste

Organism	**Disease Caused**	**Related Waste Items**
VIRUSES HIV, Hepatitis B, Hepatitis A,C, Arboviruses, Enteroviruses.	AIDS, infectious Hepatitis, Dengue,Japanese encephalitis, tick-borne fevers, etc., dysentery.	Infected needles, body fluids, human excreta, soiled linen, blood.
Bacteria Shigella spp., salmonella typhi,vibrio cholera, clostridium tetani, staphylococcus spp., pseudomonas, streptococcus, borrelia spp.	Shigellosis, typhoid, cholera, tetanus, wound infections, septicemia, rheumatic fever, endocarditis, skin and soft tissue infections, louse and tick borne fevers.	Human excreta and body fluid in landfills and hospital wards, sharps such as needles, surgical blades in hospital waste, rodent infestations of poorly managed landfills and dumping grounds.
Parasites such as giardia	Giardiasis, cutaneous	Human excreta, blood and

[23] Yves Chartier, Jorge Emmanuel, *et. al.*, "Safe management of wastes from health-care activities" pg.10 (WHO Press, World Health Organisation, 2nd Edn., 2014).
[24] Dr. Saurabh Sikka, "Bio-Medical Waste in Indian Context" *Available at*: http://www.academia.edu/4913465/BIOMEDICAL_WASTE_IN_INDIAN_CONTEXT (Last visited on Sept. 22, 2016).

lamblia,wucheraria bancrofti, plasmodium.	leishmaniasis, kala azar, malaria.	body fluids in poorly managed sewage system of hospitals.

Many of the hazards associated with biomedical wastes are hidden. Injuries are not an immediate effect from such hazards but they can accumulate or remain latent in the body for years resulted into hepatitis B, C and cancer. Therefore, all unknown substances are suspected to be considered hazardous. There are several reasons which make some of the bio-medical waste hazardous and they are the existence of infectious agents, genotoxic, contained hazardous chemicals, sharps, radioactive etc.

Let us discuss in detail the potential hazards due to the exposure of bio-medical waste on the environment and also on the people who are directly or indirectly connected with such waste and are prone to various dangerous diseases.

2.4.1 Hazards to the Environment

Poor handling of biomedical waste causes serious environmental problems in terms of air, water and land pollution. Nature of pollutants that can be classified into biological, chemical and radioactive contributed to air, water and land pollution. Air pollution can be cause in both indoors and outdoors. Indoor air pollutants like pathogens present in the waste can enter and remain in the air in the health care centers for a long period in the form of spores or as pathogens itself. This can result in hospital acquired infections (nosocomial) spread through various viruses causing diseases like AIDS, Hepatitis B & C etc. or occupational health hazards. These viruses are generally transmitted through injuries from sharps contaminated with human blood. If such wastes are disposed of in the open places without proper treatment, alongwith the general public the environment also gets polluted. Dust may harbor tubercle bacilli and other germs, which cause diseases if inhaled. However, indoor air pollution can also be caused due to poor ventilation, use of chemicals for disinfections, fumigants etc. resulted in acidic reaction and produces hazardous gases.

The outdoor pollution can also be cause by pathogens. When waste without pre treatment is being transported outside the health care centre, or if it is dumped

openly, pathogens can enter into the atmosphere. The most important are biological agents, which pollute water and food and cases alimentary infections like cholera, typhoid, dysentery, infective hepatitis, polio, ascariasis and hook worm diseases etc[25].

Most of the chemicals and pharmaceuticals used in health-care establishments are hazardous e.g. toxic, genotoxic, corrosive, flammable, reactive, explosive, shock-sensitive. Their intoxication can occur either by acute or by chronic exposure. Exposure to genotoxic substances in healthcare occurs during the preparation of particular drug/chemicals, treatment with particular drugs or chemicals and handling and disposal[26].Chemical pollutants that cause outdoor air pollution have two major sources-open burning and incinerators. Open burning of such waste is most harmful and dangerous. The presence of plastics and hazardous materials in the waste will generate harmful gases such as oxides of sulphur, oxides of nitrogen, carbon dioxide and suspended particulate matter. These when inhaled can cause respiratory diseases. Certain organic gases such as dioxins and furan are carcinogenic in nature.

Radioactive emissions and radioactive wastes through research and radio-immunisation activities may produce small quantities of radioactive gas. The type and extent of exposure determines the type of disease caused by radioactive waste that range from minor symptoms to more serious problems. Gaseous radioactive material should be evacuated directly to the outside by a special exhaust system or an activated carbon trapping device may be used. In its liquid form radioactive waste can come from chemical or biological research, from body organ imaging, from decontamination of radioactive spills, from patient urine and from scintillation liquids used in radioimmunoassay. Undoubtedly, this last source of liquid waste produces the largest volume of liquid radioactive waste. Indiscriminate disposal of radioactive waste in general waste stream may create some serious and life-threatening situation. One such accidental exposure to high activity radioactive waste in New Delhi in April 2010 left five persons critically ill[27].

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[25] *Ibid.*

[26] Anantpreet Singh and Sukhjit Kaur, *Biomedical Waste Disposal* pg.29 (Jaypee Brothers Medical Publishers (p) Ltd.1st Edn., 2012)..

[27] A. Tandon, "Cobalt-60 imported as industrial Waste?" *The Tribune*, April 12, 2010.

Water pollution is another major threat from bio-medical waste. If the waste is dumped in low-lying areas, or into lakes and water bodies, can cause severe water pollution. Besides the presence of biologicals, chemicals or radioactive substances in water cannot be ignored. The pathogens present in the waste can leach out and contaminate the ground water or surface water. Harmful chemicals present in such waste also cause water pollution. Poor land filling technology may cause water pollution in the form of leachates. Water pollution can alter parameters like pH, BOD, DO, COD, etc. There are instances where dioxins are reported from water bodies near incinerator plants. Dioxins enter the water body from the air[28].

Land pollution is caused by the final disposal of all bio-medical waste. Even liquid effluent after treatment is spread on land. Hence, pollution caused to land is inevitable. Open dumping of the waste is greatest cause for land pollution. Land filling is also harmful to a limited extent. Soil pollution from such 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 get absorbed by plants and can then enter the food chain. Nitrates and phosphates present in leachates from landfills are also pollutants. Leachate containing concentrated heavy metals and or microbes which released from landfills can lead to ground and surface water pollution[29].

Radioactive waste generated can cause soil pollution. Cadavers, protective clothing, absorbent paper generated in the nuclear medicine imaging laboratory also cause soil pollution. Last but not the least breed vermin and pests from bio-medical waste also cause pollution. Mosquitoes that transmit insect borne diseases like malaria and filarial, common houseflies which transmit infections mechanically are some examples in this regard. Soil may be rich in tetanus spores or the blood borne pathogens have gained significant attention after the attack of HIV and HBV, HCV which can lead to AIDS and Hepatitis B, C and other viral and bacterial infections[30].

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[28] Anantpreet Singh and Sukhjit Kaur, *Biomedical Waste Disposal* pg. 31 (Jaypee Brothers Medical Publishers (p) Ltd.1st Edn., 2012).
[29] *Ibid*.
[30] *Ibid* at pg. 8.

2.4.2 Hazards to Persons

All individuals coming into close proximity with hazardous bio-medical waste are potentially at risk from exposure to a hazard specially the patients. Their attendants also have a chance of contracting infections causes due to pathogens or spores which are air borne. The list is not small; it also includes those attached to the health-care facilities who produce hazardous waste, and those who either handle such waste or are exposed to it as a consequence of careless actions. Besides, as already mentioned above the other groups consisted are doctors, nurses, health-care auxiliaries and hospital maintenance personnel etc. Let us see how people are getting affected from different types of bio-medical wastes that give rise to different diseases.

2.4.2.1 From Infectious Waste

Regarding infectious waste, three infections are most commonly transmitted: Hepatitis B Virus (HBV), Hepatitis C Virus (HCV), and Human Immune Deficiency Virus (HIV). Among the 35 million health care workers worldwide, the estimations show that each year about 3 million receive hard exposures to blood-borne pathogens, 2 million of those to HBV, 0.9 million to HCV, and 170,000 to HIV. Also, the workers involved in the collection and treatment of the biomedical waste are exposed to a certain risk[31]. Apart from the diseases referred above the Table 3 below provides an extensive information relating to other diseases also that might be caused by exposure to bio-medical waste are listed in Table 3[32].

Table 3

Potential infections caused by exposure to bio-medical wastes, causative organisms and transmission vehicles

Infection Type	Pathogen Agents	Transmission Path
Gastrointestinal infections	Enterobacteria: Salmon ell, Shigella spp., Vibrio Cholerae, Helminths	Faeces or/and vomiting liquid
Respiratory infections	Mycobacterium	Respiratory secretions,

[31] Nikos E. Mastorakis, Carmen A. Bulucea, *et. al*., "Environmental and health risks associated with biomedical waste management" pg. 287 Development, Energy, Environment, Economics (2010).
[32] Yves Chartier, Jorge Emmanuel, *et. al.*, "Safe management of wastes from health-care activities" pg. 27 (WHO Press, World Health Organisation, 2nd Edn., 2014).

	tuberculosis Measles virus Streptococcus pneumonae	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
Viral Hepatitis type B and C	VHB, VHC	Blood, biological fluids

The infectious waste is likely to be contained in a variety of pathogenic microorganisms. The microorganisms from pathogens enter into the human body through a puncture, abrasion or cut in the skin, by inhalation, through mucous membranes etc.

2.4.2.2 From Chemical and Pharmaceutical Waste

The risk involved in the chemical and pharmaceutical wastes are due to the following factors: toxic, genotoxic, corrosive, flammable, explosive, teratogenic, mutagenic and this can be infused into the body through drug administered intra venous, breakage of containers, partially used vials, expired medicines etc.

Larger amounts of such biomedical waste occur when unwanted or expired chemical and pharmaceutical products are removed. These can cause poisoning by absorption through the skin or mucous membranes, by inhalation or by ingestion. Chemicals and pharmaceuticals may also determine lesions of skin, eye, and respiratory mucosa. The most common injuries are the burns. Chemical waste removed by drainage system may have toxic effects on ecosystems and water where are discharged. Similar effects may have the pharmaceuticals which contain antibiotics or other drugs, heavy metals, disinfectants and antiseptics[33].

[33] Nikos E. Mastorakis, Carmen A. Bulucea, *et. al*., "Environmental and health risks associated with biomedical waste management" pg. 288 Development, Energy, Environment, Economics (2010).

2.4.2.3 From Genotoxic and Cytotoxic Waste

Exposure to genotoxic substances in health care may occur during the preparation of, or treatment with, particular drugs or chemicals. The main pathways of exposure are inhalation of dust or aerosols, absorption through the skin, ingestion of food accidentally contaminated with cytotoxic drugs, ingestion as a result of bad practice, such as mouth pipetting, or from waste items. Exposure may also occur through contact with body fluids and secretions of patients undergoing chemotherapy[34]. Cytotoxic drugs such as alkylating agents, intercalating agents etc. are extreme irritants and have harmful local effects after direct contact with skin or eyes. Cytotoxic drugs may also cause dizziness, nausea, headache or dermatitis.

2.4.2.4 From Radioactive Waste

The nature of illness caused by radioactive waste is determined by the type and extent of exposure. It can range from headache, dizziness and vomiting to much more serious problems. Radioactive waste is genotoxic, and a sufficiently high radiation dose may also affect genetic material. Handling highly active sources, such as those used in diagnostic instruments (e.g. gallium sealed sources) may cause much more severe injuries, including tissue destruction, necessitating the amputation of body parts. Extreme cases can be fatal. The hazards of low-activity radioactive waste may arise from contamination of external surfaces of containers or improper mode or duration of waste storage. Health-care workers, and waste-handling and cleaning personnel exposed to radioactivity are most at risk[35].

2.5 Need for the Regulatory Measures for the Effective Management of Bio-Medical Waste

In the light of the above perspective, it is important to have effective bio-medical waste management system which in turn would help in the reduction of the same and thereby the risk factors involved in it could be avoided. For this purpose the need is to have effective regulatory measures which include framing of policies, proper guidelines and laws. Along with the effective policy framework and technical

[34] Yves Chartier, Jorge Emmanuel, *et. al.*, "Safe management of wastes from health-care activities" pg.29 (WHO Press, World Health Organisation, 2nd Edn., 2014).
[35] *Ibid* at pg. 30.

guidelines, national legislation is considered as the most important basis for improving bio-medical waste practices in any country. The national policy should take into account the resources and facilities available in the country concerned and any cultural aspects of waste handling. It establishes legal controls and permits the national agency responsible for the disposal of such waste. This will help in the treatment of different waste categories by following specific step like segregation, collection, storage, handling, disposal and transport of waste and responsibilities and training requirements. It is noteworthy that while preparing the guiding principle five principles which have been widely recognised as underlying the effective and controlled management of wastes should be borne in mind. These principles have been used by many countries when developing their policies, legislation and guidance. They are[36]:

- **Polluter pays principle**- implies that all producers of waste are legally and financially responsible for the safe and environmentally sound disposal of the waste they produce.

- **Precautionary principle**- is a persuasive principle governing health and safety protection.

- **Duty of care principle**- stipulates that any person handling or managing hazardous substances or wastes or related equipment is ethically responsible for using the utmost care in that task.

- **Proximity principle**- recommends that treatment and disposal of hazardous waste take place at the closest possible location to its source to minimise the risks involved in its transport and

- **Prior informed consent principle**- It requires that affected communities and other stakeholders be apprised of the hazards and risks, and that their consent be obtained.

[36] *Ibid* at pg. 42.

It is to be mentioned here that the Central Government of India in exercise of the powers conferred by Sections 6, 8 and 25 of the Environment Protection Act, 1986, in 1998 has notified a specific Rule on the subject namely, the Bio-medical Waste (Management and Handling) Rules, 1998 which have been amended thrice in the year 2000, 2003 and 2011 and recently a new rule has been notified viz. the Bio-medical Waste Management Rules, 2016. The Rule 1998 along with its amendments and the new Rule have been discussed in the subsequent chapter in detail.

The need for a comprehensive specific law on the subject lies in the fact that it will not only help in the proper management of the Bio-Medical Waste efficiently, it also reduces the chance of the risk involved in it gradually. To attain the goal of minimising the risk factor such law would also consist of provisions based on recovery, reuse and recycling policy and also provisions in connection with the segregation, labeling and disposal of the remaining waste in a scientific way by adopting advance technology for the same. Further, there must be established an authority under the law whose task would be to look into whether such laws are being effectively implemented or not. The inclusion of the provisions in connection with the waste reduction would help in the proper management of the same. Therefore, it is important to have a detail idea as discussed below:

2.5.1 Source Reduction: Recovery, Reuse and Recycling [37]

In order to minimise the risk the law should consists of provisions relating to three "R's" i.e. reduce, reuse and recycle (See Figure1) as far as possible which is consider as an important measure in the process of reducing such waste which has some advantages behind it. This is the most important steps towards reduction of bio-medical waste from sources. A comprehensive waste reduction principle from the source must be adopted in every health care institution to reduce the waste to minimum. This would help in managing the waste properly and effectively. This can be possible through product substitution, technology change and good operating practices. An effective step for the reduction of the waste at source is to focus on the potential replacement of medical and surgical supplies with reusable supplies.

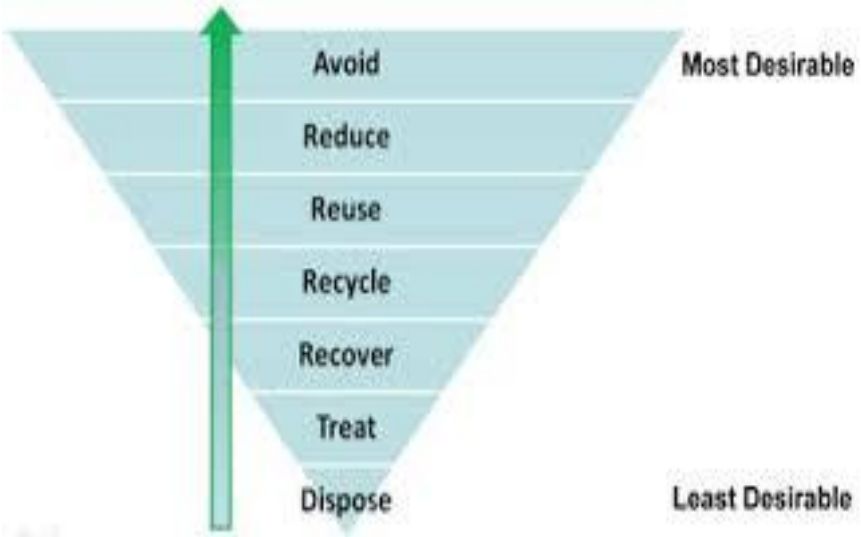
[37] *Ibid.*

Reusable items may include certain sharps, such as scalpels and hypodermic needles, syringes, glass bottles and containers, etc. Along with the reusable products consideration should be given to the costs associated with product disposal which would help in minimising the amount of packaging associated with the product.

Recycling is usually not practised in health care institutions. However, recycling of materials such as metals, paper, glass, and plastics can result in saving the cost.

Figure 1:

The desirable figure of accepting three "R's"



The concept of reducing what is produced and what is consumed is essential to the waste hierarchy. The logic behind it is simple to understand – if there is less waste, then there is less to recycle or reuse. The process of reducing begins with an examination of what you are using, and what it is used for. The last stage of the waste hierarchy is to recycle. To recycle something means that it will be transformed again into a raw material that can be shaped into a new item. There are very few materials on the earth that cannot be recycled. Product recycling and reuse can minimise the volume of costly waste disposal streams. Health care institutions should critically examine current waste streams and determine what products can be separated out at the point of generation to be effectively recycled, e.g. glass, plastics, aluminium cans, paper and cardboard, ferrous and non-ferrous metals. The most preferred action is

avoidance or deduction of waste generation, placed at the top of pyramid (see the Table). Reuse and recycle will further decrease the amount of waste generated, making treatment and final disposal of waste manageable. Reuse may involve a combination or all of the following steps: cleaning, decontamination, reconditioning, disinfection and sterilisation. After use, these should be collected separately from non-reusable items, carefully washed and may then be sterilised.

2.5.2 Advantages of Waste Reduction[38]

Waste minimisation usually benefits the waste producer e.g.

- Reduced the volume and toxicity of unavoidable waste.
- Improved transportation, storage, treatment and disposal of waste.
- Proper containment of hazardous materials.
- Prompt removal of hazardous materials from the workplace.
- Liabilities associated with the disposal of such waste are lessened.
- Long-term economic benefit.

2.5.3 Waste Collection and Segregation

One of the important steps in the entire process of bio-medical waste management is the collection and segregation of it. In fact, proper collection and segregation would help in reducing the chance of spreading the infection. Therefore, special attention is to be given to the relatively small quantities of infectious and hazardous waste, which will also help in reducing the cost of handling, treatment and disposal. For example, if general waste gets mixed with infectious waste, the whole waste has to be incinerated which may prove to be costly. Waste should be collected and segregated at the site of generation itself. Segregation is the "separation of different types of wastes by sorting or the systematic separation of biomedical waste

[38] Anantpreet Singh and Sukhjit Kaur, *Biomedical Waste Disposal* pg. 38 (Jaypee Brothers Medical Publishers (p) Ltd.1st Edn., 2012).

into designated categories."[39] This stage is the key to the whole management process, because it is at this stage that wastes are segregated as hazardous and non-hazardous, thus minimising the risks to staff and public as well as resources used for the treatment purpose. The underlying principles in any waste segregation program are[40]:

- To reduce the volume of hazardous waste destined for special treatment or expensive off-site disposal.
- To maintain safety standards during handling, transportation and treatment.
- To eliminate the need for waste segregation to occur at disposal sites.
- To facilitate the recycling process.

2.5.4 Sharp Management

While involving in the task of segregation proper care must be taken in the management of sharp. Sharp can be defined as objects that are capable of puncturing and cutting due to any points or proturbences and includes syringes, needled, scalpels, blades, pasteur pipettes and broken glass or plastic. Sharps needs special attention while segregating and storing because needles can act as a reservoirs of pathogens in which the pathogens may survive for a long time because of the presence of blood and also that the sharps can provide a direct route into the bloodstream by puncturing the skin. In fact, 98% of the health facilities generate sharp waste[41]. Sharps whether contaminated or not, should be collected together in puncture proof covered containers usually made of metal or high density plastic. Dense cardboard can also be used at places where metal or high density plastic is costly or unavailable. Containers should be rigid and impermeable so that they can retain any residual liquid from the syringes along with the sharps. Needles and syringes should be rendered unusable and containers should be temper proof in order to discourage abuse.

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[39] *Ibid* at pg. 42.
[40] Vijay P. Singh and Ramnarayan Yadava (Eds.), *Wastewater Treatment and Waste Management* pg. 365 (Allied Publishers Pvt. Ltd., New Delhi, 2003)
[41] George Nwabuko Chima, I. Clinton Ezekwe, *et. al*., "An Assesssment of Medical Waste Management in Health Institutions in Yenagoa, South-South, Nigeria" pg. 8 World Review of Science, Technology and Sustainable Development (2011).

2.5.5 Waste Containers

The key principle of successful and safe waste containers is correct source separation/segregation. Strong containers should be used, preferably lined with tie-off plastic bags and handled mechanically. When using rigid, non-lined plastic containers, they must be mechanically discharged, and when cleaning, care should be taken to avoid spraying of the same from exposure. All waste containers/bags must be colour-coded. Colour coding makes it easier for medical staff and hospital workers to put waste items into the correct container, and to maintain segregation of the wastes during transport, storage, treatment and disposal. Colour coding also provides a visual indication of the potential risk posed by the waste in that container.

Table 4

WHO-recommended segregation scheme[42]

Type of waste	**Colour of container and markings**	**Type of container**
Highly infectious waste	Yellow, marked "HIGHLY INFECTIOUS" with biohazard symbol	Strong, leak-proof plastic bag or container capable of being autoclaved
Other infectious waste, pathological and anatomical waste	Yellow with biohazard symbol	Leak-proof plastic bag or container
Sharps	Yellow, marked "SHARPS", with biohazard symbol	Puncture-proof container
Chemical and pharmaceutical waste	Brown, labeled with appropriate hazard symbol	Plastic bag or rigid container
Radioactive waste	Labelled with radiation symbol	Lead box
General health-care waste	Black	Plastic bag

[42] Yves Chartier, Jorge Emmanuel, *et. al., Safe management of wastes from health-care activities* pg. 79 (WHO Press, World Health Organisation, 2nd Edn., 2014).

2.5.6 Labelling

Labelling is essential in the correct identification and safe management of medical waste. It makes easy to understand the different categories of wastes. By way of raising awareness the health care personnel would be in a position to identify the type of waste contained in the bag or container which is to be made prior to the collection of biomedical waste. It would be better if bags and bins provided are already labeled with the appropriate hazard symbols e.g. biohazard, cytotoxic hazard symbols etc. This will help in waste audit conducted at treatment and disposal site to identify those areas that are in compliance or non-compliance with the required hospital waste management practices. Biohazard includes medical waste or samples of a microorganism, virus or toxin and also substance which are harmful to other animals. Cytotoxic waste typically includes all drug administrative equipment (eg. needles, syringes, dripsets etc.) as well as all gowns and body fluids/waste from patients undergoing such treatment. Examples of radioactive waste arising from clinical, medical and biological research activities are contaminated materials and syringes generated from nuclear medicine procedures, unused radioactive seeds from implants in radiation oncology as well as sealed sources used for calibration purposes, which are no longer useful.

Therefore, before treatment and disposal of biomedical wastes under various categories, the most important and vital task that should be borne in mind, is the segregation process. This process is so important that any negligent act at the segregation stage may result in spread of infections causing different diseases which is not curable in nature. Regarding infectious or hazardous wastes special attention must be given. It is also essential that a person must be appointed who will be responsible for the potentially infectious waste segregation programme. The institution that generates bio–medical waste should adopt universal precautions and appropriate safety measures while doing therapeutic and diagnostic activities and also while handling the bio-medical waste.

Different symbols/labelling on the containers/bags

Figure 2

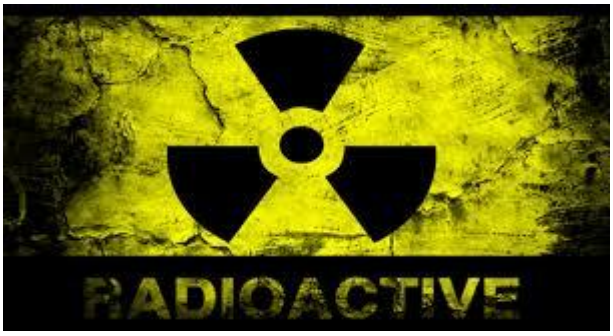
1. **Symbols for Biohazard and Cytotoxic Hazards**

HANDLE WITH CARE

CYTOTOXIC HAZARDSYMBOL

HANDLE WITH CARE

2. **Symbol for Radioactive Waste**



2.5.7 Storage

Storage of biomedical waste is necessary at two places[43]:

- The place where waste is generated,
- Common storage area for total waste of an organisation.

While storing each waste must be put into the appropriate coloured bags. When the bag or the container is sealed for transportation/treatment appropriate label should be provided on it. Label must contain "biohazard" symbol, name of department/ward where waste is generated. It should also contain details of both

[43] National Institute of Industrial Research Consultant & Engineers, *Medical, Municipal and Plastic Waste Management Handbook* pg. 83 (NIIR, Delhi).

sender and receiver over it along with the details of person who can be contacted in case of emergency. Staff should ensure that waste bags are tightly closed or sealed when they are three-quarters full. Bags should not be closed by stapling. Sharp should be placed inside labelled yellow infectious health care waste bag before it is mobilised from the hospital area. A designated area inside the health care institute should be used as central storage facility. However, the hospital waste may need to be stored if immediate treatment and disposal cannot be done. These wastes should be refrigerated at a temperature preferably no higher than 3 ºC to 8 ºC if stored for more than week[44] on-site to prevent rolling and offensive smell, needless to say that the duration of storage for refrigerated or frozen biomedical waste varies according to storage capacity, rate of waste generation and any other applicable local regulatory requirements. Waste may be stored off site before treatment and final disposal. Such area need to be notified by the government authority. All storage sites must be concrete and should be designed to allow wash out with the help of water. In doing so the following caution must be borne in mind:

- Infected glass or plastic items may fracture at lower temperatures.
- Untreated infectious waste or waste with a high content of blood or other body fluids destined for off-site disposal (for which there is a risk of spilling) should never be compacted to decrease its volume.
- Cytotoxic waste should be kept in a specific secure location separate from other healthcare waste.
- Radioactive waste should be stored in lead containers to prevent dispersion. Waste that is to be stored till its radioactivity decay completes, should be labeled with the type of radionuclide, date and detailed data of required storage conditions.
- The decay storage time for radioactive waste should be until the radioactivity is substantially reduced and the waste can be safely disposed of as normal waste. A minimum storage time of 10 half-

[44] Prerna Thareja, Brijendra Singh, *et. al.* "Biomedical Waste Management: Need for Human Civilisation" Vol. 2 Indian Journal of Clinical Anatomy and Physiology pg. 71 (April –June 2015).

life times for radioisotopes in wastes with a half-life of less than 90 days is a common practice[45].

It is to be noted that the World Health Organisation (WHO) has recommended for the central storage facility with the criteria as referred in Table the below:

WHO's recommendation for Central storage facility for health care waste[46]

1. The storage area should have an impermeable, hard-standing floor with good drainage, it should be easy to clean and disinfect.
2. There should be a water supply for cleaning purposes.
3. The storage area should afford easy access for staff in charge of handling the waste.
4. It should be possible to lock the store to prevent access by unauthorized persons.
5. Easy access for waste collection vehicles is essential.
6. There should be protection from the sun.
7. The storage area should be inaccessible for animals, insects and birds.
8. There should be good lighting and at least passive ventilation.
9. The storage area should not be situated in the proximity of fresh food stores or food preparation areas.
10. A supply of cleaning equipment, protective clothing and waste bags or containers should be located conveniently close to the storage area.
11. Floors, walls and ceiling of storage area must be kept clean in accordance to established procedures at least once per week.
12. Should have spillage containment equipment.

2.5.8 Transportation

Wastes are to be collected and deposited from clearly sign posted and designated collection points in hospital wards with the help of specially designed vehicle. Where open trolleys are used to collect containers or bags of waste from bin,

[45] Yves Chartier, Jorge Emmanuel, *et. al., Safe management of wastes from health-care activities* pg. 71 (WHO Press, World Health Organisation, 2nd Edn., 2014).
[46] *Ibid* at pg. 89.

each bin and trolley must be thoroughly cleaned and disinfected with a hypochlorite solution at least once a week. The appropriate authority shall evolve a protocol of safe transportation of such wastes taking into account various local factors, and make available a copy of the same to every authorised person. The health care establishments waste disposal strategy should include procedures for on-site and off-site transport of wastes.

2.5.8.1 On-site Transportation

This should be done by means of wheeled trolleys, containers or carts. These vehicles should be used for this purpose only for the movements of the waste bags/containers which should be placed securely in it. Transportation of waste should be done in compliance with the rule which specifies that the handlers must be provided with uniform and personal protective equipments such as apron, boots, gloves and masks, should be compulsorily followed. For on-site transport, the following points should be kept in mind and applied properly:

- The trolleys or handcarts must be designed in such a way so that it can prevent spills and should also be made of materials which can withstand exposure to common cleaning agents.
- Such trolleys should be easily cleaned, disinfected daily with an appropriate disinfectant.
- The biohazard symbol should be clearly displayed on carts.
- Transport of clinical and related wastes should be separate from general traffic.
- Chutes must not be used for the transport of clinical and related wastes. Waste disposal chutes should not be incorporated in the design of new hospitals.

2.5.8.2 Off-site Transportation

Off-site transportation is required when hazardous healthcare waste is treated outside the healthcare establishment. This requires the labelling of the healthcare waste displaying its nature and source so that if accident takes place, it would be

possible to identify the particular waste and accordingly appropriate measures can be taken. The following issues should be borne in mind:

- Vehicles used for transporting clinical and related wastes should be reserved for this purpose wherever possible.
- Vehicles must be easy to load, unload and clean and should be equipped with spillage collection sumps or other suitable spill controls.
- The driver's cabin in vehicles should be physically separated from the waste.
- The design of the vehicle should afford the driver and the general public to provided protection in the event of accident.
- Vehicles should also have provision for holders to display prominently the necessary warning symbols.

2.5.9 Treatment and Disposal

The term 'treatment' refers to the process of modifying the waste in some way before it is taken to its final resting place. Treatment is required to decontaminate or disinfect the waste at source so that it no longer acts as the source of pathogenic organisms. After such treatment, the residual matter can be safely handled, transported and stored. The choice of treatment method should be decided according to[47]:

a. The type, nature and volume of the wastes.
b. The hazard and viability of the pathogenic organisms in the waste.
c. The efficiency of the treatment method.
d. The conditions at which the treatment method operates.
e. The cost-effectiveness of the treatment method.

There are five basic processes for the treatment of hazardous components in health-care waste, in particular, sharps, infectious and pathological wastes, they are: mechanical, thermal, chemical, irradiation, and biological. In addition to these landfill and burial may be consider as a process as part of the treatment process. For proper

[47] *Ibid* at pg. 69.

understanding of treatment of biomedical waste it has divided into ten broad categories of treatment technologies.

1. Mechanical Processes,
2. Thermal Processes,

a. Autoclaving and Hydroclaving,

b. Microwave Treatment,

c. Incineration,

d. Plasma Systems,

3. Chemical Processes,
4. Irradiation Processes,
5. Biological Processes and
6. Landfill or Burial.

2.5.9.1 Mechanical Process

These processes are used to change the physical form or characteristics of the waste either to facilitate waste handling or to process the waste in conjunction with other treatment steps. The two primary mechanical processes are

- **Compaction** - used to reduce the volume of the waste.
- **Shredding** - used to destroy plastic and paper waste to prevent their reuse. Only the disinfected waste can be used in a shredder. In most instances, mechanical processes are not stand-alone health-care waste-treatment processes, but supplement other treatment methods. Mechanical destruction can render a waste unrecognizable and can be used to destroy needles and syringes (depending on the type of shredding)[48].

2.5.9.2 Thermal Process

These processes utilise heat to disinfect. They represent most treatment facilities in use across the world. Depending on the temperature they operate it is been grouped into two categories, which are Low-heat systems and High-heat systems. This sub-classification is useful because of the marked differences in the

[48] *Ibid* at pg. 107.

thermo-chemical reactions and physical changes taking place in the wastes during their treatment in the different types of equipment. Low-heat systems (operates between 93-177°C)[49] use steam, hot water, or electromagnetic radiation to heat and decontaminate the waste. Examples are:

- **Autoclaving** – It is a low heat thermal process and it uses steam for disinfection of waste. Autoclaves are of two types depending on the method they use for removal of air pockets are gravity flow autoclave and vacuum autoclave.
- **Microwaving-** is a process which disinfects the waste by moist heat and steam generated by microwave energy.

High-heat systems (operates between 540-8,300°C[50]) employ combustion and high temperature plasma to decontaminate and destroy the waste. Examples are:

- **Hydroclaving** - steam treatment with fragmentation and drying of waste.
- **Incineration**- It is a high temperature, dry oxidation technique. This process involves the combustion of waste under controlled conditions. In this, waste is converted into inert gases and material. This treatment is done at 800-1100° C temperature. Generally, rotary kiln having multiple hearths or controlled air types incinerators are used for heating up. According to rules, this method has been recommended for cyto-toxic drugs, human anatomical waste, discarded medicines, animal waste, and soiled waste. This is one of the advantages of this technique that it can be used for a variety of biomedical waste. Disadvantage of this technique is the production of ash and combustion by-products during treatment. Limitation: This is a very high cost technique.[51]

- **Plasma System**- This is another thermal disintegration method for carbonaceous materials in oxygen starved environment. It works on the principle of converting electrical energy into heat energy. In this method primary chamber pyrolysis takes place at1100° C and the secondary chamber

[49]P. Dhruv Hirani, R. Krish Villaitramani *et. al.*, "Biomedical Waste: An Introduction to its Management" Vol. 1 International Journal of Innovative Research in Advanced Engineering (IJIRAE) pg. 85 (Sept. 2014).
[50] *Ibid*.
[51] Anurag Sharma, Ravish Garg, *et. al.*, "A Study about Knowledge, Attitude, Practices and Technologies of Biomedical Waste Management Techniques" Vol. 9 IOSR Journal of Environmental Science, Toxicology and Food Technology pg. 76 (Dec. 2015).

combustion takes place at 950 to 1100°C. Advantage of this method is that lesser number of POPs (Persistent Organic Pollutants) are formed, also it is a compact smoke free technology and consumes less space. But, has a disadvantage of its high cost and high requirement of technical persons[52].

- **Gasification Technique** -This process operates with the substoichiometric air level. In this, waste is heated at 500-1600°C with O2and H2O as gasification agent at 1-45 bar pressure, depending upon the type of waste. This technique has same disadvantages as incineration technique[53].

2.5.9.3 Chemical Process

Chemical treatment methods use disinfectants such as dissolved chlorine dioxide, bleach (sodium hypochlorite), peracetic acid, lime solution, ozone gas or dry inorganic chemicals (e.g. calcium oxide powder). Chemical treatment is performed by using 1% hypochlorite solution with a minimum contact period of 30 minutes. This treatment is used for the infectious waste only[54]. Chemical processes often involve shredding, grinding or mixing to increase exposure of the waste to the chemical agent. 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 before disposal. Another example of a chemical process is a system that uses heated alkali to digest tissues, pathological waste, anatomical parts and animal carcasses in heated stainless-steel tanks[55].

2.5.9.4 Irradiation processes

These processes expose wastes to ultraviolet or ionizing radiation in an enclosed chamber. These systems require post shredding to render the waste unrecognizable. Irradiation treatment encompasses designs using irradiation from

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[52] *Ibid.*
[53] *Ibid.*
[54] *Ibid*.
[55] Yves Chartier, Jorge Emmanuel, *et. al., Safe management of wastes from health-care activities* pg. 106 (WHO Press, World Health Organisation, 2nd Edn., 2014).

electron beams, cobalt-60 or ultraviolet sources. These technologies require shielding to prevent elevated occupational exposures to electromagnetic radiation. The pathogen destruction efficacy depends on the dose absorbed by the mass of waste. Electron beams are powerful enough to penetrate waste bags and containers. Germicidal ultraviolet radiation has been used to destroy airborne microorganisms as a supplement to other treatment technologies, but is not able to penetrate closed waste bags[56].

2.5.9.5 Biological processes

These processes are found in natural living organisms but refer specifically to the degradation of organic matter when applied to health-care waste treatment. These processes use biological enzymes for treating medical waste. It is claimed that biological reactions will not only decontaminate the waste but also cause the destruction of all the organic constituents so that only plastics, glass, and other inert will remain in the residues. Composting and vermiculture (digestion of organic wastes through the action of worms) are biological processes and have been used successfully to decompose hospital kitchen waste, as well as other organic digestible waste and placenta waste[57]

2.5.9.6 Land fill or Deep Burial

In all waste systems, the removal of the remaining health-care waste materials after minimisation or treatment will require access to land for final disposal. In less developed areas, where a municipality or health-care facility lacks the means to treat wastes before disposal, the direct use of a landfill is likely to be required for much of the material produced. The alternative is often an accumulation of health-care waste at medical facilities where it is openly burnt or spread indiscriminately around the facility's grounds. This constitutes a far higher risk of transmission of infection than

[56] *Ibid* at pg. 107.
[57] *Ibid*.

controlled disposal in a land disposal site; even if the land disposal site is not designed to the precise standards used in higher income places.

2.6 An Overview

In the above scenario, realising the seriousness of the problems associated with bio-medical waste it is important to make effective provisions for the scientific management of it. Although such waste constitutes a small portion of total municipal waste, there is a need to take appropriate measures for the proper handling, treatment and disposal as it consists of highly toxic and infectious substance and this give rise to the question of effective management for the same and it can be possible with the help of proper and effective laws on the subject.