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# COMPREHENSIVE ASSESSMENT OF VARIOUS TECHNIQUES FOR BIOMEDICAL WASTE MANAGEMENT

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***ABSTRACT:*** This review article deals with the comprehensive study on various techniques being adopted for biomedical waste management for the safe disposal as if not treated at the appropriate time using appropriate methods, biomedical waste can cause havoc in the environment and for human health. The purpose of this study is to acquire an in-depth knowledge of the various treatment methods for different categories of medical waste management and their underlying technologies and to observe the impact of biomedical waste mismanagement; also to ascertain the level of progress made by India in this field. The research methodologies used are the combination of literature review, key informant interview and case studies. Biomedical waste is the waste generated during medical activities in hospitals & Clinics, biological laboratory work or research work. It is essential to classify the waste into different categories for ease of scientific biomedical waste management. The biomedical waste can be categorized in to four types, namely, general, infectious, hazardous and radioactive and accordingly strategies being adopted for its safe disposal. General medical waste is non-toxic matter similar to domestic waste. Infectious waste are the materials which have the potency to spread contagious diseases, these waste have been in contact with body fluids. Hazardous waste like used syringes; old drugs etc. can be ignitable, corrosive, reactive, or even toxic to human health. Radioactive waste is produced from nuclear medicine treatment, chemotherapies, radiation therapies, and medical equipment that use radioactive isotopes. These wastes should be treated with utmost care as a fraction of radioactive material can initiate a biohazard. Studies estimate that 15% biomedical waste is infectious in nature and hazardous waste accounts for 5%of the quantity. For hazardous and radioactive medical waste management, we should have a cradle to grave approach. Effective management is mandatory for healthy human sustenance and a clean environment, failure of which can lead to catastrophic damage to human health at mass level.

***Keywords:*** Biomedical waste, Environmental Toxicity, Hazardous waste, Contagious waste management, Radioactive waste management.

# I. INTRODUCTION

In recent times, tremendous growth and expansion of healthcare centers have been observed and likewise technological advancement has led to many new medico-tech devices & equipments for the treatments of various diseases. As an outcome of medical advancement, we are generating a substantial amount of biomedical waste. The Ministry of Environment and Forests, Government of India, defines biomedical waste as "any waste, which is generated during the diagnosis, treatment or immunization of human beings or animals, or in research activities pertaining thereto, or in the production or testing of biological".

The Government of India has broadly classified biomedical waste into 10 types: Human anatomical waste, Animal waste, Microbiology & Biotechnical waste, Waste Sharp, Discarded medicines and cytotoxic drugs, Soiled waste, solid waste, Liquid waste, Incineration ash, Chemicals.

Most prominent production sites for biomedical waste are medical facilities like hospitals, pharmaceutical industries, and research laboratories. "Biomedical waste is produced in all conventional medical units where treatment of (human or animal) patients is provided, such as hospitals, clinics, dental offices, dialysis facilities, as well as analytical laboratories, blood banks, university laboratories" [1]. They are hazardous, toxic, and can even be lethal to life. The frontline healthcare professionals and immune suppressed patients in the health care field are at highest risk. On the basis of their impact on human lives, these wastes are divided into 4 categories:

**General Waste-** This type of waste is the regular domestic waste which does not pose a threat to human life. These are the most abundantly found waste constituting about 85% of the total biomedical waste. It includes paper, plastic, liquids like phenyl solution.

**Infectious waste:** These are the waste matter which has the capacity to spread infectious diseases. These can be blood/blood soaked materials, excreta, body fluids, cultures, etc.

**Hazardous waste:** These are the waste materials which can cause harm to life in non-infectious form. They can be sharps like syringes, needles, or discarded medicines, pharmaceutical chemicals, cytotoxic drugs etc.

**Radioactive waste:** These are the nuclear treatment waste containing radionuclides which can be mutagenic or teratogenic. Certain diagnostic or treatment procedures like positron emission tomography (PET) or radiotherapy require the handling of radioactive material. It is estimated that only 15% of the biomedical waste is hazardous or toxic to life. The more technically advanced a country is, the higher the focus on ultra-modern healthcare facilities and its associated research, the more waste they generate. Biomedical waste handling is a dangerous waste action which requires a high standard of preparation. It calls for specific training that depends on the nature of the work in the hospital, the hazard and worker experience and also the responsibilities of individual workers [2]. Illicit intravenous drug users (IVDUs), who have high rates of human immunodeficiency virus (HIV**)** and hepatitis B virus (HBV) infection, are a significant source of discarded sharps. There is a theoretical possibility that a maximum of less than one to four cases of AIDS per year could occur as a result of contact with medical waste sharps. However, this contribution would be considerably less, based on the principles of infectious disease transmission. The most effective way to deal with this issue is to strive to reduce the amount of waste created, on a small scale in homes or on a large scale in industrial operations. Simultaneously, the impetus to recycle, reuse, and reclaim products is paramount to adequately manage solid waste, including medical waste, now and in the future [3]. The World Health Organization stated that "In an unregulated environment, elaborate enterprises have grown up to divert used syringes from waste stream for reprocessing and sale back into unsuspecting markets". The waste should be tackled at source rather than "end of pipe approach [4]. It is pointed out that the inappropriate treatment and final disposal of wastes containing biohazardous materials which are produced in healthcare and other facilities working with pathogens buries especially in developing countries a variety of issues potentially leading to adverse impacts to public and occupational health and safety, as well as to the environment. The four basic processes for the treatment of hazardous components in healthcare waste: thermal (e.g. incineration, autoclave, microwave), chemical, irradiative, and biological. Thus, the use of microwave technology has to always be seen in the context of other treatment options. Each treatment technology has its pros and cons, and one of them may not be optimal for every need. There are significant global differences that exist in the management of healthcare waste, especially between low income, middle income, and high income countries [5].

### 1.1 OBJECTIVES OF STUDY

The objectives of this study are:

- To study the standard steps involved in the process of biomedical waste management
- To analyse the techniques involved in biomedical waste management
- To observe the impact of biomedical waste mismanagement
- To understand the scenario of Indian biomedical waste management system.

## II. METHODOLOGY

Research methodology is the process by which the researcher goes about describing, explaining and predicting phenomena. In this study, the research methodology is a combination of literature review, analysis of published data (secondary data), and case studies. The literature review includes both published and unpublished sources of literature, which includes books, journals, magazines, and articles. Case studies and examples are taken from biomedical industries in India and around the globe.

## III. LITERATURE REVIEW

Hazardous waste constitutes merely 15 to 25% of total waste generated in a hospital, the remaining being general waste such as wastepaper, wrapper of drugs, cardboard and left-over food etc. its well documented propensity to cause transmission of 3 pathogens namely Human Immunodeficiency Virus (HIV), Hepatitis B Virus (HBV) and Hepatitis C Virus (HCV) makes it essential that due care is exercised while handling an disposing it [6]. The author also goes on to say that waste receptacles should preferably be covered ones having foot-operated lids. Various steps for safe management of bio medical waste are handling, segregation, mutilation, disinfection, storage, transportation and final disposal [7].

Four basic processes for the treatment of hazardous components in healthcare waste were highlighted: thermal (e.g. incineration, autoclave, microwave), chemical, irradiative, and biological. Thus, the use of microwave technology has to always be seen in the context of other treatment options. Each treatment technology has its pros and cons and one of them may not be optimal for every need. A first guideline for accepted treatment options and processes can be found, for example, in the list of the German Robert Koch Institute [8].

It was found that the main benefit of microwave energy is the direct delivery of energy to microwave-absorbing materials, which allows the volumetric heating of samples. Issues such as long heating periods, thermal gradients, and energy loss to the environment can be minimized. These attributes of microwave energy make it very attractive for industrial applications as an alternative to conventional processing methods [9]. Microwave processing can be also used as a method for reducing salmonella in peanut butter without producing quality deterioration [10]. [11] observed that a thin full load of clinical waste, bacterial and thermometric test pieces were passed through a microwave system with a self-generated steam decontamination cycle. These test pieces were enclosed in aluminum foil to shield them from direct microwave energy. After the treatment, none of the 100 bacterial test pieces yielded growth on culture and all pieces achieved temperatures in excess of 99°Cduring their passage through the decontamination unit. Moreover, no particles were detected outside the machine. [12] stated that incineration, autoclave, hydroclave, are the technologies to reduce the harm of biomedical waste. [13] listed that autoclaves are closed chambers that apply both heat and pressure, and sometimes steam over a period of time to sterilize medical equipment. Autoclaves have been used for nearly a century to sterilize medical instruments for reuse [14] affirmed that autoclaves are used to destroy microorganisms that may be present in medical waste before disposal in a traditional landfill. Autoclaves can be used to process up to 90% of medical waste, and are easily scaled to meet the needs of any medical organization. [15] stated infectious waste that contains non-infectious hazards should not be steam-sterilized. Encapsulation is a pretreatment method which has an objective of preventing contact between environment and target substances by forming a physical, impermeable barrier around the solid waste. It involves filling containers with waste, adding immobilizing material, and sealing the containers. [16] stated that in the United States, Portland cement is commonly used in the encapsulation process because it is inexpensive, highly alkali, and can incorporate wet waste. They also stated that the use of natural zeolite as a binding material prior to encapsulation capitalizes on the unique ability to absorb, trap, and immobilize the contaminants in the zeolite structure. When contaminants are confined, they do not interfere with the concrete development process. Lab results also indicate that there is a reduction in the amount of leachable contaminants when zeolite is included in concrete formation. They further elaborated that zeolite stabilizes contaminants and contributes to the integrity and corrosion resistance of concrete.

[17] revealed that vermicomposting is an efficient and eco-friendly technique for management of biomedical wastes, in comparison to normal composting. A study carried out using different species of earthworms independently and as mixed culture for vermicomposting of biomedical waste showed that *E. fetida* is more efficient than the other two epigeic earthworm species *E. eugeniae* and *P. excavatus*. A mixed culture of all the three species was as efficient as that of *E. fetida*. It is advisable to maintain a polyculture of earthworms to treat BMW since all three species work in unison to decompose the waste and even if one of the species fails to survive in the toxic and complex environment, the surviving species would be able to carry out the process efficiently. It was found that it is essential to mutilate used recyclables right after use thus leaving no scope for their unauthorized recirculation and inappropriate reuse. Providing training is considered an effective tool to increase compliance to guidelines for waste management [18].

Studies have shown the gaps in knowledge in waste management after segregation and safe transportation of biomedical waste from the hospital. She recommended the need of training programs to empower the healthcare professionals on biomedical waste management in broader aspects [19]. The most comprehensive global environmental treaty on hazardous and other wastes has been given by The Basel Convention on the Control of Trans-Boundary Movements of Hazardous Wastes and their Disposal. 170 countries are members of this treaty aiming to protect from the harmful impacts of hazardous waste on environment and human health. It regulates the trans-boundary movements of hazardous and other wastes by applying the "prior informed consent" principle. Shipments without consent to and from non-parties are illegal unless there is a special agreement that contains provisions no less environmentally sound than the convention [20]. The Bamako Convention on the Import into Africa and the Control of Trans-Boundary Movement and Management of Hazardous Wastes within Africa (the Bamako Convention) is a treaty of African nations prohibiting the import of any hazardous (including radioactive) waste. The Bamako Convention was negotiated by 12 nations of the Organization of African Unity at Bamako, Mali, in January1991, and came into force in 1998 [21].

The International Solid Waste Association (ISWA) is recognized as an international, independent and non-profit-making association, working in the public interest to promote and develop sustainable waste management worldwide. ISWA has national and individual members from around the world and promotes sustainable and professional waste management [22]. In Canada, Approximately 41% of Canadian hospitals reuse certain types of non-disposable medical devices, such as endoscopes. Only devices labeled "reusable" can be reused. The reuse of some devices has become common practice, primarily for economic reasons. Subsequently, the Canadian Society of Gastroenterology Nurses and Associates has produced a set of guidelines for its membership to ensure the safe reuse of non-disposable medical devices and also to address legal and ethical issues [23]. Manual on Solid Waste Management, published by Ministry of Urban Development, Government of India (2018) states that the vision for Municipal Solid Waste Management for our country is in line with Swachh Bharat Mission. General waste is treated by local municipalities in the same way as house-hold waste, but special precautions and treatment modalities are required for biomedical waste, so that it does not cause any harm to human beings and the environment [24].

### 3.1 CASE STUDIES FROM WORLD

**Case Example 1: Healthcare waste disposal in El Salvador:** Health care waste disposal practices in a hospital in El Salvador were studied by observing waste containers and re-segregating waste placed in bio-hazardous waste bags. These studies have shown that 61% waste was common waste showing the lack of awareness among staff about the cost of not segregating waste properly [25].

**Case Example 2: Use of incinerators and autoclave in Isfahan City, Iran:** A comparative study of hospitals located in Isfahan city was done and it was concluded that inappropriate operation of incinerators and lack of air pollution control devices, makes the use of incinerators seem irrational in the current times. Yet, despite the inefficiency of autoclaves in treatment of bulky wastes such as anatomical wastes, their usage seems logical considering the very low amounts of such wastes. Also, considering the amount of generated wastes in Isfahan hospitals, a combination of centralized and non-centralized autoclaves is recommended for treatment of infected wastes. Mobile autoclaves may also be considered according to technical and economical conditions. It must not be forgotten that the priority must be given to the establishment of waste management systems particularly to personnel training to produce less wastes and to separate them well [26].

**Case Example 3: Sharp disposal in Pakistan:** Ina study in Pakistan, practices of poor disposal of sharps were found as 60% of observed practitioners were found throwing syringes at open places. Disposal of used injection equipment at open places in rural areas could increase the risk of transmission to children, who play with syringes and can get pricked. The situation is not very different in the city where most of the doctors dispose of syringes in the municipal waste bin. This exposes the waste scavengers to the risk of hepatitis transmission. The risk is not limited to the waste scavengers but to the other people who are involved in trade of used medical disposable equipment. The situation of waste disposal in the rest of the developing world is not different [27].

### 3.2 CASE STUDIES FROM INDIA

**Case Example 1:** A case study was carried out at Gandhinagar hospital, Jammu. A mixture of samples of biomedical waste from the hospital were collected and observed for 3 months. Studies have shown that average solid waste generated per bed per day was 632.04g of was generated per bed per day out of which approx. 61.28g was biodegradable in nature. It was observed that Biomedical waste is collected by the sweepers and then disposing off this hazardous waste in the community dustbins showing that there was no proper waste disposal [28].

**Case Example 2:** A survey on 10 hospitals in city Pune, India was conducted to check the impact of the biomedical waste on the environment showing that more than 55 % of employees are unaware about the adequate collection and treatment methods of biomedical waste; approx. 62 % of respondents did not consider it a serious issue; approximately 45 % were unaware of adverse consequences [29].

## IV. RESULTS AND DISCUSSION

During this study, it was found that the standard procedure of biomedical waste management is divided into sorting, segregation, collection, handling, storage, transportation, treatment and disposal and it requires the use of some specialized techniques like chemical disinfection, autoclave, hydroclave, microwave, incineration, shredding, encapsulation, and vermicomposting. Each technique has its own set of advantages and drawbacks. It is observed that some of the treatment methods for biomedical waste like incineration are not 100% safe as they do emit toxic gases and produce hazardous by products. The data collected from different sources supported to establish the facts that some steps have been taken at global level for effective management of the waste but indigenous studies have shown that we definitely lag behind in taking, implementing, and complying with concrete guidelines. In India, awareness, lack of knowledge and training in this subject is a major challenge. Leaving aside the general public, 70% of the healthcare professionals and people associated with biomedical waste handling are unaware of the compulsory regulations formulated by the government to facilitate smooth management of the waste. Naturally, they do not follow the stated instructions and put the lives of several people at risk, including their own. Another main issue is the unavailability of resources and financial assistance to comply with the biomedical waste management system.

## V. CONCLUSION

During these studies it has been concluded that biomedical waste management issue should be taken care of with immediate effect to avoid its adverse consequences on environment and human health. The process of waste management is technical, expensive, tiresome, and continuously evolving; hence planning and proper management of resources and manpower is required. To effectively manage biomedical waste, the initial step should be assessment and planning. Summarization of sorting procedures, techniques associated with it, manpower requirements, and monetary estimation. The plans for management may vary for the different sources of waste production sites. The priority should always be to minimize the amount of waste production without compromising the quality of material or procedures. Once that scenario is sorted, the next lookout should be managing the generated waste in an environment friendly manner. It has been observed that some of the treatment methods for biomedical waste like incineration are not safe as it leads to introduction of toxic gases and hazardous byproducts in to atmosphere. Advancement of technology and use of clean development mechanism could be effective in controlling the havoc created by unsafe disposal and management of hazardous waste. Large scale compulsory training programmes to spread awareness, rebates on proper biomedical waste management, subsidies and other necessary aid must be provided to the public to facilitate the appropriate compliance of rules and guidelines on biomedical waste management.

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