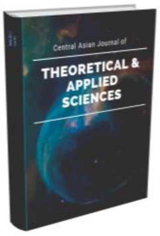

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Article

Environmental and Health Impacts of Medical Waste Combustion Gases: Current Challenges and Sustainable Solutions

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Abstract: The generation of plastic trash and biological waste has increased significantly as a result of the COVID-19 outbreak. Important challenges to the current trash disposal infrastructure were presented by the rapid growth in the number of waste automobiles intended for clearance, particularly in emerging countries. The necessity of efficient waste management has been highlighted by the COVID-19 health catastrophe. The goal of this review is to clarify every aspect of biomedical waste, including its management, classification, difficulties, and environmental effects of incineration; medical waste types and composition; management procedures; waste segregation; exposure to incinerators and the risk of neoplasia; and the rate of generation and EPI score of medical waste. In order to include improvements, new research, and system developments, biomedical waste management regulations must be updated on a regular basis. This report emphasises how important it is for hospitals, labs, and researchers to work together in order to reduce waste in healthcare settings effectively. The paper outlines recent advancements in the safe disposal of biological waste, including landfilling, chemical disinfection, autoclaving, and incineration. There is also discussion of efficient laboratory methods and procedures for shredding, encapsulating, and inertizing needles. Along with changes to these regulations, the importance of biomedical waste management policies in encouraging safe and ecologically conscious activities has been stressed.

Keywords: Medical Waste, Waste Segregation, Neoplasia Risk, Developing Countries, LMICs

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1. Introduction

"Medical waste" is any garbage produced by healthcare institutions, such as clinics, hospitals, dental offices, and labs, that might pose a risk to public health or the environment. This wide category includes harmful items, medications, infectious waste (tissues, blood, body fluids), and sharp instruments (needles, syringes, scalpels). Inappropriate treatment of medical waste can have major repercussions, such as the spread of infectious illnesses, environmental contamination, and work-related risks for waste management and healthcare personnel. Every year, a large volume of hazardous and potentially contagious trash is produced by healthcare facilities all over the world. Unfortunately, the resources needed for proper treatment of these wastes are insufficient in a number of economically developing nations. Furthermore, the majority of health care workers are not familiar with appropriate waste management procedures. Because of this, waste management is often left to untrained and poorly educated staff members who carry out their duties without enough guidance or safety measures [1].

Improvements in technology in community networks, transport, and business have sped up worldwide commercial evolution. This has caused healthcare systems to grow and the demand for medical equipment and supplies to expand. In other countries, the wrong way of handling and getting rid of medical waste from hospitals is likewise getting worse all the time. Health Care Without Harm (HCWH), an international initiative, says that the healthcare manufacturing is the fifth biggest source of greenhouse gas (GHG) emissions, making up 4.4% of all worldwide emissions. At a compound annual growth rate of 5.3%, spending on "healthcare waste management is expected to rise from $11.77 billion in 2018 to $17.89 billion in 2026" [5]. Many countries with changing economies are likely to see a big rise in healthcare waste because of the ongoing COVID-19 pandemic and strict regulatory constraints. The "COVID-19 pandemic in 2020" caused the previously unmaintainable rise in the creation and processing of medical waste to speed up suddenly. This was an immediate threat that, if not stopped, would lead to a disaster for human health and the environment [6-7-8]. Research indicates that prior to the COVID-19 pandemic, more than half of the global population was already vulnerable to environmental degradation and public health issues resulting from improper medical waste disposal. One of the main causes of infectious illnesses, which kill between 0.4 and 1 million people annually in developing nations, is believed to be the improper disposal of medical waste [11]. According to the World Health Organisation (WHO), infected syringes cause nearly 32%, 40%, and 5% of all new impurities, individually, with 260,000 instances of HIV, 2 million cases of hepatitis C, and 21 million cases of hepatitis B. A survey of 24 transitional economies found that between 18% and 64% of healthcare facilities improperly dispose of medical waste. The survey found that just 58% of the institutions in 24 low-income countries have a suitable system in place for safely disposing of medical waste. The South-East Asia Region (SEARO), comprising Bangladesh, Bhutan, India, Nepal, Sri Lanka, and Timor-Leste, exhibits the lowest safe disposal rate among member countries, with just 44% of institutions implementing a system for the safe collection, disposal, and destruction of healthcare waste. These consequences intensify health problems in resource-limited settings, marked by elevated disease rates in underdeveloped nations [13].

2. Classification of medical waste

Together dangerous and non-hazardous waste components are included in medical waste. Non-hazardous products like wool and kitchen trash don't stance any different management problems or risks to human health or the environment. Among other places, nonhazardous waste is produced in offices, kitchens, outpatient sections, and patient wards [14–15]. Hazardous waste includes chemical waste, pathological waste, and infectious sharps.Operating rooms, labor wards, labs, and other medical facilities frequently create hazardous waste.The following categories are used by the WHO to classify the 10–25% hazardous portions of all medical waste:

A. Organs, tissues, biological components, and fluids like blood are all considered unreasonable and anatomical waste. One type of pathological waste that includes identifiable human body parts is called anatomical waste [16]. B. Infectious: any waste items thought to have enough germs to infect other people or hosts. It is made up of wasted tools or supplies, such as bandages and swabs, that were used in the diagnosis, treatment, and prevention of diseases. Blood, sputum, urine, and pulmonary secretions are examples of liquid wastes that fall under this category [17]. C-Outdated, unused, spilt, and dirty therapeutic supplies, medications, and vaccines are examples of hazardous pharmaceuticals that constitute pharmaceutical waste [18]. D. Chemical wastes, which are released substances (gaseous, liquid, or solid) produced during cleaning or disinfection procedures, are referred to as hazardous chemicals [19]. E. High concentrations of heavy metals: Metal waste from thermometers or manometers, such as cadmium or mercury, is extremely harmful. Although they are classified as a type of chemical waste, they need to be managed differently [20]. Aerosol cans and full or empty containers holding liquids, pressurised gases, or powdered particles are examples of F-pressurized containers [21]. G. Sharp wastes: Sharps, like needles, are objects that may pierce skin or create cuts. Needles and other objects that might cause puncture wounds or cuts are considered sharp wastes. They are considered potentially infectious wastes and extremely hazardous devices [22]. H. Sharp wastes include objects that can cause serious infections, such as needles that can cause cuts or wounds, bodily fluids from people with microbial cultures, highly infectious diseases, and frameworks of highly infectious go-betweens from therapeutic examination laboratories [23]. I. Cytotoxic and genotoxic There is a serious risk of cytotoxicity or mutagenicity from genotoxic wastes, which come from medications often used in radiation or cancer departments. Furthermore, urine or vomit from patients receiving cytotoxic or chemical therapy ought to be classified as genotoxic [24]. J. Gaseous, solid, and liquid wastes containing radionuclides whose ionising radiations are genotoxic are referred to as radioactive wastes. [25].

3. Challenges and Environmental Concerns of Medical waste incineration

Radioactive waste exists in gaseous and solid forms. Medical waste incineration (MWI) is a recognised method for waste disposal; nonetheless, it presents specific problems and environmental issues. Although it efficiently lowers infections and waste volume, there are disadvantages to contemplate. The main concern is the discharge of trace pollutants, such as polychlorinated dibenzo-p-dioxins (PCDD), polychlorinated dibenzofurans (PCDF), and heavy metals (cadmium, lead, and mercury). The past lack of adequate regulation of pollutants, especially in older facilities, has raised worries about their potential negative effects on the environment and human health [26]. Communities next to incineration factories may be subjected to harmful pollutants, adversely affecting their health. Moreover, incineration incurs significant expenses owing to the necessity for specialised apparatus and maintenance obligations. Moreover, despite the reduction in waste volume, the residual ash may still harbour harmful compounds. Accurately evaluating the benefits and disadvantages of incineration compared to alternative techniques is crucial for determining the most appropriate and sustainable solution for certain situations. Certain findings suggest that garbage incineration may result in reduced greenhouse gas emissions under specific conditions [27]. and liquids contaminated with radionuclides whose ionising radiations are genotoxic

4. Medical waste categories and composition

Figure 1 shows the normal volume and kind of medical waste. The data showed that the medical waste that was made up of around 4% sharps, 27% infectious or hazardous waste, and 67% regular trash. According to the waste survey, around half of the trash was ordinary refuse, which is stuff like food, paper, and drink. Plastic garbage made up more than 36% of all medical waste, making it the second most important part. Only 4% of all the trash is syringes and glass.

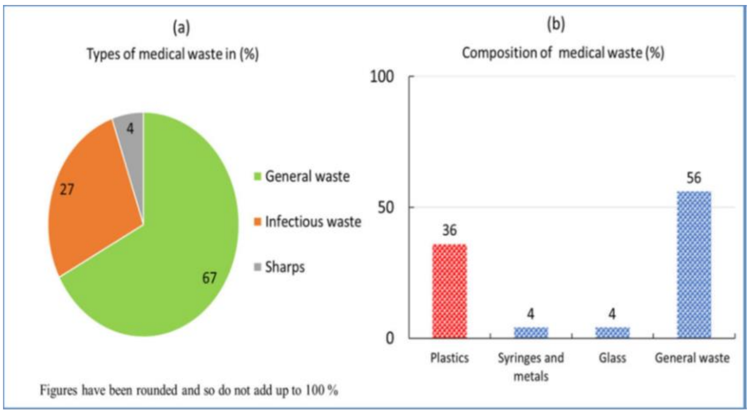

Figure 1. The average percentage of different kinds of medical waste and what they are made of. General garbage is trash that doesn't pose a biological, chemical, radioactive, or physical harm. This includes organic items like food, paper, wood, and textiles.

Despite a lower generation rate, the generated medical waste eventually lacks proper management. Despite these conclusions, we discovered a notable example for the US, where the rate of medical waste creation was reported to be the highest among the nations we examined and the EPI score was extremely low, particularly when compared to other transitional economies.The findings imply that the successful medical waste management system in the US might not be environmentally viable. This might alternatively be explained by the fact that medical waste in the US is subject to different laws than municipal solid garbage [28].

5. Medical waste management practices

Waste production planning for trash management requires data on rubbish creation. It offers detailed information on the projected waste quantities, aiding in the establishment of necessary capacities for storage facilities, treatment techniques, containers, and transportation. The volume of trash generated in hospitals is determined by several factors, including patient count, bed availability, waste management practices, kind of medical institution, and operational intensity across different departments [30]. The custom of patients and families concealing information and getting rid of it on their own may account for some countries' lower reported levels of medical waste as compared to other emerging nations [31]. Numerous studies have demonstrated that the generation rates of medical waste fluctuate according on geographic location. Nonetheless, discrepancies persist in the methodologies employed by researchers to examine the rates of medical waste generation. The creation rates of medical waste are higher in private medical centres compared to public (government-owned) medical centres [32]. The rationale is that private hospitals are predominantly frequented by middle-class and affluent individuals capable of affording the high rates, in contrast to public hospitals, which offer essentially free medical services with little charges. Furthermore, the medical waste produced in private hospitals has more hazardous components if there are more privately owned hospitals than public (government-owned) hospitals [33].

6. Waste segregation

Given that 75 to 90 percent of the trash produced is non-hazardous and may be managed as standard solid waste, sorting or segregation is a crucial component in the management of medical waste. Specialised handling processes are necessary for the remaining 10% to 25% of hazardous compounds, which are often not economically viable [31]. As any garbage that has contacted infectious materials is deemed contagious, insufficient waste segregation elevates the volume of infectious objects [34]. Consequently, a fundamental aspect of effective medical waste management is waste segregation [35]. Consequently, meticulous waste segregation will provide cleaner streams that are safer, more manageable, and more cost-effective for recycling, composting, and landfilling [36]. Colour-coded bags are utilised in the standard segregation procedure. These are prevalent in affluent countries [37]. The "three-bin system" is the most straightforward and secure approach for waste segregation; garbage is categorised at the source into hazardous and nonhazardous general waste, which often constitutes a larger volume. The hazardous components are categorised as used sharps and potentially infectious objects. Insufficient source segregation, inadequate data collection, absence of colour coding, and negative staff attitudes are significant challenges for medical waste segregation in developing countries [38].

7. Waste incinerator exposure and neoplasia risk

Several studies show that the emissions from waste incinerators may expose local residents to hazardous levels of pollutants. However, because some studies omit crucial details about the type of incineration design, specific criteria for defining the local population, and thorough information about the study of bias and confounders, the research's applicability in guiding incinerator design is limited. Exposure to waste incinerators has been connected to non-Hodgkin lymphoma. In contrast to a control group, Floret et al.15 examined the relationship between the incidence of non-Hodgkin lymphoma in nearby residents and exposure to waste incinerators, which have been in operation since 1971 in two locations and since 1976 in another. After adjusting for confounding variables, exposure levels over 0.0004 pg/m3 resulted in an odds ratio of 2.3 (95% CI 1.4–3.8), suggesting a link between dioxin exposure and non-Hodgkin lymphoma.The low-risk ratio for non-Hodgkin lymphoma among local female inhabitants from 1972 to 1985 was 1.120 (95% CI 1.002–1.251), according to Viel et al.62. Pollutant exposure from waste incinerators has been linked to soft tissue sarcomas. According to Zambon et al.63, exposure to many incinerators and waste streams is linked to an increased incidence of sarcoma. Dioxin species concentrations over 6 fg/m3 were the sole exposure linked to a significant odds ratio (OR 3.27; 95% CI 1.35–7.93). This study focused on peak exposure over the years 1972–1986. In Mantua, Italy, Comba et al.16 investigated the local population near an incinerator and discovered that those who lived within 2 km of the factory had a concerning odds ratio of 31.4 (95% CI 5.6–176.1) for sarcoma. Mantua was widely known for its dangerous and unregulated rubbish releases between 1974 and 1991.

8. Medical waste generation rate and EPI score

Figure 2 shows the Environmental Performance Index for organized solid waste management in several countries, along with the average rate of medical waste generation in each country. The results show that medical waste generation in low- and middle-income countries is significantly lower than in industrialized and high-income countries. Each bed produces, on average, between 0.3 and 8.4 kilograms of waste per day. The United States and Canada produce the largest quantities of medical waste, at 8.4 and 8.2 kilograms per bed per day, respectively. Spain and Italy lead Europe with 4.4 and 4.1 kilograms of medical waste per bed per day, respectively, while Kazakhstan and Iran produce the largest quantities of medical waste in Asia with 4.6 kilograms per bed per day. Greece and Pakistan are the countries with the lowest medical waste generation, at approximately 0.3 kilograms per bed per day. A previous study identified similar trends in medical waste generation, indicating that transition economies produce significantly less medical waste than developed countries [39–40]. This may be attributed to the superiority of healthcare services and the aging of populations in wealthy countries, which exploit most healthcare resources and services. However, millions have emerged from poverty thanks to improved access to healthcare services as a result of recent economic transformations in emerging countries. The continued and subsequent demand for medical resources due to the COVID-19 pandemic may lead to a rapid global increase in medical waste production [41-42].

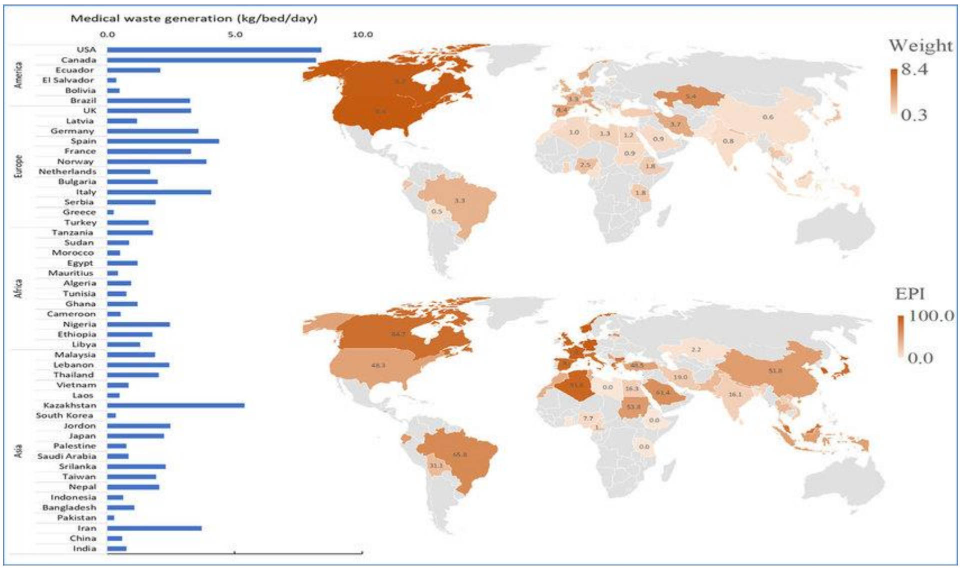

Figure 2. Volume of medical waste produced in various nations with their EPI for regulated solid waste management.

The rate of medical waste generation and the EPI ratings for regulated solid waste management in each of the evaluated countries are shown in Figure 2. The nations under examination have a wide range of EPI ratings for regulated solid waste management, from 0 in Tanzania, Ethiopia, Libya, and Palestine to 100 in the Netherlands. The results show that whereas poor and middle-income countries have lower EPI scores, most wealthy countries have higher EPI scores. Consequently, although rich nations produce the biggest volume of medical waste, they exhibit superior solid waste management practices, ensuring the correct disposal of the created medical waste [43].

9. Conclusion

Considering the extensive infrastructure utilised by hospitals, labs, research institutions, and other healthcare sectors, it is imperative to prioritise the management of biological waste and the implementation of appropriate strategies to mitigate health and environmental risks. This research seeks to clarify the multiple sources of biomedical waste, the health and environmental risks resulting from its mismanagement, and the role of advanced facilities in its safe disposal. Regulations for handling biomedical waste vary from country to country. Biomedical waste management requires close supervision. Solid and non-sharp biomedical waste must be steam sterilized and disposed of in landfills as red bag waste. Similarly, animal waste must be incinerated. Moreover, it was determined that there is a necessity in modern times to mitigate the danger of infection, minimize soil pollution, and avert the proliferation of antibiotic-resistant bacteria.

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