EVOLUTION AND TRENDS IN MANAGEMENT OF MEDICAL WASTE

Abstract

A society not only has right to a cleaner environment but it is also obligatory for all involved in healthcare activities that effective Biomedical Waste (BMW) management is carried out. Ever since the time of Hippocrates, the Biomedical Waste has been produced but it was not of a grave concern as quantity produced was lesser with respect to population and area available. Till recent times, up to the beginning of 19th century also, no one paid a heed to it and it was being dumped in open, burnt or washed away into drains and rivers. With the outburst of population on the Earth, the number of patients increased and consecutively, the quantity of BMW. COVID gave an exponential jump of 46% to that quantity in India within two months of outbreak of the pandemic. It is eventually social & legal responsibility of all who are involved in supporting & funding the healthcare (HC) activities. For the health of living beings and for clean environment, effective BMW management is a prerequisite.The management of biomedical waste is not only restricted to healthcare workers. In fact, there is an equal involvement of government; which frames the laws, allots finances and provides infrastructure, of corporate; to manufacture eco friendly instruments used in these activities and their subsequent disposal, of scientists; who find newer and newer techniques and methods to reduce the menace of BMW and of the society; which includes sanitation workers, attendants, relatives of the patient, environmentalists, social workers and NGOs etc.

This has opened a vast field of management and technology which has set various trends rolling in the BMW management. This article reviews the trends while touching upon the history and evolution of rules and regulations with times, population, quantity the lucrative BMW market, the conventional and latest techniques including environment protection to include latest eco friendly methods for BMW disposal. However, basic knowledge of the readers on the subject is pre solicited.

Keywords: Biomedical Waste, regulations, technology, trends.

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I. INTRODUCTION

All medical waste produced in the hospitals or healthcare facilities are not infectious. Medical waste shall not be misunderstood as normal waste. WHO has given a proper definition; waste generated in hospitals, laboratories, clinics, medical research facilities, medical teaching institutions, immunization, treatment of humans & animals is medical waste. The handling, treatment and management of hazardous waste needs to be given due importance, else, it may have widespread risk to humans and negative effect on environment. As per chart given below, only 10% to 15% waste generated by HCFs is infectious Dwivedi et al (2009) has studied that all the waste materials which is generated by hospitals are not hazardous in nature as only 10-15% of these wastes are infectious.(Figure 1). The hazardous BMW has to be disposed off as per rules framed by WHO, international agreements & conventions & laws of the country. The hazardous waste can be a cause of worry to the society due to its infectious nature and can cause contagious or more serious diseases. Hence, a continuous research is always ON to find newer, suitable, eco friendly & economic ways to deal with safe disposal of such waste generated in Healthcare Facilities (HCFs).

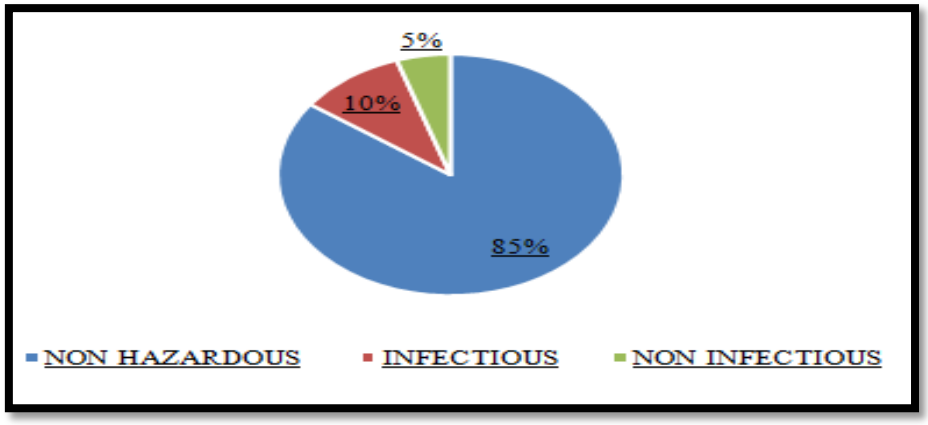

Figure 1: Biomedical Waste

Biomedical Waste

II. HISTORY, EVOLUTION AND TRENDS IN LEGISLATIONS

It was in 1848, that Edwin Chatwick came out with Public Health Act when he saw that human urine, dead animals and other waste was lying in the streets of New York. Before that, sanitation and waste disposal was inconceivable. This being the maiden initiative towards improvement of health of living beings and environment, it was followed by much such legislation, rules and regulations were developed from time to time.

Environment Protection Agency (EPA) of USA enacted the Solid Waste Disposal Act of 1965 which aimed to minimise waste & protect health of living beings. The Resource Conservation & Recovery Act (RCRA) was enacted in 1976 which laid down rules to deal with HC hazardous waste. The US Congress passed Medical Waste Tracking Act of 1988 which ended in 1991 & was later taken over by states to regulate the disposal of BMW. It included guidelines for the disinfection of medical waste, laid down the system to track it, established procedures to segregate, pack, store and label the waste and had provision in which the fines could also be imposed in case of failure to adhere to the laid down regulations.

III. INTERNATIONAL AGREEMENTS & CONVENTIONS

For sustainable development, environment protection & BMW management, there are certain important agreements & conventions which braced the society to fight BMW menace. The same are discussed in brief as under:-

1. Basel convention: With the objective to save humans & environment from ill effects of hazardous waste, specially clinical waste from healthcare establishments, 53 nations came on table in 1989 at Basel, Switzerland, to discuss the management of BMW and signed a treaty for its efficient disposal. It restricted the developed nations to send their hazardous waste to lesser developed nations for dumping and minimise rates of toxicity and assist less developed countries in environment friendly sound management of hazardous waste

2. Stockholm convention: Persistent Organic Pollutants (POPs) like dioxins & furans which are toxic in nature and have affect on health of living beings by causing damage to internal tissues.. These toxins & furans are by products of thermal combustible methods of waste disinfection like incinerators etc.. The global treaty was signed by 152 countries in Stockholm in 2001 to protect human health & environment, in which guidelines and best environmental practices were released which aimed to eliminate or reduce the production of POPs.

3. Minamata convention: To reduce the mercurial pollution, 128 nations, on 10 Oct 2013, signed the global convention on environment & health in Japan. They agreed upon reducing the medical equipment like blood pressure devices & thermometers etc which use mercury and stop its future usage in a phased manner, to save humans and environment from green house gas emissions and ill effects of mercury and its compounds.

4. Monitoring by WHO: WHO is a supreme international body which is responsible for all health related issues in the world. WHO developed a handbook, 'The Blue Book' in 1999, of which second edition was printed for distribution in 2014. It advocates the methods for safe handling of BMW, its disposal and & various measures to control pollution. It also covers the topics on healthcare waste management in ICU, in pandemics, regarding drug resistant bacteria and also on climate change. In July 2007 at Geneva, WHO called a meeting and stressed for corresponding investment of finances and the commitment to protect humans & environment from harmful effects of healthcare waste. It was advised that all stakeholders involved have legal and moral obligation to contribute financially and share the cost of BMW management, so as to guarantee the safety to one and all.

A survey was conducted by WHO in 2012 of 24 countries based on few important areas of BMW management to include policies, regulations in place, training of healthcare workers, techniques being adopted, and amount of funds being earmarked and spent . Micronesia, Kiribati & Nauru were the only countries in west pacific which faired just satisfactorily & the BMW system of others was found to be far from ideal. Japan & South Korea were noticed to have best laid down practices in BMW management. Their procedures and drills were good and their disposal facilities as well. Canadian states have their own methods in place for BMW management, however, it was noticed that they are leaving the idea of on-site incineration but adopting the centralised provincial facilities for BMW sterilization.[8] The new document was released by WHO in 2018, which discussed about safe management of waste form HC activities , reduction in waste , its treatment, its careful handling & storage & the regulatory framework related to BMW.

- **Osha (Occupational Safety & Health Administration):** Environment Protection Agency (EPA) is the agency in USA , which is responsible to study, suggest, implement and carry out audit and certification with respect to handling management of BMW. EPA conducts the OSHA audit of the facilities in USA once a year which covers health, safety & fire hazards. All health workers in USA need to undergo training on blood borne pathogens. Other agencies like US Food and Drug Authority (FDA) & Drug Enforcement Authority (DEA) also help govt in its fight towards management of BMW.

- **IDC-10 certification:** The International Classification of Diseases is a clinical cataloging system in USA healthcare industry which is used to record diseases on health records and track epidemiological trends.

It provides more detailed coding which helps in improving upon the reporting on new medical advancements in medical devices & treatment. It has more than 50,000 codes. This is also very helpful in monitoring medical insurance cases in USA.

- **BMW and Indian regulations:** In India, the Ministry Of Environment and Forests (MoEF) introduced the Medical Waste Handling and Management Rules in 1998.[9,10] These rules were amended to Biomedical Waste Management (Management and Handling) Rules in 2003 to lay down the guideline for healthcare waste management. Central Pollution Control Board (CPCB) along with State Pollution Control Boards are responsible agencies to implement orders of the government. CPCB also listed out the guidelines on Common Bio Medical Waste Treatment Facilities (CBMWTF). Several other government agencies to support the government were also framed, like OSHA, Centre of Disease Control (CDC) etc, to assist , implement and reinforce the rules and regulations.

International Clinical Epidemiology Network carried out a survey on BMW practices in vogue along with regulatory setup across primary, secondary and tertiary care HCFs in entire India. It reported that India's BMW management system was not up to the mark. In 2009, around 240 people in Gujarat contacted Hepatitis B following the reuse of unsterlised syringes[11]. However, the need was felt and the govt came cracking in taking control of the stock & refined the regulatory framework and its immediate implementation.The draft BMW rules 2011 could not get modified due to lack of consensus on categorisation and students. These rules were amended in 2016 which has four schedules, five forms & eighteen rules. . These new rules expanded the coverage, simplified the categorisation & authorisation improve the disposal methods and reduce the environmental pollution.

With arrival of COVID pandemic, the special guidelines were gazetted by the govt from time to time commencing March 2019, which kept on getting refined with the development of extant of quantity of BMW generated and required special handling. It contains extensive instructions to manage the COVID waste generated from HCFs and home confinements.

- **Trends in generation of quantity :** With the development in medical science, increased population, increased affordability, increased number of disease and increase in no of HCF resulted in multi-fold rise in the quantity of HC waste generated. The infrastructure & technology are continuously being improved to combat the increased quantity. As per CPCB India data of 2017, the total BMW generated was 557 TPD (tonnes / day) from 3,22,425 HCFs in India, but only 21870 HCFs carry out treatment of waste on their premises. Others use CBMWTFs. There are 198 CBMWTF already operating in the country and 28 are under the process of construction [1]. 233 incinerators were working in the country.

COVID-19 created an unprecedented challenge to the global healthcare system leading to disruption in supply chain, delay in surgical procedure and reduced patient visits to the hospitals. Accordingly to the study by UNDP of 5 Asian cities, COVID-19 increased the amount of hazardous waste by 3.4 kg/per/day. This is about 10 times the dose of hazardous healthcare waste, raising from 0.2 to 0.5 kg/per/day.

	Before COVID (2019	**During COVID(2020)**
BMW generated	557 TPD	850 TPD
HCFs	3,22,425	3,52,014

Table 1: Comparative Figures in India(CPCB)

It amounted to generation of 850 TPD against the treatment capacity of 700 TPD and balance was left untreated [1] (Table 1). Various governments, WHO, including CPCB India issued directions on management of HC waste produced by COVID patients generated during their treatment, diagnosis or confinement.

5. Market trends: Due to the presence of highly developed health sector, as well as increase in infection & chronic diseases, large quantities of BMW & residues are being produced. There is a new trend amongst few hospitals who have begun the process of recycling and this recycled BMW is absorbed back into the hospitals which costs them

traction of the actual cost. There is a requirement of heavy investment, high value equipment & new technological equipment, which is the major hindrance in the medical waste management market.

Medical waste mmanagement market is likely to grow at a CGAR of 5.5 % in the years 2022-2027. In 2020 the global medical waste reached 14 bn USD. BMW shall continue to gain traction as demand of different infectiousus components has increased, especially after COVID. The infrastructure has also increased like research centres, blood banks, hospitals etc.

The global market of face masks increased from 737mn in 2019 to 22145 mn in 2021, and is expected to reduce to 3021mn by 2025. However, the number is much much higher from pre COVID era. According to recent ADAC, medical waste management market size will surpass 3.9 bn USD by 2026. It also brought out the recycling services segment value shall witness a robust growth in next 5 yrs, which was around 350 mn USD in 2018. The nursing homes garnered 12% revenue share in 2019 due to surge in demand of PPE kits, syringes and needles in USA. Demand of BMW management of morturaies, autopsy centres, blood banks, dental clinics, ICU & oral surgeries grew at a healthy CGAR of over 9.5 in 2019.

Due to COVID, China witnessed a heavy increase in BMW. For eg; 365 tonnes of medical waste was collected across Hubei province (an increase of 600%, Haque et al 2021), out of which 60% originated from the hospitals only and the balance from other HCFs in 2019. Its HC waste management market revenue share was around 20% in 2019, and the similar growth is expected through 2026. In India stakeholders are also likely to infuse funds, as the demand of BMW collection has surged and the market is likely to grow over 8.5% through 2026.

- **Trends in Technology**

  - **Contemporary Technologies of BMW disposal Incineration:** Methods like incineration where heat is used to destroy BMW. These are in application but are thought to be primitive. The rapid combustion of solid waste leads to the production of by-products through incineration. The toxic material gets converted to non toxic material due to continuous flow of oxygen. So it was considered the safest method. More than 90% of BMW is being disposed by this method but still due to incomplete combustion several toxic substances get released. Besides dioxins and fur-ans, other chemicals are also produced during incineration [11]. These were found to be causing immunological & neurological disorders.These have carcinogenic effects and various studies suggest an increase in quantity of dioxins which are entering into human bodies, and thus , red flags the use of this technique in future.

  - **Chemical disinfection** is carried out on the equipment which can not be disposed off. It is carried out on that kind of HC waste which can not be taken to incinerator or cannot be disposed off in landfills [www.lentech.com]. It is mandatory to disinfect liquid HC with chemicals like Chlorine, Sodium Hypochlorite solution etc. Another effective disinfectant is Ethylene, which when used, disinfects maximum of liquid

waste. It produces halogenated chlorine compounds after reaction with waste liquid, and the product is less toxic.

- **Steam and thermal treatment like autoclaving:** This method comes into play while disinfecting various reusable instruments. It involves use of steam at high temperatures to disinfect the BMW and does not have any by-products. Different temperatures are set for different types of bacteria to be destroyed but the growth of bacteria was again noticed within 2-3 days. But thermal treatment was not found much useful in highly contagious diseases like COVID.

- **Microwave radiationns**: Are being used without producing any pollutants. Its main advantage is that it is green by nature and does not harms environment.[13] The microwaves produced along with electron beam radiations have proven to be very effective in sludge and waste treatment of waste water.However, application of this technique is rare in hospitals but its future is very bright.

- **Land disposal:** Large amount of BMW is disposed of by putting it in large dug pits and covering it by soil. It's not only popular, cost effective but very effective also. Ashes generated from incinerators can also be disposed off in similar manner. The Bio simulators which are in use now a days, also dispose off the BMW very efficiently. The Leachate re circulation can reduce the carbon content of BMW more than the dry simulators.This method has great significance in hospital waste management, especially in case of COVID waste.

- **Inertization** It is a method to dispose of ashes of incinerator and pharmaceutical components. The instruments are shredded into small pieces, put in non toxic containers and these small capsules are then disposed off in safe places. A process called Nano Catalysis can also be put to use in disposal of BMW. This method has proven to be good for COVID waste also.

- **Trending new techniques:** As per EPRI 2000, there have been trends to develop new technologies which include thermal, chemical and radiation methods of BMW disposal, which can provide a breakthrough and revolutionise the system of disposing BMW.

  - **Thermal techniques:** First in line are the thermal process which have been grouped in low, medium, and high, as per temperatures required for disinfecting. Microwaves and autoclaves fall in low heat technologies which operate in the range 95^0 C to 177^0 C. All infectious waste, laboratory waste and instruments used in HCFs are sterilised in autoclave due to air evacuation, since it is more effective with vacuum cycles, . But heat resistant containers, beddings etc cannot be disinfected by autoclave. Reverse polymerization and thermal de polymerization fall in the medium heat technologies which range from 177^0 C to 540^0 C . High energy microwaves are applied in the presence of Nitrogen to initiate the breakdown in organic substances and compounds. The range of operation of high heat technologies is 540^0 C to 830^0 C and the process is called Pyrolysis. All kinds of waste to include organic waste, solid waste, and liquids are vaporised at higher temperatures which ultimately gets converted into ash, which is inert and fragments of glass and metal.

In the process of **Plasma Pyrolysis**, a torch is used to generate high temparature beams. Vast variety of HC waste like sharps, plastic waste, hazardous waste, carcinogenic waste etc can be treated and disinfected in an eco friendly manner by this method. Mercurial waste can not be treated by this method. The main advantage is that it reduces mass and volume of waste up to around 90% . Also the emissions are lesser and the end waste left is mostly sterile and inert which is good for environment. As it involves huge capital, uses tremendous amount of electricity and due to its limited life span, the overall operational cost comes out to be quite high.

- **Chemical techniques:** Next is the chemical based technology in which chemicals are used to kill or inactivate pathogens in BMW disposal and the processes are continuously evolving. These include liquid wastes, waste produced by humans, waste generated in and the soft waste like gauze, gowns and bandages etc. It is advisable not to treat volatile, semi volatile organic compounds, mercury & radiological waste s by this method as it requires a closed system or negative pressure. In this method, prior shredding of BMW is must. The advantage is that it is fully automated technique, easy to use and no by-products of combustion are formed. The disadvantages include toxic by-products due to large scale use of chlorine, sodium hypochlorite and hydrogen peroxide.

- **Biological techniques:** Here, BMW is to be treated at four levels. Level 1 involves low level disinfection in which most of the bacteria, fungi and viruses are neutralized, except mycobacteria and bacteria spores. Mycobacteria are neutralized in level two which is the intermediate level. At third level, even bacterial spores are neutralized up to 99.99%. However, level four is sterilization which has proved to be best for treatment of BMW

- **Radiation techniques:** The ionised radiation is produced in the electron beam technology which releases high energy electrons having enough speed to strike the target. This a very effective method and has little effect on environment. This process is expensive and thus used rarely, but the world is understanding its importance and turning towards use of this technique.

- **Energy conversion:** The best way to make BMW management attractive is to harness energy it can produce. A study claims that two key elements which are of a good deal is blood and saliva which can be converted into energy. The research is under progress and breakthrough is likely in future.

- **Converting glucose into energy:** The biological fluids contain glucose and can be converted to generate electricity, enough for the physician's cabin. This technology can change BMW management drastically by which we can harness the energy produced which can prove to be more sustainable disposal process. So, as per the advancement in technologies,disposal of medical waste is also changing rapidly as per the need of planet and taking care of environment as well. Furthermore, different techniques are in process of evolution and will benefit the humans and climate also.

- **Tracking Medical Waste:** Medical Waste is to be transported on daily basis within 24 hours of generation to the treatment facility. But choice of treatment has to be

made depending on various factors like; what is the composition of waste; how much space is available; status of regulatory. approvals; any objections by the public; the cost involved and; the availability of technology in CBMWTF. Various new methods including geo tagging and satellite monitoring of vehicles carrying BMW has been developed to ensure that the vehicle reaches CBMWTF. It is important due to the fact that if the waste does not reach the treatment facility and gets disposed off anywhere in the countryside, it can lead to polluting the environment and also lead to widespread diseases.

BMW Transportation Van

- **Eco friendly trends:** The preliminary trends are heavily biased towards incineration. Approximately 97% of plastic waste from COVID-19 was burned. Burning is the most common and preferred method used to dispose of medical waste, although it is not environmentally safe as it leads to global warming. Steam autoclaving is also in use since 2010. Environment protection Agency and CPCB have imposed stricter laws on global warming due to the rising effect of the same. The increase in health care waste contributes to market growth. As the climate change blues galore, the research processes are trending towards development of such technologies which release less heat in the environment. The latest trend is to trap the solar energy which can substantially decrease the cost and and can be used for various processes , including transport as well. Since it is not possible to make a treatment facility in all hospitals due to various factors like, space, cost, population etc, a common facility on zonal level is the answer. If efficiently managed, it can reduce the cost and can also reduce the harm we are doing to the planet. **Say No to Plastics** Insufficient waste management system allows mixing of BMW with other garbage which makes the situation very critical especially in the countries with high density of population. There is a major surge in manufacture of single use plastic instruments and devices which are causing menace from land to sea, from animals to mankind and for the climate and environment too. Excessive use of PPE kits, masks and syringes during COVID has led to enormous generation of plastic waste which gets converted into microplastics and the it enters our system. The ocean is a sink to all garbage. The plastics break into microplastics and enters the body of fishes and other sea animals. Through fishes, they have now entered the human body. The mothers milk, which was considered the purest once upon a time , has also been polluted by microplastics and is causing cancer. There was a recent incident of microplastics being found in the snow of Antartica. Campanale et al carried out a study on microplastics to

understand their negative effects on living beings and environment. However, there are miles yet to be covered to find the solution to these micro pollutants. The immediate solution seems to be segregation of single use plastic at source and its proper disposal.

IV. CONCLUSION

Increase in population density is leading to increase in polluted environment worldwide. BMW is also one of the causes of the same which affects not only the environment but also the living beings and their future generations. There lies an inherited risk of infections along with other health hazards. Therefore, it becomes our duty to set the trend of freeing the environment from this pollution and let everyone enjoy the right to clean, green and safest environment. The good practice of BMW management should be based on three R's that is ; to reduce; to recover and; to reuse. Aim should be to avoid generation of waste, recover the maximum possible instead of disposing. Various methods are in place to handle & dispose such BMW. It needs to be tapped in the beginning of generation at segregation stage, rather than letting it mix and reach the last stage and then acting upon it.. For less developed nations, solar heating is the cheapest method and in developed nations, sterilization/ sanitation are commonly viable alternative to BMW destruction. BMW management has be a teamwork by healthcare workers, HCFs, and strong legislature by continuous monitoring of BMW practices. Good BMW practices need to be followed . We also need to to reduce dependence on plastics in medical instruments and find novel and eco friendly means of manufacturing them . The research is ON to find out various new technologies to decontaminate the medical devices, PPE kits, masks etc, which is a big big challenge. Mass awareness of society and proper training of health workers is the immediate solution which can be acted upon now, and keep our anticipations positive on the outcome of research processes so that we are able to find out correct means and ways to dispose off BMW waste and make the planet , a healthy place for generations to come.

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