Novelty Journals

ISSN 2394-7330

International Journal of Novel Research in Healthcare and Nursing
Vol. 11, Issue 1, pp: (28-39), Month: January - April 2024, Available at: www.noveltyjournals.com

A REVIEW ON INTERNATIONAL EXPERIENCES AND PRACTICES ON MEDICAL WASTE MANAGEMENT

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DOI: https://doi.org/10.5281/zenodo.10526497

Published Date: 18-January-2024

Abstract: **Waste generated during treatment, diagnosis, testing, and research connected to the health care of humans or animals is referred to as medical waste. Management of medical waste is a complicated field with many components relating to environmental preservation, public health, and legal compliance. An integrated system that addresses waste generation, segregation, collection, treatment, and disposal in its whole is necessary for management of medical waste. Although the composition of medical waste may contain dangerous chemicals and pathogenic viruses there is however, a latent possibility for resource recovery and reuse within its frequently inconspicuous constituents. Medical waste generation has in recent times increased as a result of the Covid-19 pandemic. When comparisons are made, more medical waste is produced in developed countries than in developing ones as a result of high healthcare offered in developed countries. Medical waste tracking systems are not adequate in developing countries as compared to their developed counterparts. This paper aims to: shed light on the current state of medical waste management, highlight its environmental and public health implications; provide a comprehensive overview of different medical waste management techniques, their effectiveness, and limitations; as well as to pinpoint areas where further research is needed to improve medical waste management methods.**

Keywords: **Medical waste, hazardous waste, segregation, disposal method, incineration, treatment method.**

1. INTRODUCTION

Medical waste is all waste produced in treatment, diagnostic, testing and research activities related to human or animal health care. The growing population has necessitated an increase in health care activities resulting in an increase in the production of medical waste. In recent times, the Covid-19 outbreak has seen a tremendous increase of medical waste. Medical health poses a risk to the health care givers, the waste handlers as well as the environment at large. It is of outmost importance that medical waste be generated and managed in a manner that minimizes or eliminates the risk to people and the environment. In general, developed nations produce more waste than their developing counterparts. However, developed countries have better capacities, systems and facilities in place for medical waste management. This paper seeks to explore the medical practices and experiences of various countries around the world. It also gives recommendations on the best practices in medical waste management.

2. DEFINITION OF MEDICAL WASTE

The term medical waste covers all wastes produced in health-care or diagnostic activities (International Committee of the Red Cross, 2011). It consists of wastes from any medical practice in healthcare facilities, testing centers, and laboratories (Makajic-Nikolic et al., 2016; Bagali, 2021; Salvi, 2022). Waste generated in the human beings or animals immunizations, in research, and in production and testing activities pertaining to health related activities may be included in the concept of medical waste (Nagpal, 2019). Waste generated from care related activities done in home settings is also considered as medical waste (Dewi & Bayhakki, 2020).The United States Medical Waste Tracking Act of 1988 defines medical waste any solid waste produced during the diagnosis, treatment, or vaccination of humans or animals, during related research, or during the manufacture or testing of biologicals. (Dewi & Bayhakki, 2020; Shareefdeen, 2012; Singh et al., 2021; Windfeld & Brooks, 2015). It is apparent that definitions of medical waste vary and there is no globally agreed upon definition of medical waste. This poses a challenge from a comparative standpoint, as different definitions makes it difficult to carry out meaningful comparisons between countries, in terms of quantities generated, handled and disposed (Wilson et al 2012; Windfeld & Brooks, 2015). Terms used when referring to medical waste include biomedical, hospital, regulated and infectious medical waste.

3. TYPES OF MEDICAL WASTE

Waste generated from health facilities is extremely heterogeneous. It comprises of pathological waste, pharmaceutical waste, radioactive waste, chemical waste, sharps, infectious and domestic waste (Gillian et al., 2016; Sonkar et al.,2023). The World Health Organization (WHO) classifies medical waste into eight categories such as general waste, pathological, radioactive, chemical, infectious to potentially infectious waste, sharps, pharmaceuticals, and pressurized containers (Nagpal, 2019). In the US there are four major types of medical waste: general, infectious hazardous and radioactive. Approximately 85% of the waste generated in the majority of healthcare facilities is made up of non-hazardous wastes. (Bagali, 2021). Non-hazardous waste involves wastes such as food leftovers and fruit peels, as well as wash water and paper cartons, packaging materials, and so on. This waste can be put through the same collection, recycling and processing procedure as the community's municipal waste. The remaining 10% to 25% is referred to as special waste or hazardous medical waste. (Birchard, 2002; Singh et al., 2021). There are various ways of waste classification. It can be categorized based on composition, risk and the disposal route. In India the following system of classification based on waste composition is used:

Table I: Classification of medical waste in India (Bagali, 2021).

Waste content	**Components**
Human Anatomical Waste	Human organs, tissues, and body parts
Animal Waste	All types of Animal tissues, organs, body parts carcasses, bleeding parts etc., generated by different health sectors
Microbiology & Biotechnology Waste	Wastes from laboratory cultures, stocks or specimens of microorganisms used in research
Waste sharps	Needles, syringes, scalpels, blades, glass etc.
Discarded Medicines and Cytotoxic drugs	Out-dated, contaminated and discarded medicines
Solid Waste	Blood contaminated cotton, dressings, soiled plaster casts, lines etc.
Solid Waste	Wastes generated from disposable items other than the waste sharps such as catheters, intravenous sets etc.
Liquid Waste	Waste generated from laboratory and washing, cleaning, house-keeping and disinfecting activities
Incineration Ash	Ash from the incineration of any bio- medical waste
Chemical Waste	Chemicals used in the production of biologicals, chemicals used in disinfection, insecticides, etc.

However, it is also easier to characterize the waste with respect to the waste disposal routes employed outside the hospitals as shown in the table below. (Muhlich et al., 2003).

Table II: Type of Medical Waste with regards to disposal route (Muhlich et al., 2003)

Type of waste	Remarks	Proposal for disposal route
Domestic-type waste	Without hospital-specific waste	As municipal domestic wastes
Hospital-specific waste	Without risks of infection	As 1, but without direct contact
Infectious waste	(a) After waste treatment to eliminate any risk of infection (e.g., disinfection) (b) Without waste treatment	(a) As 2 (b) Incineration like domestic waste
Cytostatic agents	(a) Traces of contamination (b) Severe contamination	(a) As 2 (b) High temperature incineration
Sharp-edged objects	Pierce-proof, labelled containers	Dumping or incineration like domestic waste

4. SOURCES OF MEDICAL WASTE

The sources of medical waste can be categorized as primary and secondary sources according to the quantities produced. Although some medical waste from small and dispersed sources may fall into the same categories as other medical waste, their makeup is distinct. (Nagarajani et al., 2016). Hospitals, research facilities, clinics, laboratories, blood banks, animal houses, and veterinary schools are among the establishments that produce medical waste. (Salvi, 2022).

Table III: Sources of medical waste (Nagpal, 2019)

Major Sources of Medical Waste	Minor Sources of Medical Waste
▪ Govt. hospitals/private hospitals/nursing homes/ dispensaries ▪ Primary health centers ▪ Medical colleges and research centers/ paramedic services ▪ Veterinary colleges and animal research centers ▪ Blood banks/mortuaries/autopsy centers ▪ Biotechnology institutions ▪ Production units.	▪ Physicians/ dentists' clinics ▪ Animal houses/slaughter houses ▪ Blood donation camps ▪ Vaccination centers ▪ Acupuncturists/psychiatric clinics/cosmetic piercing ▪ Funeral services ▪ Institutions for disabled persons

5. AMOUNT OF MEDICAL WASTE GENERATED

The quantity and composition of medical waste generated is dependent on many factors. The level of national income and the type of facility concerned is a factor when it comes to the quantity of waste produced (International Committee of the Red Cross, 2011). Affluent countries produce a higher amount of medical waste (Singh et al., 2021). Growing medical advances and new hospital facilities for improved healthcare have increased the amount of waste generated by health care facilities (Bagali, 2021). The sudden outbreak of the COVID-19 virus has led to an exponential rise in the quantity of biomedical waste (Salvi, 2022). It is estimated that since the outbreak, COVID-19 has produced 2.6 million tons of medical waste per day globally. The pandemic has resulted in the daily disposal of large quantities of single-use gowns, facemasks/face shields, aprons, gloves, goggles, sanitizers, sharps, and syringes in Australia for instance (Andeobu et al., 2022). In India the national daily waste generation rose up to around 850 tones/day (Salvi, 2022).

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In evaluating medical waste generation, it is helpful to use a common basis for quantification, so that data from different regions can be compared (Windfeld & Brooks, 2015). This however presents a challenge since different countries use deferent recording and quantification systems. The most common metric for quantifying the amount of medical waste generated at a hospital is calculated by measuring the total kilograms of waste generated by the hospital per day, and then dividing that total by the number of occupied beds at the hospital. This yields kg/bed-day, a metric which attempts to adjust waste generation at hospitals for both the number of illnesses treated and the seriousness of patient maladies, as a single patient with a serious illness may occupy a hospital bed for many days, while a patient with a less serious injury may occupy a bed for a matter of hours. It is generally accepted that kg/bed-day is the best available basis for hospital waste production comparison, with studies finding that the number of beds in service strongly relates to the amount of medical waste produced at similar hospital facilities (Windfeld & Brooks, 2015).

Studies focusing on Italian hospitals found that the type of sanitary service offered greatly impacted on the amount of infectious waste produced (Windfeld & Brooks, 2015). According to the study, short-term patients in rehabilitation services account for up to 52% of the total amount of infectious medical waste produced. These patients are followed in descending order by analytical laboratories (23%), surgeries (14%), dialyses (7%) and first aid (4%). A similar study done in Taiwan found the dialysis unit to generate the greatest amount of infectious medical waste (23%), flowed by the intensive care unit (17%), the emergency care unit and the outpatient clinic (12% each). According to a survey conducted in Bangladesh, hospitals produce 5562 kg of waste per day, of which 22.6% are hazardous and 77.4% are non-hazardous. The hospital that was surveyed had an average waste generation rate of either 0.5 kg per patient or 1.9 kg per bed per day (Shareefdeen, 2012).

6. RISK OF MEDICAL WASTE

Health-care activities are a means of protecting health, curing patients and saving lives but they can produce waste that can be detrimental to health and the environment. (Gillian et al., 2016). Persons who are in contact with hazardous medical waste are potentially exposed to the various risks. If there is no medical waste management or insufficient medical waste management, these people include those who work inside the establishment producing the waste, those who handle it, and people outside the facility who might come into contact with hazardous wastes or their byproducts. (International Committee of the Red Cross, 2011). The table below shows the groups of people who are potentially exposed.

Table IV: Groups of people potentially exposed to risk of medical waste

Inside the hospital	**Outside the hospital**
Care staff (doctors, nursing staff, auxiliaries)	Off-site transport personnel, personnel employed in processing or disposal infrastructures, the general population (including adults or children who salvage objects found around the hospital or in open dumps).
Stretcher-bearers, scientific, technical and logistic personnel (cleaners, laundry staff, waste managers, carriers, maintenance personnel, pharmacists, laboratory technicians, patients, families and visitors)	

This type of waste poses some health risks. It can be divided into five categories according to the risks involved. The table below gives a description of those various categories and their sub-groups.

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Table V: Classification of medical waste according to the risk involved (International Committee of the Red Cross, 2011).

Category	Nature of Waste	Risk
1	▪ Sharps	▪ Waste entailing risk of injury
2	▪ Waste entailing risk of contamination ▪ Anatomical waste ▪ Infectious waste	▪ Waste containing blood, secretions or excreta entailing a risk of contamination. ▪ Body parts, tissue entailing a risk of contamination ▪ Waste containing large quantities of material, substances or cultures entailing the risk of propagating infectious agents (cultures of infectious agents, waste from infectious patients placed in isolation wards).
3	▪ Pharmaceutical waste ▪ Cytotoxic waste ▪ Waste containing heavy metals ▪ Chemical waste	▪ Spilled/unused medicines, expired drugs and used medication receptacles. ▪ Expired or leftover cytotoxic drugs, equipment contaminated with cytotoxic substances. ▪ Batteries, mercury waste (broken thermometers or manometers, fluorescent or compact fluorescent light tubes). ▪ Waste containing chemical substances: leftover laboratory solvents, disinfectants, photographic developers and fixers.
4	▪ Pressurized containers	▪ Gas cylinders, aerosol cans.
5	▪ Radioactive waste	▪ Waste containing radioactive substances: radionuclides used in laboratories or nuclear medicine, urine or excreta of patients treated.

7. MEDICAL WASTE MANAGEMENT

The management of medical waste has been of major concern due to potentially high risks to human health and the environment. Medical waste used to frequently be dumped in municipal solid waste landfills along with household waste. (Shareefdeen, 2012). Waste management is a process by which wastes are gathered, transported and processed before disposal. The day-to-day operations of waste management issues involve the effective supervision and handling, keeping, collection, conveying, treatment, and disposal of waste in a manner that protects the environment and the public. It also makes use of skills and knowledge from various disciplines, including legal, financial, and administrative. The main reason for managing waste is to ensure a safe and healthy environment (Amasuomo & Baird, 2016). Medical waste management should minimize the risk of infection outside the hospital for waste handlers, scavengers and those living in the vicinity of hospitals (Sharma, 2018).

7.1 SORTING AT SOURCE

Sorting at source involves segregating waste is the best way to reduce the volume of hazardous wastes requiring special treatment. By making sure that only infectious materials are disposed of in the infectious waste stream, healthcare facilities can lower their costs associated with disposing of medical waste. (Windfeld & Brooks, 2015). Moreover, segregation makes it easier to transport the waste. Waste is segregated depending on the quantity, composition, and the disposal method of the waste stream (Shareefdeen, 2012). Sorting consists of clearly identifying the various types of waste and how they can be collected separately. It the responsibility of the entity that produces waste and it must be done as close as possible to the site where the wastes are produced (Bagali, 2021).

Different labeling and color coding is used for containers of different streams of waste to make it easy for identification. However, the color selected for each waste type, along with what types of waste that go into each stream, varies from region to region, with some using the source of the waste as a basis for sorting, while others use the likelihood of an objects pathogenicity to determine its disposal waste stream (Muhlich et al., 2003). This lack of standardization makes effective waste sorting difficult for healthcare workers, and causes workers to err on the side of caution, disposing objects within the stream of infectious waste and causing unnecessary infectious waste generation (Almuneef & Memish, 2003). Staff training and information is essential for successful waste segregation (Muhlich et al., 2003)

7.2 STORAGE

Medical waste must be stored in a designated area at healthcare facilities until it is collected for treatment and disposal. The location of storage areas should be carefully considered; they should be safe, out of the public's reach, and have warning signs and symbols. It needs to be kept dry and away from moisture, wind, animals, rodents, and insects. It is not recommended to store hazardous biomedical waste for longer than 48 hours onsite (Sonkar et al.,2023)

7.3 ON-SITE TREATMENT

Incineration, steam-sterilization (autoclaving), or burial are the on-site treatment techniques (for anatomy wastes). Chemical disinfection, grinding, shredding, and disinfection techniques, energy-based technologies (such as microwave or radio wave treatments), and disinfection/encapsulation techniques are some of the treatment methods that have been developed recently.

7.3.1 Incineration

The process of burning waste at high temperatures in furnaces is known as incineration. The procedure turns the waste into ash, gases, and heat while removing hazardous materials and reducing the waste's mass and volume. 60% combustible wastes are suitable for incineration. Sharps and other pathological and infectious waste are good candidates for incineration. The main benefit of incinerating wastes is that their volume can be reduced; nevertheless, there are drawbacks such as high expenses, the possibility of pollution, and the production of smoke. Incinerators used in hospitals produce more furans and dioxins than incinerators used in municipality (Guo et al, 2023). The increased levels of furans and dioxins are caused by frequent starts and stops, laxer emission regulations, inadequate combustion management, and different waste feed compositions than municipal solid waste. Toxic chemicals found in the ash and wastewater the process produces must be treated to prevent negative effects on human health and the environment. Energy-recovery facilities are found in most large, contemporary incinerators. Incinerator steam and/or hot water can be fed into urban district heating systems in colder climates, and in warmer climates, the steam can be used to create electricity. The heat extracted from small hospital incinerators is utilized to warm up waste before it is burned (Buekens, 2013; Cheremisinoff, 2013).

7.3.2 Plasma disinfection

Plasma has the ability to disinfect medical waste as well. In this process, a combustion process is organized by low temperature plasma that is created by the plasma generator using air as the working fluid. Because the medical waste is continuously mixed, all energy loss is minimized through mass and heat exchange. In the process, the heat generated serves as an extra heat source. With the use of this technology, the atmosphere is kept free of highly hazardous compounds like dioxins and irregular forms of NO_X. The fact that it uses less energy than other mineralization processes is another significant benefit. (Cai &Du, 2021.

7.3.3 Chemical Disinfection

Chemical disinfectants, such as per acetic acid, sodium hypochlorite, or chlorine dioxide, are occasionally used to lessen the toxicity of some medical wastes. Disinfection works best for solid wastes if the waste is limited to shredding. It is not advised to treat pharmaceutical, chemical, or certain infectious waste types because the disinfectants themselves can be dangerous in certain situations. (Manita et al., 2023).

7.3.4 Autoclaving

Autoclaving is a process of steam sterilization and is the most common alternative to incineration. Autoclaving requires 121 degrees Celsius and about 15 pounds per square inch (psi) of pressure for 20 to 30 minutes. The purpose of this treatment is to sterilize the medical equipment and render the infectious agents inactive. It is less expensive and has no known negative effects on health (Sharma, 2018). However, steam sterilization should not be applied to waste containing anti-neoplastic medications, hazardous chemicals, or chemicals that would volatilize in the presence of steam (Salvi, 2022).

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7.3.5 Shredding and grinding

Sharp cutting blades that are installed inside the containers shred and grind the infectious medical waste bags. The shredded waste is reduced in volume by 80% as a result of the blades rotating at a rate of about 1750 revolutions per minute. Loading, shredding, heating, sterilizing, cooling, draining, vacuuming, and unloading are the steps in the process. There is no intermediate waste handling during the process because the entire thing is contained within a small system. This system is easily installed in hospitals and used for on-site waste treatment due to its compact size. As a result, the expense of transporting medical wastes is decreased. Regarding environmental factors, this technology is non-hazardous, chemical-free, and clean. (Shareefdeen, 2012)

7.3.6 Irradiation

The application of gamma, electron-beam, ultraviolet, and X-rays are examples of radiation treatment techniques. Radioactive cobalt-60 is used to sterilize waste in an enclosed chamber. The radioactive cobalt-60 emits gamma rays that are lethal to microbes. It is highly costly in comparison to alternative techniques, and safety measures need to be implemented to shield employees from the negative effects of radiation, including cancer, radiation sickness, and even death. (Sharma, 2018).

7.3.7 Thermal inactivation

The process of thermal inactivation entails treating waste at high temperatures in order to eradicate infectious agents. Usually, this technique is applied to large volumes. A steam jacket or heat exchangers surround the vessel that collects the liquid waste and heats it. The temperature and length of treatment are determined by the types of pathogens present in the waste. Following treatment, the contents may be disposed of in a way that conforms with local, state, and federal regulations into the sanitary sewer. Compared to steam treatment, this technique needs higher temperatures and longer treatment cycles. (Salvi, 2022).

7.3.8 Gas/vapor sterilization

Chemicals that are vaporized or gaseous are used as the sterilizing agents in gas/vapor sterilization. The most widely used agent is ethylene oxide, although it should be used carefully as it may cause cancer in humans. Handling sterilized materials carries the risk of worker exposure due to the possibility of ethylene oxide adsorbed on their surface. (Salvi, 2022).

7.4 WASTE TRANSPORTATION

The most crucial aspects of health care waste management are the collection of appropriately separated waste and safe transportation within the medical facility. (Kumar et al., 2015). This refers to transporting and managing medical waste from within healthcare facilities to treatment locations, which may be central off-site facilities or on-site hospitals. A second stage of transportation usually consists of moving the treated waste residual—that is, waste that has been autoclaved, microwaved, or incinerator-ash—to a landfill for ultimate disposal. (Tata, 1995). It is common practice for healthcare facilities to have their infectious waste stream transported by a third-party firm, contracted to take the waste from the healthcare facility to an appropriate waste depot. Waste should be collected and transported in a manner so as to avoid any possible hazard to human health and environment

7.5 OFF-SITE DISPOSAL

Waste can be gathered and disposed of off-site, particularly from small waste generation centers. Pharmaceutical and pathological waste are usually incinerated. Medical waste is incinerated in a regulated environment to guarantee full combustion and reduce any adverse environmental effects. Up to 99% of microorganisms can be eliminated by incineration, which produces very little waste. Waste that has been shredded, cleaned, and decontaminated is usually disposed of on land. It can also be used in some circumstances to handle hazardous waste or other untreated waste that cannot be cleaned up using other methods. There are specialized sanitary landfill sites available to safely dispose of medical waste while lowering the possibility of contaminating the land, water, or air.

8. MEDICAL WASTE MANAGEMENT REGULATIONS AND PRINCIPLES

Several international agreements have been concluded which lay down fundamental principles concerning public health, environmental protection and the safe management of hazardous wastes. The following international principles are widely recognized as underlying the effective management of wastes: polluter pays principle, precautionary principle, duty of care principle, proximity principle and prior informed consent principle. Polluter pays principle means that any producer of waste is legally and financially liable for disposing of that waste in a manner that is safe for people and the environment. Precautionary principle states that when the risk is uncertain it must be regarded as significant and protective measures must be taken accordingly. According to the duty of care for wastes, it is morally required of everyone handling or managing hazardous materials or associated equipment to exercise the highest caution. Proximity principle states that hazardous wastes must be treated and disposed of as close as possible to where they are produced. Prior Informed Consent requires that affected communities and other stakeholders be apprised of the hazards and risks involved in the transport of wastes and the siting and operation of waste treatment and disposal facilities (Klangsin & Harding, 1998; Windfeld & Brooks, 2015).

International laws and conventions include the Basel Convention on the Control of Transboundary Movements of Hazardous Wastes and Their Disposal (UNEP, 1992). The primary goals of the Basel Convention are to decrease the production of hazardous wastes, handle those wastes as near to their source as feasible, and lessen their transboundary movements. Stockholm Convention on Persistent Organic Pollutants (UNEP, 2004). This convention aims to reduce the production and use of persistent organic pollutants and to eliminate uncontrolled emissions of substances such as dioxins and it states that the only situation in which the export of hazardous waste from a nation lacking the knowledge or infrastructure necessary for safe disposal to another nation that does is permitted and furans. National Legislation National legislation constitutes a basis which must be drawn on to improve waste treatment practices in a country. Many countries are currently drawing up national medical waste management plans. The Global Alliance for Vaccines and Immunization (GAVI) has been financing a project in collaboration with the World Health Organization (WHO) in this context since 2006, the aim being to help 72 countries adopt a policy, strategy and plan for managing the wastes generated in health-care activities (WHO 2018).

9. MEDICAL WASTE MANAGEMENT PRACTICES AROUND THE WORLD

Medical waste generation and management varies between developed and developing nations. Although developed countries generate more waste than their counterparts in developing nations, they have better facilities and management systems that are oftentimes capable of properly managing the waste.

9.1 DEVELOPING COUNTRIES

Developing nations Medical waste management is a significant challenge, especially in the majority of healthcare facilities in developing nations where it is impeded by social, economic, and technological issues as well as by staff members who have not received the proper training. (Awodele et al., 2016). An assessment by WHO revealed that in twenty-two developing countries, the proportion of healthcare facilities that do not practice proper healthcare waste management ranges from 18 to 64%. In many developing countries, regulations governing safe disposal of healthcare waste is either lacking or poorly enforced. Poor clinical waste management, particularly ineffective methods of segregation, treatment, and disposal, endangers public health, the environment, and workplaces in these nations. It also raises the risk of blood-borne pathogen transmission. Wastes are handled haphazardly with no systematic management of healthcare waste (Letho et al., 2021). However, India's has managed to change the attitudes of the operators of health care facilities so that they incorporate good management practices in their daily operations and to purchase on-site treatment technologies from the private sector (Nagpal, 2019).

In the African continent, solid medical waste management in most countries is substandard. In a recent review of solid medical waste management in Africa, only 30% of countries met half of WHO's recommendations on medical waste management with the greatest compliance recorded on daily collection of waste from points of generation (100%). In addition to the fact that waste is never segregated and poorly handled in these countries, uncontrolled and sub-standard burning is widely practiced creating additional environmental problems including emission of toxic air pollutants (particularly dioxin) and heavy metals which might be present in gaseous and solid by-products. Sound management of medical waste is highly necessary to protect human and environmental health (Windfeld & Brooks, 2015).

The majority of medical facilities in Cameroon do not have an incinerator, and those that do may have a malfunctioning or broken one. Within the facility, waste is burned in pits. Toxic gases released into the air by burning in waste pits have the potential to threaten the ecosystem. Most medical professionals were not aware that national or international policies addressed safe clinical waste management. The precarious working conditions waste pickers endure in medical facilities endanger not just their own health but also the health of their families. The unstable working conditions faced by waste pickers in medical facilities pose a threat to their families' health as well as their own. Medical waste is transported from the point of generation to the designated disposal location. (Gillian et al., 2016)

In developing nations like India, where governments are battling disease outbreaks brought on by private companies obtaining medical waste from healthcare facilities and then reselling goods like sharps on the black market for repurposing, there is an additional issue with the illicit disposal of infectious medical waste. From an incentive perspective, using third-party disposal companies presents a problem because the companies or the people who work for them stand to gain financially from improper waste disposal. (Windfeld & Brooks, 2015).

Illegal medical waste dumping is a problem that developing countries are increasingly having to deal with. If the nation has a poor infectious medical waste tracking system, the issue may become especially chronic. Illegal dumping is a serious problem because untreated infectious waste deposits can release pathogens, endangering public health, and draining public coffers because medical waste cleanup is very expensive (Windfeld & Brooks, 2015). In terms of legislation in Africa: Angola, Benin, Burkina Faso, Burundi, Cameroon, Chad, Comoros, Congo, Central African Republic, Côte d'Ivoire, Eritrea, Ethiopia, Gambia, Ghana, Guinea, Guinea Bissau, Kenya, Lesotho, Liberia, Madagascar, Malawi, Mali, Mauritania, Mozambique, Niger, Nigeria, Uganda, Rwanda, Senegal, Sierra Leone, Somalia, Sudan, Tanzania, Togo, Zambia and Zimbabwe have managed to develop waste management regulations with the assistance of WHO. According to a study on the condition of healthcare in Asia, very few developing countries in the region have integrated, specialized laws controlling the disposal, treatment, and collection of infectious medical waste. Where medical waste legislation does exist, it is frequently relegated to a sub-section of other waste legislation, rather than specifically addressed in a dedicated piece of legislation (Khan et al., 2019)

9.2 MEDICAL WASTE MANAGEMENT IN ZIMBABWE

Studies suggest that 85% of medical waste in Zimbabwe is non-hazardous, similar to the global average. This includes general waste like paper, packaging, and food scraps from healthcare facilities. The remaining 15% is hazardous, encompassing infectious waste (used needles, bandages, etc.), chemical waste, pharmaceutical waste, and anatomical waste The Ministry of Health and Child Care (MoHCC) reported in 2023 that there are over 1,500 health facilities across Zimbabwe. This includes, 6 central government hospitals, 63 district hospitals, and rural hospitals and clinics. Hospitals in Zimbabwe generate around 0.7 kg of medical waste per bed per day. This translates to roughly 255 tons of medical waste per year for a 365-bed hospital. There are however challenges with regard to medical waste data in the country as systematic tracking and reporting of medical waste generation are often lacking. Some healthcare facilities, particularly smaller clinics, might resort to informal disposal methods, making it difficult to track waste quantities. Segregation of different waste types isn't always efficient, making it challenging to isolate and quantify medical waste accurately (Takunda & Stephen, 2023).

Medical waste management is a critical public health and environmental concern in Zimbabwe. Improper disposal of infected needles, used bandages, and other medical waste poses a serious risk to healthcare workers, communities, and the environment. There are a lot of challenges that bedevil the medical waste sector in the country. One of the challenges is inadequate infrastructure and resources. Only big referral has incinerators capable of hospitals dealing with sharps. However, some incinerators are not being properly maintained or used as in the case with Victoria Falls Hospital where there is a good incinerator but waste is dumped outside the incinerator. The country has limited access to proper segregation, storage, and treatment facilities for medical waste. Most smaller hospitals have incinerators that are often outdated and inefficient, leading to air pollution and incomplete waste treatment. Healthcare workers often lack be adequate training on safe handling and disposal procedures for medical waste. This can lead to accidental exposure to pathogens and improper segregation of waste streams. Enforcement of the waste management regulations is done by local authorities in conjunction with the Environmental Management Agency (EMA). Enforcement is weak as EMA is burdened by enforcing quite an array of other pieces of environmental legislation and s district is only manned by one inspector. This lack of accountability contributes to the persistence of unsafe practices. Most hospitals are government owned, meaning that even if hospitals run the waste disposal facilities, the burden of maintaining and repairing them lies with the central government, thus creating a bureaucratic system that creates delays in terms of procurement of necessary materials. Zimbabwe is facing severe economic constraints and the inflation being experienced in the country makes it difficult to raise the finances necessary to implement of proper medical waste management systems. Financial burden of implementing such a system can be can be significant especially in resource-limited settings. In 2020 the country used a paltry 3.43 of its $1,267.00 GDP per capita on health care, meaning that medical waste management may not be given apriority as there are more pressing medical care needs (worldbank.org, 2024).

It should be noted that human biological waste is not only produced in hospitals and clinics or health facilities. The country has a lot of boarding schools, and universities. Most of these institutions lack a clear policy on the management of menstrual waste ant that subject is not openly discussed. However, it is worth noting the Premier Medical Aid Society (PSMAS) has embarked on a drive to construct incinerators in colleges throughout the country. Another initiative of Rural Electrification Agency (REA) has seen the construction of biogas plants in rural hospitals that are able to transform medical waste to energy. One such facility was constructed in St. Luke's Hospital in Lupane. Harare City Council is also working to improve the Pomona's waste disposal site such that it becomes a waste-to-energy plant. Such collaboration between the government, private sector, and non-governmental organizations (NGOs) can leverage resources and expertise to develop and implement sustainable medical waste management solutions.

There is a need for the country to invest in medical waste management systems. continuously upgrading and expanding incineration facilities and exploring alternative technologies, such as autoclaving and microwave treatment, can improve waste treatment efficiency and reduce environmental impact. Healthcare personnel need to be training and educated on medical waste management so as to promote safe practices and prevent exposure to pathogens. Raising awareness among communities about the risks of improper medical waste disposal can encourage responsible waste management practices and foster community support for improved systems.

9.3 DEVELOPED COUNTRIES

The leading method of disposing infectious medical waste in developed nations is through incineration, whereby the wastes are burned at very high temperatures so that nothing but a residual ash remains. This ash is then sent to a landfill facility to be buried. Incineration has the advantage of ensuring sterilization by reducing the infectious waste to an unrecognizable ash, and of reducing waste volumes which reduces transport and landfill impacts and costs. However, a major drawback of the medical waste incineration process is the release of undesirable toxins into the atmosphere. Because of its composition, infectious healthcare waste produces toxic gases in meaningful quantities when incinerated, and thus incinerator emissions are tightly regulated in most developed nations. The three toxins that are of greatest concern with medical waste incineration are dioxins, furans, and mercury (Windfeld & Brooks, 2015). In the United States, between 49 and 60 percent of medical waste is burned, 20 to 37 percent is autoclaved, and 4-5% is treated with other methods. (Wisniewski et al., 2020)

The Medical Waste Tracking Act (MWTA) of 1988 is the primary piece of legislation governing medical waste in the United States, where it is subject to strict regulations. In Canadian provinces there are no specific regulation relating to the disposal of medical waste. Instead, most provinces regulate the disposal of medical waste through umbrella waste legislation; the province of Quebec is a notable exception to this rule, as it has legislation specifically pertaining to medical waste. The European Commission (EC) establishes guidelines and standards for waste regulations within the European Union. Member states are then in charge of passing laws that both comply with and further the goals of these EC directives. The Environmental Protection Act serves as the foundation for medical waste regulations in the United Kingdom (Klangsin & Harding, 1998; Windfeld & Brooks, 2015).

10. CONCLUSION

Medical waste in itself is a huge problem. As developing countries are making transition into developed countries, need for healthcare is increasing and due to such economic advancements, medical waste generation is also increasing at rapid pace. Proper planning and control are required in order to prevent the negative impact of medical waste on the environment. Well formulated waste management plans with written policy, and mandatory in-service education, continuous waste audit, and the cooperation of all involved can lead to a reduction in the risk posed by medical waste on the environment. Despite the fact that most developing nations lack resources, medical waste management must be given top priority in order to avoid using those resources later on to treat health-related issues brought on by inadequate medical waste management. Adopting good waste management practices will result in a reduced risk of infection and death from reusing and repackaging infectious disposables, a cleaner and healthier environment, a decrease in the cost of infection control within the hospital, a decrease in the incidence of occupational and community health hazards, a decrease in the expense of waste management and the creation of income through appropriate waste treatment and disposal, an enhanced public perception of healthcare facilities, and an improvement in quality of life..

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