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Role of Biotechnology in Biomedical Waste Management for Sustainable Development

Abstract

Management of biomedical waste is a central issue for human health, safety and the environment. The waste generated in the hospitals has the potential for spreading infections and causing diseases. Unregulated biomedical waste management (BMWM) is a public health problem. Safe and effective methods for handling of biomedical waste (BMW) are vital for public health. It is not only a legal necessity but also a social responsibility. This article reviews the current outlook on BMWM and rules, conventions and the treatment technologies used worldwide. Now BMWM should be the subject of a national strategy with dedicated infrastructure, cradle-to-grave legislation, competent regulatory authority and trained personnel. Civilizing the management of biomedical waste begins with waste minimization. These standards, norms and rules on BMWM in a country regulate the disposal of various categories of BMW to ensure the safety of the health-care workers, patients, public and environment. Furthermore, developing models for the monitoring of hospital health-care waste practices and research into eco-friendly sustainable technologies, recycling and polyvinyl chloride-free devices will go in long way for safe carbon environment. Globally, greater research in BMWM is warranted to understand its growing field of public health importance.

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Keywords: Biomedical Waste Management (BMWM), Gujarat Pollution Control Board (GPCB), Common Bio-Medical Waste Facilities (CBMWF), Global Positioning System (GPS), World Health Organization (WHO), Health-care facility (HCF), Environment Protection Act (EPA), 1986, Stockholm Convention on persistent organic pollutants (POPs), 2004, NIMBY (Not In My Back Yard), less developed countries (LDCs), Best available techniques (BAT) guidelines and promote best environmental practices (BEP), polyvinyl chloride (PVC)-free medical devices, Department of Atomic Energy (DAE), Ministry of Environment and Forest and Climate Change (MoEF& CC).

Introduction

Biomedical waste (BMW) is any waste produced during the diagnosis, treatment, or immunization of human or animal research activities pertaining thereto or in the production or testing of biological or in health camps. It follows the cradle to grave approach which is characterization, quantification, segregation, storage, transport, and treatment of BMW.

Objective of the Study

The objective of this research is to discuss the biomedical waste management practices, internationalagreements and conventions to that effect and regulatory framework in India. Further, it aims at Scientific methodologies employing biotechnology and emphasis is given towards the goal of sustainable development/production and particular attention is given to: regulatory consideration and trends; characterization of toxics for resource reuse; eco toxicological assessment evaluations; treatment trends and innovative techniques, residual management.

Review of Literature

This article reviews the recent BMWM (Amended) rules, 2018 practical problems for its effective implementation, the major drawback of conventional techniques, and the latest eco-friendly methods for BMW disposal. The new rules are meant to change the dynamic of BMW disposal and treatment in India. For effective disposal of BMWM, there should be a collective teamwork with committed government support in terms of finance and infrastructure development, dedicated health-care workers and health-care facilities, continuous monitoring of BMW practices, tough legislature, and strong regulatory bodies.Besides, a lot of research and development need to be in the field of developing environmental friendly medical devices and BMW disposal systems for a greener and cleaner environment.The Government of India comesup with "The National Action Plan for Municipal Solid Waste Management"[1] wherein the serious concern over the conditions of waste management and strategies of disposal in various Indian cities and towns were identified.[2] Further, underlining the effort to protect the environment and human health from infectious bio-medical waste, Union Minister for Environment, Forest and Climate Change, Dr. Harsh Vardhan has said that Bio-Medical Waste Management Rules, 2016 Rules have been amended[3] to improve compliance and strengthen the implementation of environmentally sound management of biomedical waste in India. Dr. Harsh Vardhan pointed out that the amended rules stipulate that generators of bio-medical waste such as hospitals, nursing homes, clinics, and dispensaries etc will not use chlorinated plastic bags and gloves beyond March 27, 2019 in medical applications to save the environment. The Minister added that Blood bags have been exempted for phase-out, as per the amended BMWM rules, 2018.[4]

The research methodology which the researcher has adopted in preparing this work is primarilydoctrinal in nature. Also there have been analytical discussion supported by well thought out original issues in thecourse of preparation. In order to have deep understanding about various facets of Biomedical Waste management strategies and legal System, various committees report issued by Govt. of India, legislations and proposedamendments, journals, articles, case repositories, newsletters etc. has been studied &analyzed.Efforts have also been made to incorporate the latest facts & figures from the statisticsavailable on the relevant site of Govt. of India & elsewhere.

The basic principle of good BMW practice is based on the concept of 3Rs, namely, reduce, recycle, and reuse. The best BMW management (BMWM) methods aim at avoiding generation of waste or recovering as much as waste as possible, rather than disposing. Therefore, the various methods of BMW disposal, according to their desirability, are prevent, reduce, reuse, recycle, recover, treat, and lastly dispose. Hence, the waste should be tackled at source rather than "end of pipe approach."[5]

In a World Health Organization (WHO) meeting in Geneva, in June 2007, core principles for achieving safe and sustainable management of health-care waste were developed. During this meet special emphasis was given on right investment of resources, complete commitment and strategic assessment and management of health-care waste and how to minimize its impact over people and environment. Further, all stakeholders associated with this process should share in the cost of proper management of BMW and the responsibility of manufacturer to produce environment-friendly medical devices to ensure its safe disposal. WHO reinforced that separate allocation of funds should incorporate as the budget for creation, support, and maintenance of efficient health-care waste management system. These include novel and ingenious methods/devices to reduce the bulk and toxicity of health-care waste. Nongovernmental Organization should undertake program and activities that contribute in this incentive.[6]

Since the 1970s[7] biotechnology has attracted the most attention. It has influenced almost every significant sector of the economy. It has considerably affected healthcare; production and processing of food; agriculture and forestry; environmental protection and production of materials and chemicals. In biotechnology, a biological material is used to realize a product in commercial scale. As a result of increasing interest to these biotechnological processes, many institution and work groups define biotechnology separately. [8]

For preventing environmental pollution and processing wastes some lucid and less expensive methods are required. In this regard intensive research and development activities/studies are done continuously on inventing new processes. Among these research studies, microbiological processes are one of the most interesting topics wherein micro-organisms (or their parts) are used to make or to modify products or in which new micro-organisms are developed for specific uses.[9] The objectives of these processes are the degradation of wastes and the occurrence of new products. The living organisms used in this method are yeasts, bacteria, fungus and algae. The board defined the term "micro-organism" as including not only bacteria and yeasts, but also fungi, algae, protozoa and human, animal and plant cells, i.e. all generally unicellular organisms with dimensions not visible to the naked eye which can be propagated and manipulated in a laboratory, including plasmids and viruses. The products and processed waste materials obtained by these processes are very different and they exhibit diversities from one country to another. Biotechnology has various application fields ranging from waste treatment to medical treatment of cancer. A cleaner environment, advanced methods of diagnosis and medical treatment, better products and alternative energy resources can be considered among the benefits of biotechnology. Nowadays, environmental pollution is one of the most important problems in all world countries. Biotechnology offers many treatment methods to overcome this pollution problem. In this paper, removal of wastes by biotechnological treatment is examined in depth and some examples are given to the treatment studies of wastes by biotechnological processes in environmental management.

Biotechnology in Environment Management[10]

Environmental pollution occurs by deterioration of natural equilibrium of environment via various human activities. Nowadays, environmental pollution is the most important problem for all world countries. Pollution existed since the beginning of industrialization and grew by the parallel of rapidly increasing industrialization after World War II. Precautions were taken after 1970s for preventing and reducing this pollution. Biotechnology finds application fields in the treatment of wastewaters by biological methods and disposal of solid wastes by composting technique in environmental engineering. Biological methods are also applied to treatment of air emissions. The methods based on biotechnology in wastewater treatment are activated sludge, trickling filters, oxidation ponds, bio filters and anaerobic treatment. Furthermore, solid waste composting techniques, bio trickling filters and bio sorption are the examples of biotechnology applications in environmental engineering. In all these methods, it is essential to find suitable microorganisms that will degrade organic substances and to complete the treatment process in favorable conditions. Some biotechnological applications used in environmental engineering for waste treatment will be discussed below.

Expansion of health-care facilities as well as the recent trends of using plastic disposables and increase in medical and surgical interventions has led to unprecedented burden of biomedical waste (BMW). In a major boost to safeguarding public health from irresponsible biomedical waste disposal and related hazards, the new Bio-Medical Waste (Management and Handling) Rules[11] now require a bar code system for identifying bags or containers carrying biomedical waste, and a GPS system to track the movement of the containers. The system was originally suggested and implemented by Gujarat Pollution Control Board (GPCB), and would now be replicated across the country, said GPCB officials.[12]

The new rules have also made formation of advisory committees for disposal of biomedical waste at state and district levels. The respective committees have to meet at least once in six months. The GPCB was the first to come up with the system while implementing the guidelines for biomedical waste disposal over a year. State of Gujarat has about 21 incinerators and 14 Common CBMWF [Common Bio-Medical Waste Facilities] to dispose biomedical waste.[13] However, to address the question of illegal dumping, GPCB deployed the method to ensure containers of biomedical waste as well as vehicles carrying them could be tracked by GPS.

According to the new rules applicable to the entire country, bar codes and global positioning system tracking are to be arranged for individual containers by the organization or person getting rid of the biomedical waste. This would help to check whether the waste has been disposed of properly and whether the container has deviated from the route.

The new rules further state that the operator of common biomedical waste treatment facility shall transport the biomedical waste from the premises of an occupier to any offsite biomedical waste treatment facility only in the vehicles and containers, which have been properly labeled.

The new rules also state that untreated human anatomical waste, animal anatomical waste, soiled waste and, biotechnology waste shall not be stored beyond a period of 48 hours, while microbiological waste and all other clinical laboratory waste shall be pre-treated by sterilization before packing and sending to the common biomedical waste treatment facility.

A nationwide survey performed by International Clinical Epidemiology Network[14] in 25 districts across 20 states highlighted that only two big cities in India, Chennai and Mumbai, had comparatively better system for BMWM.[15] Improper pretreatment of BMW at source and improper terminal disposal was the major challenges observed. It was observed that around 82% of primary, 60% of secondary and 54% of tertiary care health facilities were in the red category, i.e., the absence of a credible BMWM in place or ones requiring major improvement. According to the studies conducted by the World Health Organization (WHO) in 22 developing countries showed that the proportion of health-care facility (HCF) that do not use proper waste disposal methods range from 18% to 64%.Of the total amount of waste generated by health-care activities, about 85% is general, non-hazardous waste comparable to domestic waste. The remaining 15% is considered hazardous material that may be infectious, chemical or radioactive. WHO developed the first global and comprehensive guidance document, Safe management of wastes from health-care activities, and a short guide that summarizes the key elements for effective bio medical waste management in respective countries. In India, annually about 0.33 million tons of BMW is generated and rate ranges from 0.5 to 2.0 kg per bed per day. The poor BMWM practices are attributed to lack of awareness and training as was concluded in a recent study.India was one of the first countries to implement BMWM rules in 1998 (amended as draft in 2003, 2011, 2016& 2018) under Environment Protection Act (EPA), 1986. India was signatory to an international legally binding and environmental treaty, Stockholm Convention on persistent organic pollutants (POPs), 2004[16] that aims to eliminate or restrict production of POPs.

The Ministry of Environment Forests and Climate Change, Government of India, notified the BMWM Amended rules, 2018 on 16th March 2018, [17] under the provisions of EPA, 1986. These rules fill up the gaps in the old rules to regulate the disposal of various categories of BMW. Safe and reliable methods for handling of BMW are of paramount importance. Effective BMWM is not only a legal necessity but also a social responsibility

BMW is any waste, which is generated during the diagnosis, treatment or immunization of human beings or animals or in research or in the use of biological or in health camps. It involves all persons who generate, collect, receive, store, transport, treat, dispose or handle biomedical waste in any form.

Classification

Hazardous health-care waste includes sharp waste, infectious waste, pathological waste, pharmaceutical waste, cytotoxic waste, chemical waste, liquid infectious waste, radioactive waste, and general health-care waste.

International Agreements and Conventions

The Basel Convention on the Control of Transboundary Movements of Hazardous Wastes and Their Disposal, 1992[18]

It is an international treaty that was designed to reduce the movements of hazardous waste between nations, and specifically to prevent transfer of hazardous waste from developed to less developed countries (LDCs). It does not, however, address the movement of radioactive waste. The Convention is also intended to minimize the amount and toxicity of wastes generated, to ensure their environmentally sound management as closely as possible to the source of generation, and to assist LDCs in environmentally sound management of the hazardous and other wastes they generate.

The Basel Convention on the Control of Transboundary Movements of Hazardous Wastes and their Disposal was adopted on 22 March 1989 by the Conference of Plenipotentiaries in Basel, Switzerland, in response to a public outcry following the discovery, in the 1980s, in Africa and other parts of the developing world of deposits of toxic wastes imported from abroad.

Awakening environmental awareness and corresponding tightening of environmental regulations in the industrialized world in the 1970s and 1980s had led to increasing public resistance to the disposal of hazardous wastes – in accordance with what became known as the NIMBY (Not In My Back Yard) syndrome – and to an escalation of disposal costs. This in turn led some operators to seek cheap disposal options for hazardous wastes in Eastern Europe and the developing world, where environmental awareness was much less developed and regulations and enforcement mechanisms were lacking. It was against this background that the Basel Convention was negotiated in the late 1980s, and its thrust at the time of its adoption was to combat the “toxic trade”, as it was termed. The Convention entered into force in 1992.

The Stockholm Convention, 2004[19]

The Stockholm convention is a global treaty to protect human health and the environment from persistent organic pollutants (POPs). POPs are chemicals that remain intact in the environment for long periods, become widely distributed geographically, accumulate in the fatty tissue of living organisms and are toxic to humans and wildlife. POPs circulate globally and can cause damage wherever they travel. In implementing the Convention, Governments will take measures to eliminate or reduce the release of POPs into the environment. Over 152 countries ratified the Convention and it entered into force, on 17 May 2004.

It is essential to reduce or eliminate releases of POPs by incinerators and other combustion processes through best available techniques (BAT) guidelines[20] and promote best environmental practices (BEP) for new incinerators within 4 years. The training, collection, transport, source reduction, segregation, resource recovery and recycling are BEP. The BAT guidelines for BMW incinerators and waste water require in achieving air emission levels of dioxins and furans no higher than 0.1 ng I-TEQ/Nm3 and aims at alternative technologies.[21]

Aarhus Convention of the United Nations Economic Commission for Europe, 1998[22]

This convention focuses on access to information, public participation in decision-making and aims at access to justice in environmental matters and rights.

The International Solid Waste Association[23]

It is an independent, international and non-profit making association and aims to promote and develop sustainable and professional waste management worldwide.

WHO guidance[24]

The WHO policy paper suggests that government organisations adopt recycling, polyvinyl chloride (PVC)-free medical devices, risk assessment and sustainable technologies to promote environmentally sound management of BMW.

Biomedical Waste Management Amended Rules, 2018 (Ministry of Environment Forests and Climate Change)[25]

The ambit of the rules has been expanded to include vaccination camps, blood donation camps, first aid rooms of schools, forensic laboratories, medical colleges, research laboratories, household BMWs and other such camps/programmes, any other health-care activity related to any system of medicine, apart from HCF. Duties of occupier, common biomedical waste (CBMW) management disposal facility and authorities are delineated better.

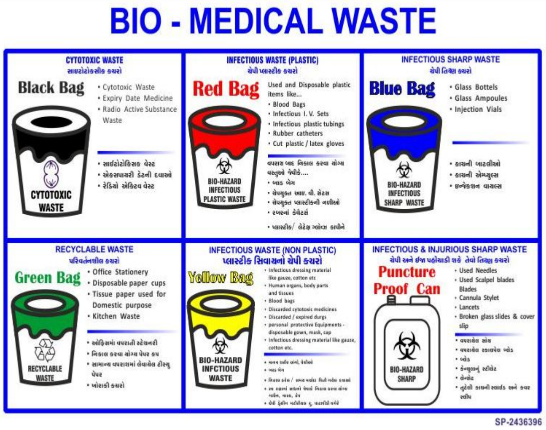
The occupier ensures the pretreatment of the laboratory waste, microbiological waste, blood samples and blood bags through disinfection or sterilization on-site in the manner as prescribed. Occupier provides training, immunization, health check-up and occupational safety to all its health-care workers (HCWs). The major accidents are also reported to the prescribed authority and in the annual report. The occupier establishes a system to review and monitor the activities related to BMWM a committee. The occupier and CBMWTDF are liable for damages caused to environment or public due to improper handling BMW.

In BMWM rules, emission standards and other standards of equipment, effluent, pits are delineated. For traceability of the BMW, bar coding and GPS are introduced. Emphasis has been laid on accident reporting, records and website related to BMW. In the final disposal technologies, sustainable, eco-friendly (plasma pyrolysis), green technologies, newer technology, waste to energy options and recycling (authorised recyclers) are mentioned

Risks Associated With Biomedical Waste

The main groups of individuals at risk are HCWs, scavengers and the public. The microbial infections caused by exposure to BMW and samples include systemic and local infections. Mercury, disinfectants and pesticides affect multi systems. Improper handling of sharps can lead to needle stick injuries thereby leading to infections with blood-borne pathogens such as HBV, HIV and HCV, etc. The hazards of cytotoxic and radioactive waste include headache, dizziness, vomiting, tissue destruction, geno toxicity, death and ecological disturbances. It can cause malignancies, fetal malformation, cardiac and respiratory disorders.

Management of Biomedical Waste[26]



Segregation

The essential aspect of waste-segregation system is to separate all hazardous waste from the larger quantity of non-hazardous general waste. The waste is segregated into different fractions based on their potential hazard and disposal route and separate containers should be available for each segregated waste fraction.

Special Category of Waste Disposal

Mutilation of Plastics and Sharps

To prevent reuse of plastics and sharps, mutilation is required on-site before transportation to CBMWTF. A needle destroyer or hub-cutter is used to destroy/mutilate the needles, and then, the later are put into the tamper proof, leak proof, puncture proof container. All the plastic items, intravenous (IV) bottles, urobags, drains and gloves are given a nick or clipped immediately after use, wherever applicable, by the dedicated pair of scissors placed in the area to prevent reuse, and then, they should be disposed in a red bag. Each bag is labeled and securely tied when three-fourth full and then handed over to CBMWTF for recycling.From the novel technique of encapsulation, the recycled sharps can be used for benches, hangers, bricks, etc.

Discarded Medicines (Cytotoxic Drugs and Antibiotics)

Cytotoxic wastes including all items contaminated with cytotoxic drugs are put in a non-chlorinated yellow container, sealed and labeled as cytotoxic. After expiry dates, Cytotoxic drugs to be returned to the manufacturer or supplier for incineration at temperature > 1200°C. The antibiotic and other drugs are discarded in yellow bag with biohazard label. Dilution in water and discharge into a sewer for solutions containing vitamins, cough syrups, IV solutions and eye drops, salts, amino acids is recommended.

Mercury and Lead Waste

The mercury and lead waste generated are contained and then handed over to authorised vendors and covered under the respective rules. The WHO guidelines on mercury lay stress on safe mercury clean-up, handling and storage procedures, and replacing mercury-containing products with mercury-free alternatives in the long term.

Disposal of Radioactive Waste

The waste management activities for both radioactive and chemical wastes generated from nuclear power plants and other nuclear fuel cycle facilities are in the purview of the regulatory body. The waste management in industrial and research facilities of DAE also are under AERB's purview. Radioactive wastes generated in the medical facilities using radioactive source for diagnostic and/or therapeutic applications also have to meet safety requirements stipulated by AERB.[27] Infectious radioactive waste required to be decontaminated after containment by decay time (ten times the half-life) in an isolated, identified and designated room site before final disposal as BMW. Low-level radioactive waste can be discharged in sewers.

Liquid Chemical Waste

Liquid waste generated due to the use of chemicals in production of biological, used or discarded disinfectants, infected secretions, aspirated body fluids liquid from laboratory, labour room, operation theatre, floor washings, cleaning, housekeeping and disinfecting activities should be collected separately and directed to effluent treatment plant (ETP). The infected body secretions such as blood and faces should be pre-treated and then disposed of in ETP. Silver X-ray film developing liquid, after resource recovery, the chemical liquid waste needs to be pre-treated before mixing with waste water.

Laboratories

The blood sample glass vials or broken or discarded and infected glass need to be disinfected/autoclaved, (pretreatment), wherever applicable and then packed in cardboard boxes with plastic liner with blue-colored marking and sent to CBMWTF for autoclaving or microwaving for final recycling. The non-infected glass does not need on-site pretreatment.

Microbiology, Biotechnology Waste And Infectious Waste

Laboratory waste including microbiology laboratory cultures, stocks or specimens of microorganisms and infectious waste of patients in isolation have to be pre-treated on site by autoclaving in an autoclave safe plastic bags or containers as per the WHO guidelines there after sent for final disposal of autoclaved hazardous waste in yellow bag to CBMWTDF for incineration.

Blood Bank

The discarded blood bags are to be counted, sealed, weighed and all the records to be made then packed in autoclave-safe plastic bags or containers to be autoclaved on site and then these are sent for incineration.

Packaging, Labeling and Transport To Common Waste Site

All the biomedical wastes are labeled as waste type, site of generation, date of generation before transportation from the generation site. BMW is transported through designated route, on dedicated, colour coded, covered and leak proof trolleys on fixed and at reliable time and stored in a common waste site. From common waste site, it is then transported to CBMWTF for the final treatment and disposal. No untreated BMW is kept stored beyond a period of 48 h.

Each patient care area has been provided with the waste receipt book to record the quantity/number of yellow, blue, red, white (translucent) bags handed over to HCW. All the staff is required to duly fill in the waste book colour code wise mentioning the number and size of bags handed over and signs the slip for further record.

Transport staff should wear adequate personal protective equipment. The central storage site is cleaned once a week. It should have an impermeable, hard standing floor with good drainage, include the facility to keep general waste separated from BMW, have an exhaust and water supply as per the WHO guidelines.

Transportation to common biomedical waste treatment facility

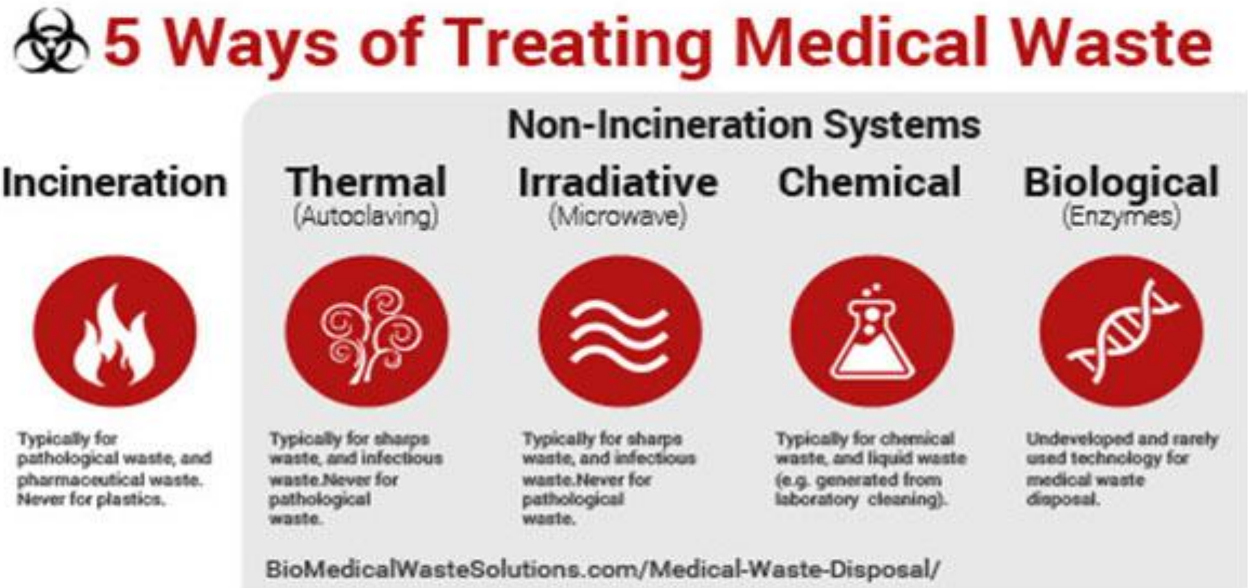
The operator of CBMWTF shall transport the BMW from the premises of HCF to any off-site CBMWTF only in the vehicles complying as per the existing rules of the country or as per the United Nation norms. The body of the vehicle should be of a suitable size to carry secured load and it should have BMW articles, PPE and cleaning equipment. It should be marked with the name and address of the waste carrier, hazard sign.

Minimal Approach to Biomedical Waste Management

Minimal approach in BMWM includes reducing, reusing and recycling, arrangements for waste storage and transport, expenses in the annual budgeting; separate chemical and pharmaceutical waste segregation and storage management, separate storage zones and documentation related to BMWM.

Waste Treatment Technologies

The waste treatment technologies include thermal, chemical processes, irradiation technologies, biological processes, disinfection and sterilization.[29]



Thermal: Autoclaves: Steam Treatment Technologies

Autoclaves sterilize a range of infectious waste (cultures, stocks, sharps, materials contaminated with blood and fluids), laboratory waste and linen waste, medical instruments and for the treatment of BMW. Unlike instrument sterilization autoclaves, waste-treatment autoclaves (prevaccum autoclaves) must treat the air that is removed at the start of the process to prevent the release of pathogenic aerosols through a high-efficiency particulate air filter before it is released and therefore require less time for action and have greater efficiency.

The autoclaves should be able to withstand the repeated build-up and release of steam pressures and should have construction materials, engineering design, fabrication, accuracy of pressure and temperature sensors, and testing must meet basic requirements to operate safely as per the international standards related to pressure vessels including EN 13445, EN 285 and ASME. The operation of autoclave requires a minimum of recommended temperature–exposure time criterion of 121°C for 30 min, pressure of 205 kPa or 2.05 bar (15 psig or 30 psia). After the initial tests, regular validation tests using biological indicators (weekly), Bowie-Dick test (for prevaccum autoclaves with every batch) and thermochromics strips should be performed at periodic intervals.

Autoclaves for medical devices often use trays or stainless steel baskets, while waste autoclaves use autoclavable carts or bucket-shaped open containers into which the plastic waste bags are stacked. Depending on the type of plastic bags used, some bags may melt and stick to the surfaces of the cart or container. Use of autoclavable plastic bags or liners that prevent sticking is an option. A post-treatment shredder or grinder could be used if the waste is to be rendered unrecognizable and if reduction of waste volume is desired. Advanced single- or multiple-shaft shredders specially made for medical waste can reduce waste volume by about 80%. The advanced shredders are typically low-speed, high-torque, single-pass shredders with easily replaceable cutters and with discharge screens to control the size of shredded waste.

Microwave Treatment Technologies

Microwave technology is a steam-based process where the treatment occurs through the action of moist heat and steam generated by microwave energy with a cycle of 30 min to 1 h. The types of waste treated are cultures and stocks, sharps, materials contaminated with blood and body fluids, other infected waste, laboratory waste and soft waste (e.g., gauze, bandages, gowns and bedding). Microwave treatment should not be used for cytotoxic, volatile compounds, hazardous or radioactive wastes, contaminated animal carcasses, body parts and large metal items. Biological indicators for microwave are *Bacillus atrophaeus* spores using vials or spore strips with at least 10^4 spores.

Dry heat treatment technologies

Hot air ovens have been used to sterilize glassware and other reusable instruments and infectious health waste. The waste is heated by conduction, natural or forced convection or thermal radiation at higher temperatures (up to 185°C) and longer exposure times (90–150 min) than steam-based processes. It should completely and consistently kill the biological indicator GeobacillusStearothermophilus hilus or B. atrophies' spores using vials with at least $\log10^6$ spores per ml or by a chemical indicator strip.

Sodium hypochlorite (NaOCl, 1-12%)

Chemical disinfection is most suitable for treating liquid waste. Recently, commercial, self-contained and fully automatic systems have been introduced which are more reliable than the manual autoclave.

Chemical Disinfectants

The disinfectants used are chlorine compounds, aldehydes, lime-based powders or solutions, ozone gas, ammonium salts and phenolic compounds.

Sodium hypochlorite (NaOCl, 2%–12%): It is active against bacteria, viruses and spores, not effective for disinfection of liquids with high organic content, (blood or stool) and is widely used owing to relatively mild health hazards. Unused solutions should be reduced with sodium bisulphite or sodium thiosulphate and neutralised with acids before discharge into sewers. PPEs should be worn to protect HCWs. Chlorine dioxide is an alternative to hypochlorite. It is a toxic but soluble and stable in water and can be generated onsite. Lime-based chemical treatment systems use dry powder or calcium hydroxide solutions. Glutaraldehyde and peracetic acid are used to disinfect instruments.

I*ncineration*

Incineration is an increased temperature, dry oxidation process that reduces organic and combustible waste to inorganic, incombustible matter and results in a significant reduction of waste volume and weight, at temperatures from 600°C to more than 1000°C through combustion, pyrolysis or gasification under standard conditions. Its disadvantages include release of combustion by-products (dioxins and furans) and residual ash. The incinerator emissions should comply with national standards and in accordance with the Stockholm Convention BAT and BEP.

The waste types which are not included for incineration are pressurized gas containers; reactive chemical waste; silver salts and photographic or radiographic wastes, PVC plastics, heavy metals, batteries, sealed ampoules or vials, radioactive materials, unstable pharmaceuticals.

Encapsulation and Inertisation[30]

Encapsulation involves filling containers (polyethylene/metallic) with waste, adding an immobilizing material (plastic foam, bituminous sand, cement mortar, or clay) and sealing the containers. It is used for pharmaceuticals and for incineration ashes with a high metal content. Following filling, the containers are sealed and placed into landfill sites to prevent scavengers gaining access to it and prevention of percolation into groundwater.

Emerging Technologies

Emerging technologies include plasma pyrolysis, alkaline hydrolysis, superheated steam, ozone and promession. Plasma pyrolysis makes use of an ionized gas in the plasma state to convert electrical energy to temperatures of several thousand degrees using plasma torches or electrodes with minimal or no air. It is used to break down pathological waste, infectious, plastic, hazardous chemical or pharmaceutical wastes. It is safe, eco-friendly, has energy recovery and has negligible harmful emissions of dioxins and furans. Production of clean alloyed slag which could be used in construction material and value added products such as metals. Its disadvantages include large initial investment costs, carbon dioxide pollution, large electrical energy input, and highly corrosive plasma flame leading to frequent maintenance. Ozone (O3) can be used for especially pharmaceutical waste, water and air treatment. It is a strong oxidizer and breaks down to a more stable form (O2). Ozone systems require shredders and mixers to expose the waste to the bactericidal agent. Regular tests should be conducted to ensure that the microbial inactivation standard is met.

Promession

It includes freeze-drying using liquid nitrogen and mechanical vibration to disintegrate cadavers into powder before burial. The process speeds up decomposition, reduces both mass and volume and allows the recovery of metal parts.

Alkaline Hydrolysis

It is a process that converts body parts, specimens and cadavers into a decontaminated aqueous solution and destroys fixatives, hazardous chemicals and waste contaminated by prion. After the waste is loaded in the basket and into the hermetically sealed tank, alkali is added along with water at temperature of 127°C or higher and stirred. After digestion time of 6–8 h, by-products include mineral constituents of bones and teeth, solution of amino acids, sugars, soaps and salts. It can also destroy chemotherapeutic or cytotoxic agents and aldehydes (such as formaldehyde and glutaraldehyde) commonly used in hospitals.

Nanotechnology

It is used to cleanse environmental air to improve indoor quality air and includes a photo catalyst with wide spectrum of light and is bactericidal and fungicidal. It utilizes the energy from light to generate hydroxyl species and superoxide anion ($O2^-$) which decompose and oxidize toxic pollutants to carbon dioxide and water.

Photocatalysis

It is a novel technology for disinfection and decontamination of hospital waste water which utilizes solar energy or ultraviolet rays to disinfect microbes and decontaminate antibiotic from waste water at the point of origin. It is efficient and affordable technology.

Membrane Bioreactors

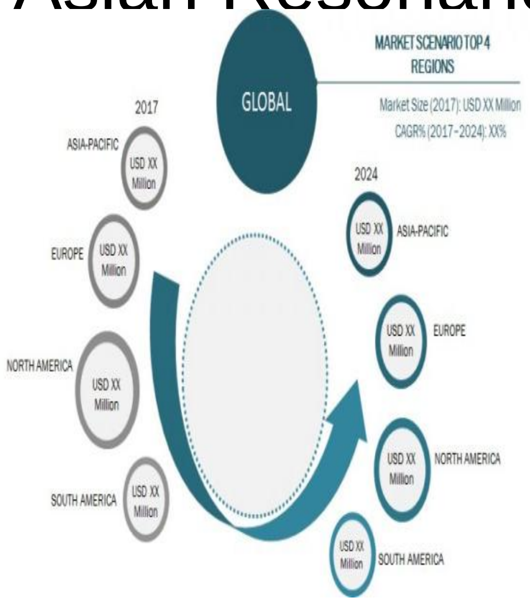
It combines the biological-activated sludge process with a membrane filtration step for sludge water separation. Various types of membrane bioreactor (MBRs) are available such as aerobic MBR, anaerobic MBR, organic pollutant MBR.

Other emerging technologies for destruction of BMW include gas-phase chemical reduction, base-catalyzed decomposition, supercritical water oxidation, sodium reduction, verification, superheated steam reforming, Fe-TAML/peroxide treatment (pharmaceutical waste), biodegradation (using mealworm or bacteria to eat plastics), mechanochemical treatment, sonic technology, electrochemical technologies, solvated electron technology and phytotechnology. These emerging technologies are not ready for routine application to health-care waste.

Global Health Care ScenarioandBiomedical Waste Management

Improving financial performance and operating margins is likely to remain a top issue. Many public and private health systems have been experiencing revenue pressure, rising costs, and stagnating or declining margins for years. The trend is expected to persist, as increasing demand, funding limitations, infrastructure upgrades, and therapeutic and technology advancements strain already limited financial resources. Combined health care spending in the world's major regions is expected to reach USD $8.7 trillion by 2020, up from USD $7 trillion in 2015[31]

At the global level, 18%–64% of HCFs have unsatisfactory BMWM facilities; predictors include lack of awareness, insufficient resources and poor disposal mechanisms. In South-East Asian region countries, 56% of facilities lack adequate waste disposal and treatment. Similar situation existed in several other developing countries such as Iran, Nigeria, Senegal and Pakistan and the authors reported poor infrastructure, state of collection, transportation, disposal, training, capacity building, PPEs and resource constraints in BMWM.



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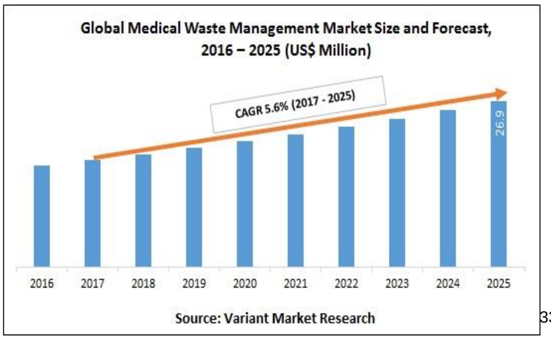

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The global medical waste management market

The global medical waste management market was valued at over 10 Bn in 2016 and is expected to expand at the CAGR of above 5% during the forecast period of 2017 to 2025. Increase in incidence and prevalence of infectious and life style diseases, rapidly growing population, rise in healthcare expenditure, and adoption of novel technologies to treat the diseases are the major factors responsible for rise in the generation of medical waste. According to World health Organization (WHO), developed regions about 0.5 kg of hazardous waste per hospital bed per day; whereas developing regions generate on average 0.2 kg. Stringent regulations and rising health care costs leading to outsourcing of waste management, initiatives by governments and non-government organizations (NGOs) to manage medical waste, and technological advancements in the methods of waste disposal are the factors expected to drive the medical waste management market growth during the forecast period. However, lack of awareness about proper methods of waste segregation among healthcare workers, and high initial capital investment required to establish a medical waste disposal facility are the factors restraining the medical waste management market.

Geographically, the global Medical Waste Management is segmented into North America, Europe, Asia Pacific, Latin America, and Middle East & Africa. North America dominates the global medical waste management market owing to highest use of biomedical technologies and products, rapidly aging population, increasing healthcare expenditure, stringent laws for medical waste management, and highest awareness about safety and security of the public health and environment. Europe held second largest market in the year 2016 in the global medical waste management owing to increasing prevalence of infectious and lifestyle diseases, growing adoption of advanced medical technologies leading to increased diagnosis and treatment of various diseases, and presence of large number of healthcare waste generators in the region.[34]

A study conducted jointly by industry body ASSOCHAM and Velocity has said, "India is likely to generate about 775.5 tonnes of medical waste per day by 2022 from the current level of 550.9 tonnes daily since the medical waste is expected to grow at a compounded annual growth rate (CAGR) of about 7 per cent."[35]

DrKirtiBhushan, the Director General of Health Services of the Delhi government said, "Safe and effective management of waste is not only a legal necessity but also a social responsibility. Lack of concern, motivation, awareness and cost factor are some of the problems faced in proper biomedical waste management."

Waste management market in India is expected to reach USD 13.62 billion by 2025, DrBhushan said, adding, "There is a need for education regarding the hazards associated with improper waste disposal. Education of staff about management of biomedical waste is crucial in today's healthcare arena." Major waste sections such as municipal solid waste management market, e-waste market and bio-medical waste are expected to grow at CAGR of 7.14 per cent, 10.03 per cent and 8.14 per cent respectively.

In India, it was observed in many studies the gap in knowledge and practice in relation to availability of resources and processes in place was found as was the need for organised training and structured supervision to bridge this gap. The key challenges in bio-medical waste management include speed of data availability, under-reporting of waste generated and handling capacity, operation of healthcare facility without authorisation under Biomedical Waste Management Rules, lack of awareness among various sections of the staff at all levels among others.

A study on tertiary care hospitals in India found that people with higher education such as consultants, residents and scientists had good knowledge of biomedical rules but was not reflected in their practices. Prior studies from geographically diverse states of India revealed that awareness among hospital staffs regarding segregation of BMW was slightly higher in urban areas compared to rural areas and that employee training and awareness can be a major determinant of establishing optimal BMWM. A multistate study revealed that surveillance and monitoring of BMWM were consistently deficient; BMWM was alarming both at macro- and micro-levels across different parts of country. It was observed that the processes of BMWM was poor and unacceptable across levels of HCFs and were poorest in primary care settings as compared to secondary and tertiary care settings.

Conclusions and Suggestions

These basic recommendations are meant simply as guidelines to stimulate better and more specific planning and action programs at the municipal government level and then at the level of individual health care facilities.

Clearly Define The Problem

Before any clear improvement can be made in medical waste management, consistent and scientifically based definitions must be established as to what is meant by medical waste and its components, and what the goals are for how it is managed.

Focus on Segregation First

The current waste management practice observed at many hospitals is that all wastes, potentially infectious, office, general, food, construction debris, and hazardous chemical materials are all mixed together as they are generated, collected, transported and finally disposed of. As a result of this failure to establish and follow segregation protocols and infrastructure, the waste leaving hospitals, as a whole is both potentially infectious and potentially hazardous (chemical). At greatest risk are the workers who handle the wastes (hospital workers, municipal workers and rag pickers).

Institute A Sharps Management System

Of the 10 percent or less portion of the waste stream that is potentially infectious or hazardous, the most immediate threat to human health (patients, workers, public) is the indiscriminate disposal of sharps (needles, syringes, lancets, and other invasive tools). Proper segregation of these materials in rigid, puncture proof containers which are then monitored for safe treatment and disposal is the highest priority for any health care institution. If proper sharps management were instituted in all health care facilities most of the risk of disease transmission from medical waste would be solved. This would include proper equipment and containers distributed everywhere that sharps are generated (needle cutters and needle boxes), a secure accounting and collection system for transporting the contaminated sharps for treatment and final disposal, and proper training of all hospital personnel on handling and management of sharps and personal protection.

Keep Focused on Reduction

Establishing clear guidelines for product purchasing that emphasized waste reduction will keep waste management problems in focus. New emphasis needs to be put on waste reduction of hazardous materials. For example, hospital waste management would benefit from a policy of a phase out of mercury-based products and technologies. Digital and electronic technology is available to replace mercury-based diagnostic tools. This is a purchasing and investment decision. Since there is no capacity in most countries to safely manage mercury wastes, this reduction policy will make a serious contribution to cleaning up the hospital waste.

Ensure Worker Safety through Education, Training and Proper Personal Protective Equipment

Workers who handle hospital wastes are at greatest risk from exposure to the potentially infectious wastes and chemical hazardous wastes. This process starts with the clinical workers who generate the wastes without proper knowledge of the exposure risks or access to necessary protective gear, and includes the workers who collect and transport the wastes through the hospital, the staff who operates a hospital incinerator or who take the waste to municipal bins, the municipal workers who collect wastes at the municipal bins and transport it to city dumping sites, and the rag pickers, who represent the informal waste management sector, but play an important role in reducing the amount of waste destined for ultimate disposal.

Provide Secure Collection and Transportation

If the benefits of segregation are to be realized then there must be secure internal and external collection and transportation systems for waste. If waste is segregated at the point of generation only to be mixed together by laborers as they collect it, or if a hospital has segregated its waste and secured it in separate containers for ultimate disposal only to have municipal workers mix it together upon a single collection, then the ultimate value is lost.

Require Plans and Policies

To ensure continuity and clarity in these management practices, health care institutions should develop clear plans and policies for the proper management and disposal of wastes. They need to be integrated into routine employee training, continuing education, and hospital management evaluation processes for systems and personnel.

Invest In Training and Equipment for Reprocessing Of Supplies

The science of the reprocessing of equipment and materials for reuse in medical facilities is well established in India and should be supported. Professional health care associations should be urged to firmly support judicious reuse of materials, and should begin to set standards for reprocessing. Maintenance of this effort within hospitals will provide quality products and thwart efforts to increase reliance on disposables.

Invest In Environmentally Sound & Cost Effective Medical Waste Treatment and Disposal Technologies

The rush to incinerate medical waste in countries around the world as an ultimate solution to a problem without definition is doing a great injustice to the community, the public health of its people, and the environment. The mass incineration of hospital waste given current practices of waste disposal will not reduce risk to workers (this is where the greatest risk of disease transmission or chemical exposure exists) and will actually create a greater threat to the general public as mercury and other heavy metals are spewed out into the general air, or dioxins and furans are created from the combustion of plastics such as PVC which is growing in use in medical packaging. Additionally, the ash generated from incineration of medical waste is also tainted with heavy metals and other toxic residues. Lesser risks are associated with the treatment of unsegregated wastes through other treatment technologies such as autoclaving, hydroclaving, microwaving and chemical disinfection, which affect workers more than the general public, and contaminate water sources rather than air if improperly operated. Choices of treatment technologies should be made in line with a clear knowledge of the waste stream to be managed and the goal to be achieved through treatment. If the technology is to be environmentally sound, the waste stream should be able to be treated (disinfected) without creating other hazardous by-products. Incineration may be an “overkill” technology. Its goal is sterilization, not disinfection.

Develop an Infrastructure for The Safe Disposal And Recycling For Hazardous Materials

There was little or no observable capacity for the management, treatment, recycling or final disposal of hazardous wastes in most countries (e.g. chemicals, mercury, batteries). Hospitals seeking to segregate hazardous wastes are left with little or no option for safe disposal. The development of an industry which is capable of managing hazardous waste (chemicals) is essential. On-site reprocessing technology is available for hospitals for materials such as xylene or formalin, and recovery technology for silver from developing solution. These technologies may be cost prohibitive at this time. Pollution prevention and the choice of nonhazardous or less hazardous material is the only real option left to hospitals, which should be followed regardless of the existence of a hazardous waste industry.[36]

BMWM beingessentially, the subject of a national strategy. Since this require dedicated infrastructure, cradle-to-grave legislation, competent regulatory authority and trained personnel. Improving the management of biomedical waste begins with waste minimization. These standards, norms and rules on BMWM in a country regulate the disposal of various categories of BMW are envisaged therein, so as to ensure the safety of the staff, patients, public and the environment, in furtherance to its vehement commitment, to ensure the fundamental right to live in clean and safe environment. The novel waste which is generated but not documented in rules should have a company buy back policy or should be treated as per recommended guidelines of Centers for Disease Control and Prevention or WHO. Furthermore, developing models for the monitoring of hospital health-care waste practices and research into non-burn eco-friendly sustainable technologies, recycling and PVC-free devices will go in long way for safe carbon environment. Globally, intensive scientific research in BMWM is necessary to understand its immense impact on public health.

Finally, protection of the environment, proper management of hazardous and solid waste and keeping ecological balance unaffected is a task which not only the government but also every individual, association and corporation must undertake. It is a social obligation and fundamental duty. Moreover a positive attitude on the part of everyone in the society is essential for effective and efficient enforcement of these legislations.

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