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Review Article

Biomedical Waste Management

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ABSTRACT

Interaction of micro– (internal) and macro– (surrounding) environment of human beings determines the status of health of an individual or of community at–large. On daily basis, generation and disposal of biomedical wastes has become a emerging problem not only in India but the world over. These are being produced during the process of sampling, testing, diagnosis, therapy, immunization and surgery of humans, animals, and in research experiments. Several categories of biomedical wastes have been discussed along with steps involved in the management of biowaste include segregation, storage in containers, labeling, handling, transport, treatment, disposal and waste minimization. Potential implications of biomedical wastes include transmission of diseases like Hepatitis B, C, E, dengue and HIV through improperly contained contaminated sharps; proliferation and mutation of pathogenic microbial population in the municipal waste through dumping of untreated biomedical waste; physical injury and health hazards. Certain other implications include degradation of the environment esthetically by careless disposals, having negative effect on public health; increased risk of nosocomial infections; change of microbial ecology and spread of antibiotic resistance; increased density of vector population, resulting in spread of diseases in public. Sensitization and public awareness is important to protect environment and public health globally.

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INTRODUCTION

Status of health of an individual or community is determined by interplay and integration of micro (internal) environment of human beings and macro (external or surrounds) environment. Imbalance in these two may have serious repercussion on the national well-being. Therefore a balance has to be maintained in order to increase living standard and promote healthy society (Neema and Gareshprasad, 2002; Murthy et al., 2011).

There has been generation of insignificant amount of waste by human population throughout the history of mankind due to lower societal levels of exploitation of natural resources. Mainly ashes as biodegradable wastes were commonly produced during the times of pre–modern era and had been released back in the local ground with environmental impact becoming minimum. Certain civilizations are however more prolific in their output of wastes than others for which management of wastes has become a pre–requisite. Physical as well as social factors in and around surroundings of man's environment includes land, water, atmosphere, climate, sound, odour and taste along with certain biological factors viz., animals, plants etc. These factors play significant role in regulations' formulation for appropriate management of biological wastes (Hegde et al., 2007; Centre for Environment Education and Technology, 2008).

Medical wastes in hospitals are otherwise known as clinical wastes. Normally, waste products is the term applied for those wastes which are produced in healthcare premises (hospitals and clinics; offices of doctors and veterinary hospitals) (National Research Council Recommendations Concerning Chemical Hygiene in Laboratories, 2013). So far management of wastes in medical profession was not considered an issue. In 1980s concerns have been raised regarding exposure to human immunodeficiency virus (HIV) and hepatitis B viruses (HBV). Disposal of biomedical wastes has thus become a major emerging problem in India and worldwide as well. There is urgent need for planning, implementation of procedures practices that are updated at various levels of plan concerning management of biomedical wastes associating it with health of the environment (Patnaik, 2007; Gautam et al., 2010).

Biomedical waste (BMW) is the waste produced during the process of sampling, testing, diagnosis, therapy, immunization and surgery of humans, animals, and in research experiments. This includes categories mentioned in Schedule I of BMW (Management and Handling) (second Amendment) Rules, 2000 amended by Ministry of Environment and Forests Notification. Common Biomedical Waste Treatment Facility (CBWTF) is a set up that necessitates biomedical waste treatment generated from numerous healthcare units reducing the adverse effects. It must be managed properly for protecting public particularly the healthcare and sanitation workers who are exposed to biomedical wastes on regular basis leading to occupational hazard. Wastes that are treated may be dispatched finally to dump in landfill or recycling.

Recently as a major concern biomedical waste management has emerged as an issue both to hospitals as well as authorities of nursing home and so also to the environment. From health care units the biomedical wastes that is generated depend upon several factors viz., methods of waste management; various types of units of health care; health care unit occupancy; health care unit specialization; reusable items and their ratio in use; infrastructure and resources and their availability (Mandal and Dutta, 2009). As a humanitarian topic the biomedical waste and their proper management has become a global issue. Worldwide hazards of biomedical wastes and their poor management have raised a concern especially on the ground of its far reaching effects on human as well as health and environment (**Govt. of India, 1998**). During the care of patients several hospital wastes are generated that have several harmful as well as adverse effects to the environment. To the workers associated with health care too hospital wastes possess a health hazard potentially. An increasing issue of concern to the hospitals as well as other health care workers is the problems of disposal of wastes (Sharma and Chauhan, 2008).

The objectives of biomedical waste management involve mainly prevention of disease transmission from one patient to another; to health workers from patients and vice versa; prevention of injury to the workers in health care units as well as workers involved in support services. This helps in turn in prevention of exposure to the deleterious effects of the cytotoxic as well as genotoxic and chemical wastes in general that are generated in the hospitals. Management of waste can be relatively effective as well as efficient practice that is related to compliance when designing is done properly (Pasupathi et al., 2011).

For implementation of the industrial programme for medical wastes a pilot project has been launched improving separation of hazardous as well as non–hazardous wastes that can cause reduction of wastes that are hazardous in this sector. Special type of containers (for medical wastes that are hazardous in nature) disposal have been used by various employees of the hospitals to dispose off various types of wastes that are harmless in nature (**Singh and Kaur, 2011**). Generation of medical wastes that are hazardous in nature can be significantly reduced by provision of on–site informations along with appointment of a training officer who acts as an in charge of continuing education for personnels in the hospitals.

As per the report of World Health Organization (WHO), among the non–hazardous materials 85% are hospital wastes; wastes that are not of hospital origin (rest 15%) are divided into two: infectious (10%); and non–infectious but wastes of hazardous nature (5%). This can range from 15 – 35% in the country like India that depends on generation of overall waste materials (Glenn and Garwal, 1999; Chitnis et al., 2005).

As far as the management of biomedical wastes is concerned its proper management has become a humanitarian topic worldwide. Hazardous and poor waste management (biomedical) has become a matter of concern particularly in the light of its effects that are far reaching affecting human and animal health and the environment (Sharma and Chauhan, 2008; Mathur et al., 2012). Present review discusses in brief the biomedical wastes and their management.

Definition of Biomedical Waste

As per Biomedical Waste (Management and Handling) Rules, 1998 of India, BMW is defined as "Any waste generated during the process of diagnosis and treatment or immunization of human beings or animals or in research activities contributing to the biological production or testing" (Govt. of India, 1998). One of the major achievements of India has been modification of the health operators' attitudes to accommodate in waste management concerning health care nicely in their operation routinely (Bekir Onursal, 2003).

Classification of Biological Wastes

Non–Hazardous Wastes

In most of the set–ups of health–care approximately 85% of generated wastes is constituted by non–hazardous wastes. This includes wastes constituting remnants of food and peels of fruit; wash water as well as paper cartons; packaging materials etc. (Hegde et al., 2007)

Hazardous Wastes

Potentially Infectious Wastes

In the scientific documents as well as in the regulations and guidance various terms for infectious wastes have been used over the years. These include: infectious as well as infective; medical and biomedical; hazardous and red bag; contaminated; infectious medical wastes; along with regulated wastes in the medical profession. Basically all these terms indicate the similar types of wastes even though the terms involved in regulation are defined usually in more specific manner (Block, 2001).

Biomedical Waste Management (Bwm) Rules and Schedules

Biomedical waste disposal is a legal issue. In 1998, Biomedical Waste Management & Handling Rules (1998) came into power in India. In agreement with such rules, it is the responsibility of each "inhabitant" to take all necessary steps to make certain that generated waste is managed / handled without any unfavorable human health effects as well as safeguarding environmental aspects too. Six schedules are included viz. schedule I–VI. Schedule I consists of 10 categories of biomedical waste. Category 1 consists of wastes in human anatomy that includes body parts as well as organs and body tissues. Category 2 consists of wastes from animals that includes parts of carcasses and bleeding along with fluids and bloods; animals kept for experimentation; hospital (both medical and veterinary) and animal house generated wastes. Category 3 consists of microbiological and biotechnological wastes from

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laboratory cultures; stocks or microbes; vaccines (live attenuated); human and animal cell cultures used for research activities; toxins; wastes from biological products; cell culture transferring dishes and devices. Category 4 consists of sharp wastes starting from needle and syringe till blade and glasses for puncturing and cutting. Category 5 consists of medicines and cytotoxic drugs that are discarded as they are backdated and contaminated. Category 6 consists of wastes that are soiled and include blood and body fluid contaminated wastes (cotton and dressings; plaster casts, lines and beddings that are soiled). Category 7 includes solid wastes produced from items that are disposable but not sharps (tubings, catheters and intra–venous sets). Category 8 consists of liquid materials viz., laboratory and washing generated wastes; during cleaning; and those generated from activities of housekeeping and disinfection procedures. Category 9 includes ashes that are incinerated. Category 10 consists of wastes generated during biological production along with those for disinfection (chemical wastes). Schedule II consists of coding of color and type of container used for management of biomedical waste. Schedule III comprises of Biomedical Waste Containers'/Bags' labels. Lastly, Schedule IV consists of Biomedical Waste Containers/Bags, labels required for transportation.

Constrains Associated with BMW Management

Due to adaptation of improper and indiscriminate manner of waste disposal by some health care centers, the biowaste regulation is not up to the mark. There has been admixing of wastes from hospital with wastes in general that has made streams dangerous. The consequence of this improper admixing ultimately resulted in incorrect waste disposal method. This in turn causes pollution of the environment along with impressible odour along with insects as well as rodents or worms growth. It ultimately favors transmission of diseases like typhoid, cholera, hepatitis and AIDS via injuries from contaminated sharps (CEET, 2008). This facilitates easy incoming movement of flies, insects, rodents as well as cats and dogs that widely spread the diseases like plague and rabies. It is thereby necessary to undertake waste management appropriately for maintaining good standard environment and lessening health hazards.

Steps in Waste Management

For effective management of biomedical wastes several steps are necessary to be followed from gathering of such wastes till disposal, which are briefed as below.

Waste Segregation

Segregation is a very important factor in waste management system. Depending upon the treatment and disposal option for various categories of wastes, specific colored containers are required to segregate and store these at temporary central storage place till disposal within 48 hours. The waste going for incineration or deep burial should be collected in yellow plastic bag or bin. The waste which is planned for autoclaving or microwaving or chemical treatment and finally to secured landfill or for recycling, should be collected in red or blue bin or bag. The waste sharps such as needles, blades *etc*. which are used for disinfection and destruction or shredding must be collected in white puncture proof translucent container, which will be encapsulated or can go for recycling as final disposal. The chemical waste (solid), out dated medicines and cytotoxic drugs which goes for disposal in secured land fill should be collected in black bin or bag with cytotoxic label. All the bins and bags should have biohazard label except on black colored bin or bag on which cytotoxic label need to be inserted (Ndiaye et al., 2003; Friends of the Earth, 2008).

This step also includes management of wastes of various kinds in several containers at the point of generation (reuse, recycle and reduction). Reuse of chemicals, medical equipments *etc*. translates into cost saving. Recycling of specific materials like disinfected and shredded plastic helps a secondary industry reducing generation of wastes that decrease cost of waste disposal. The spread of infection is contained through segregation thereby reducing the chances of health care workers' infection. Laceration or puncture injuries causing wastes need to be disposed of as "sharps" and they must be separated from rest of the wastes. Intermixing of sharp metals as well as glasses that are broken is permitted but not with waste that are non–sharp. Commingling of glass or plastic wastes with inflammable wastes or biological wastes with chemical wastes or certain laboratory trash must be avoided (Sita, 2004).

Waste Storage

The wastes must be stored like what is required as per the Biomedical Waste (Management & Handling) Rules, 1988. Between waste generation point and waste treatment and disposal site event of storage of wastes occur. There may be temporary withholding of biological wastes under refrigerated condition before safe disposal without causing problem aesthetically. Near the waste treatment sites location of storage areas are present. There must not be floor drains for containing spills which should be recessed for holding liquid. Imperviousness to liquid is required for floors and walls, with easy follow up of cleaning procedures. Regular disinfection is also mandatory. There is requirement for refrigeration for storing putrifiable and other wastes for a prolonged period of time. There must be a post in the storage area showing 'EXPLICIT' signs (Da Silva et al., 2005).

Containers and their Labeling

Non–leaky containers must be used along with proper labeling and maintenance of their integrity, provided treatment is done chemically and thermally. Containment for biohazardous material must be sealed. Use of containers that are leak–proof having the capability of withstanding thermal as well chemical treatment must be employed for chemicals. Rigid containers that are resistant to puncture and can be encapsulated well must be used for metal sharps for proper disposal and it must be able to withstand 40 psi pressure without getting ruptured. Plastic bags of heavy–duty standard or other such containers must be used for non–hazardous materials along with symbol of Biohazard. Biohazard bags of red or orange colour must not be used for materials that are non–hazardous. Rigid as well as puncture–proof containers must be used for pasteur pipettes as well as glasswares that are broken (plastic, heavy cardboard or metal) and sealing should be done in "Biohazard bags" that are made up of heavy–duty plastic and are autoclavable. No labeling is required unless there is any chance of recycling of the wastes and in such instances the

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container must be labeled as 'Do Not Recycle'. Wastebaskets must not be used for syringes that are loose or any other kind of sharps (Khan et al., 2001; Gayathri and Kamala, 2005). Each bag or container must have label that is backed by adhesive with generator information that are placed into the bags that contains medical wastes. Building services should provide with special labels having space for recording dates along with contact person and such labels must be applied to all the containers placed inside the medical waste boxes. Clear identification of every container of biohazardous wastes that are untreated along with their proper labeling with the symbol of Biohazard must be done **(United States Environmental Protection Agency, 2013).**

Handling and transport

Biomedical wastes must be collected and transported in a way of avoiding any possible peril to health of human and environment. Biohazardous waste that remains untreated must be handled or transported by only technical personnels who have undergone proper training. Soon after generation of the wastes segregation into containers or bags that are specifically color coded must be followed. Reducing the risk of needle prick injury and infection is required while handling these wastes. No other forms of waste should be mixed with biomedical waste. Transportation of untreated waste from the facility of generation to another treatment site and disposal is required if medical waste remains untreated on site (Kautto and Melanen, 2004; Marinkovic et al., 2005).

Following points need to be considering for transportation of BMW:

1. Split cabins should be provided for the vehicle carrier person and the containers of biomedical wastes.
2. Verification of the waste cabin base for leak proof quality.
3. Designing of the waste cabin must be done in such a way that it can be easily cleaned with disinfectants, and facilitates preserving containers of wastes in tiers.
4. Minimize water stagnation; the inner surface of the cabin should be smooth enough.
5. There should be provision for sufficient rear openings and/or sides for easy loading or unloading of waste containers.
6. Labeling of vehicle with BMW symbol is required.

Treatment and Disposal Methods

The basic principle involved in the treatment of biological wastes is that mutilation or shredding must be able to prevent unauthorized reuse. In the simplest form 1 per cent solution of hypochlorite is used for chemical treatment. On the other hand incineration procedure does not involve any pre–treatment. Procedure of deep burial is required in towns only wherein the population of human is less than 5 lakhs. Treatment of wastes moreover should be done as near to the point of origin as much as possible. Keeping all these points in mind the treatment and disposal methods of various kinds of wastes must be carried out cautiously and appropriately

1. Animal carcasses and body parts – Incineration, biodigestion or landfill.
2. Animal waste; solid (bedding, manure, *etc*)
   a. Animal waste (Biohazardous): Thermal or chemical treatment for incineration and disinfection.
   b. Animal waste (Non–hazardous): Using as compost or fertilizer.
3. Chemical waste: It should be treated by using 1% sodium hypochlorite solution or any other equivalent chemical agent thereby ensuring proper disinfection. After treating for liquids and securing landfills for solids discharging into drains is required (Saurabh and Ram, 2006).
4. Genetic material: National Institute of Health (NIH) guidelines must be followed for disposing off materials that contain recombinant DNA or organisms that are genetically altered.
5. Human pathological waste
   a. Dead body, recognizable body parts: cremation or burial for disposing off.
   b. Other solids – incineration or disinfection for discarding.
   c. Body fluids – disinfection by thermal or chemical treatment for discharging into the drain system
6. Metal sharps: Preventing laboratory as well as custodial and landfill workers' injuries metal sharps are needed to be discarded along with encapsulation. Needles, blades etc. possess the threat of biohazard even after sterilization or capping and in the original container. If there is requirement of autoclaving an autoclave indicator tape strip must be placed in container before the process of autoclaving. Rinsing of gas chromatography needles must be done for removing chemicals (hazardous) along with their disposal with glasswares that are broken (non–contaminated) (Patil and Pokhrel, 2004).
7. Microbiological waste: Treatment thermally or chemically is required for discharging into the sewer system.
8. Non–hazardous biological waste.
   a. Autoclaving or treating chemically all microbial products is necessary for good laboratory practice even if the materials are non–hazardous.
   b. Solid – Trash dumpster placement of the wastes.
   c. Liquid – Discharging into sewer system.
9. Plastic waste, pasteur pipets; glassware (broken): Disinfection by treating thermally or chemically or encapsulation and trash dumpster placement if there is contamination with biohazardous material. If these are not contaminated, place in a trash dumpster. Glassware and plastics should not be incinerated (Ravikant et al., 2002).
10. Radioactive waste: Freezer temperatures are required for withholding animal carcasses that are radioactive for decaying for their half–lives (ten). Health physics/ programme for radiation safety must be implemented especially for metal sharps that having radioactive materials' contamination. Packaging and shipping of carcasses containing long–lived radionuclides is mandatory by Federal as well as State authorities and are needed to be sent to a repository site where nuclear materials are approved.

The radiation safety requirement generally while disposing off wastes that are radioactive in nature is that the degree of exposure to radiation of the waste treatment plan at large or personnel should not exceed the following values: as an effective dose 0.01 mSv a year. The preparation of waste treatment plan is required to be done by a responsible party who can discharge into the sewer system or environment radioactive material.

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For generators that dispose medical wastes the methods of disposal that are followed include truck service on site and mail–back disposal. Treatment on site uses equipments that are very expensive and only large hospitals carry out such activities. Medical wastes are hired by truck services having trained employees for collecting medical wastes in containers that are special. Treatment is carried out in an area that is planned to hold a huge concentration of medical wastes. Similar is mail back disposal of medical wastes except the fact that shipping of the wastes is done through postal services instead of haulers (private) (**United States Environmental Protection Agency**, 2013).

Waste Minimization

Preventing waste material (also known as waste reduction) is a significant method of management of wastes. Manufacturing processes in industries can be used more efficiently and materials that are of better quality will result in reduction of waste production. The techniques involving minimization of waste materials and their application technique has led to innovative as well as commercially successful replacement products' development. Minimization of wastes has been proven beneficial to industries and helps in creating value along with increasing work quality (Royal Commission of Environmental Pollution, 2007). The methods of avoidance include re–using of second–hand products, repairing of broken items instead of buying new designer products, ability of their refilling and reusing. Consumers get encouraged by that way to avoid disposable products' use; removing any remains of food/ liquid from cans; for using lesser material for packaging as well as designing for achieving the same purpose (Kvist et al., 2004; Rao and Prabhakar, 2013).

Technologies Associated with Treatment and Disposal of Biomedical Wastes

Incineration

This is considered as a thermal process requiring high temperature under controlled waste combustion conditions in order to convert them into materials that are inert in nature along with gases. For hospital wastes use of three different kinds of incinerators are in vogue: multiple hearth type; rotary kiln and air types (controlled). Both primary as well as secondary combustion chambers are provided in all the three types ensuring combustion at optimal level. These are interestingly refractory lined (Gravers, 1998). Most of the wastes in the medical hospitals are incinerated but the solid as well as medical wastes that are regulated are burnt in reality thereby creating problems to the health care workers. Incinerators (medical wastes) use to emit air pollutants that are toxic in nature as well as residues of toxic ashes that possess in the environment the major source of dioxins. In the landfills the toxic ashes that are sent for disposing have got the potential of leaching into the ground water. For avoiding production of dioxin plastic bags that are non–chlorinated are required to be introduced into the incinerator. Incineration of red bags must be avoided as cadmium is present in red colour causing toxic emissions as if a red bag is filled in with items that contain mercury for the wastes that are infectious environment will be contaminated by mercury (Singh et al., 1996).

Non–Incineration

Four basic processes are included in non–incineration treatment viz., thermal and chemical, irradiative and biological. Thermal as well as chemical processes are employed in majority of the non–incineration technologies. Decontamination of wastes by destruction of pathogens is the most important purpose of this treatment technology. In order to meet the state criteria of disinfection facilities should be provided (Thornton et al., 1996).

Plasma Pyrolysis

Direct use of waste products as combustion fuel or their indirect processing into another kind of fuel helps in harnessing the energy contents. In this context pyrolysis has been found as a related form of thermal treatment wherein high temperatures are used for treating waste materials with limited supply of oxygen. A state–of–the–art is plasma pyrolysis technology that ensures disposal safe of medical wastes. It is an environment–friendly technology converting organic wastes into byproducts that are commercially useful. Disposal of various types of wastes that include solid waste of municipality, biomedical waste and hazardous waste safely as well as authentically are enabled by plasma generated intense heat. Pyrolysis of medical wastes into carbon–mono–oxide and hydrogen, hydrocarbons is possible when it comes in close contact of plasma–arc. Such gases generate high temperature (1200 °C) when burned (Surjit et al., 2007).

Accumulation of Wastes and their Storage

Between the generation point of wastes and treatment of waste sites, waste disposal accumulation and their storage occurs. Wastes when temporarily held in small quantities are referred to as accumulation while waste storage is characterized by holding period for longer period and large quantity of wastes. The location of treatment of wastes needs to be in vicinity to storage areas. Storage also includes any offside holding of wastes. Floor drains should be avoided in order to contain spills and must be recessed. Impervious nature of floors and drains are mandatory that helps to easily contain liquid and cleaning also becomes easy. For prolonged storage refrigeration is necessary in case of putrifiable as well as other wastes. 'EXPLICIT' signs must be posted in the storage area (Hegde et al., 2007).

Potential Implications of Biomedical Wastes

- Greatest infectious risk due to biomedical wastes is associated with containment of sharps improperly resulting in Hepatitis B, C, E and HIV transmission.
- The dumping of untreated biomedical waste in municipal bins may increase the chance of survival along with proliferation and mutation of pathogenic microbial population in such wastes. This causes epidemics as well as increased incidence and prevalence of communicable diseases in the community.
- Pathogen associated health risk may lead to aerosolization during the processes of compacting, grinding or shredding which is seen in association with certain management of wastes of medical profession or with practices of treatment.
- There is also association of physical injury as well as hazardous health with the temperatures of incinerators as well as steam sterilizers that are highly operating along with poisonous gases that are emitted into the atmosphere post treatment of wastes.

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- There is confinement of the public impact to degradation esthetically in the environment that prevents disposal as well as environmental impact of incinerators that are operated improperly or other equipments that are used for treating biomedical wastes.
- Poor management of wastes leads to enhanced risk of nosocomial infections.
- Chances of vectors becomes high like that of mosquitoes, flies, cats, rats and stray dogs getting infected or becoming carriers which can spread diseases among the public.
- Management of waste improperly can lead to microbial ecological changes and spread of resistance to antibiotics.
- Preparation of contingency plans is must for health care facilities to deal with refrigerated or frozen waste storage. If wastes are produced in excess then the facilities of disposal or equipments become inoperative and thus special care must be taken in this regard.

CONCLUSION

Management of biomedical wastes is one of the major social responsibilities of individuals as well as Government / State officials. For proper management of biomedical wastes lack of concern and awareness as well as cost factors are the certain problems/limitations. Therefore general public should be educated and must be concerned regarding health hazards that are associated with biomedical wastes. Ultimately, sensitizing ourselves is of utmost importance for protection of environment and our own health. Thus the knowledge on BMW is of general interest for the community as a whole rather the health associated employers. In the present day world of one health the proper management of biomedical wastes is of significant importance. This will ensure maintenance of ecological balance; biodiversity as well as health of global community as a whole.

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