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Comprehensive Overview of Role of Environmental Biotechnology in Reductionof Medical Waste

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Abstract

Medical waste is a growing global concern because of its potential implications on the environment and human health. The amount of waste generated by the medical business is rising along with the demand for medical services. Inappropriate handling and disposal of medical waste can have a substantial negative impact on the environment by contaminating the soil and water, emitting greenhouse gases, and spreading infectious diseases. An emerging discipline called environmental biotechnology employs biological mechanisms to address environmental issues. This thorough study addresses how environmental biotechnology can be utilised to lessen the negative effects of medical waste on the environment. The forms of medical waste produced in healthcare institutions are covered in this review paper, along with any potential effects and current waste management techniques of environmental biotechnologies of all kinds that have been created to handle medical waste. These include bioreactor systems, microbial treatment, and composting. These technologies' benefits and drawbacks are also highlighted. Further into detail about how bioremediation is used to treat medical waste that is polluted with dangerous chemicals, has been explained with the case studies from different parts of the world that show how environmental biotechnologies have been successfully applied to the disposal of medical waste. These case studies show the difficulties encountered, the methods used, and the results obtained. Highlighting the necessity of a thorough strategy for managing medical waste that includes environmental biotechnologies. In order to boost the effectiveness, efficiency, and sustainability of medical waste management, more research and development is required in this area.

1. Introduction

In the healthcare sector, managing medical waste properly is a major concern because it can seriously endanger the environment and the general public (Buyukgungor & Gurel, 2009). The classification of medical waste as infectious, dangerous, or non-hazardous necessitates distinct methods of treatment and disposal (Buyukgungor & Gurel, 2009). According to the World Health Organization (WHO), of the total amount of waste generated in 2020-2021 by health-care activities was 87 thousand tonnes of PPE (personal protective equipment), 0.73 million litres of chemical waste, and 0.15 million tonnes of additional medical waste over 8 billion vaccine dozes. Solid medical waste generation of top 50 country has been depicted in Figure 1. WHO also reported that about 85% is general, non-hazardous waste comparable to domestic waste while the remaining 15% is considered hazardous material that may be infectious,

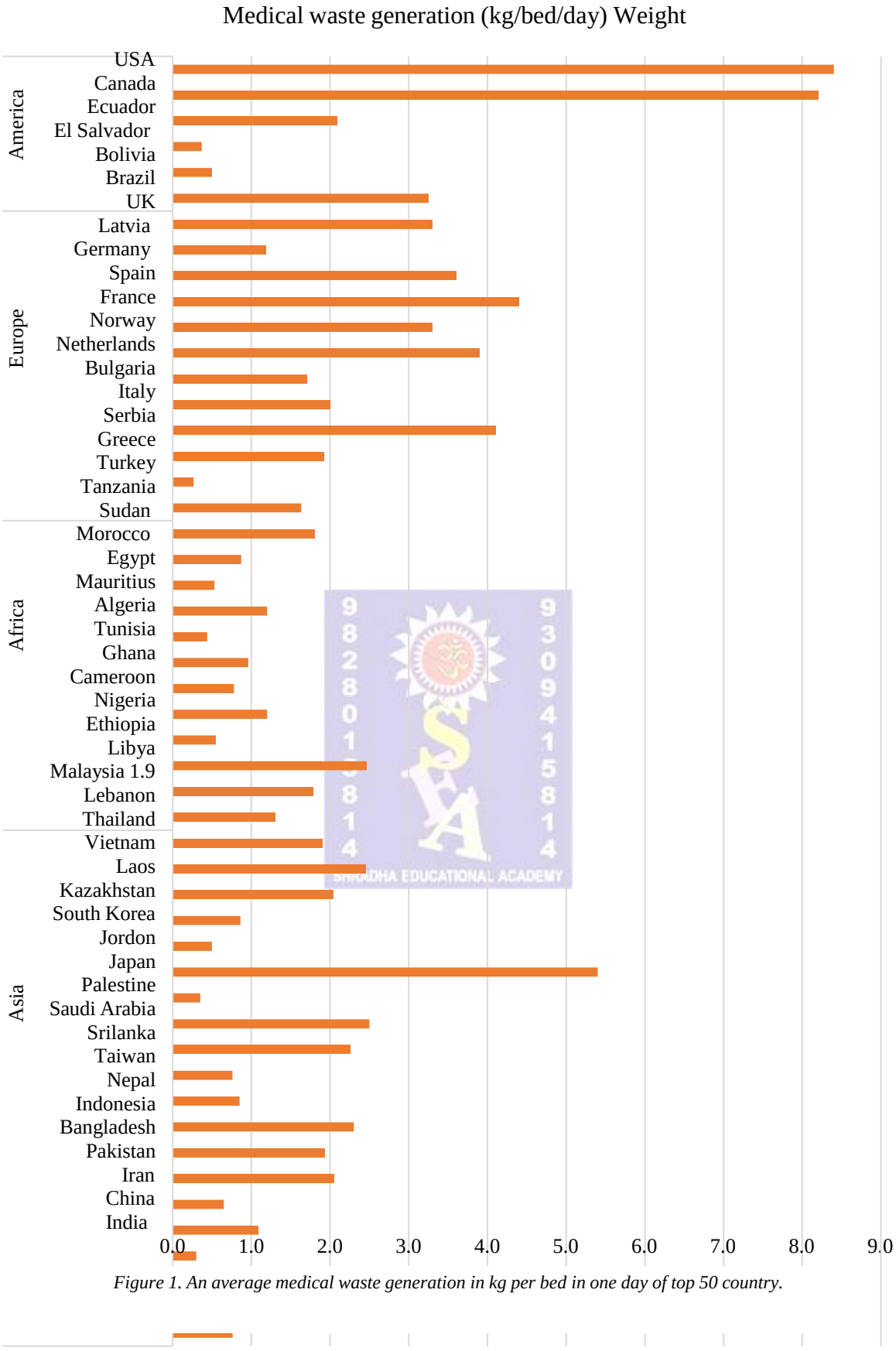

Figure 1. An average medical waste generation in kg per bed in one day of top 50 country.

the environment and human health if not properly treated and disposed of. For example, open burning and incineration of health-care wastes can result in the emission of dioxins, furans, and particulate matter, which are carcinogenic and can cause respiratory diseases. Moreover, improper disposal of sharps waste (such as syringes, needles, disposable scalpels, and blades) can lead to injuries and infections among health workers and waste handlers. Furthermore, pharmaceutical waste (such as expired, unused, and contaminated drugs and vaccines) can contaminate water sources and soil, affecting aquatic life and crops (Ye et al., 2022). Additionally, radioactive waste (such as products contaminated by radionuclides including radioactive diagnostic material or radiotherapeutic materials) can pose long-term risks of radiation exposure to humans and animals. Further, the amount and composition of health-care wastes vary depending on the source (such as hospitals, laboratories, blood banks), the level of development (such as high-income or low-income countries), and the type of treatment (such as conventional or alternative medicine). Hence, there is no one-size-fits-all solution for waste management. Rather, a combination of different methods may be required depending on the local context and conditions.

Although the lots of research and development on removal of medical waste are continuously published. However, medical waste management is a critical issue that requires continuous research and development. The type and amount of medical waste are increasing due to the advancement of medical instruments and the emergence of epidemic and pandemic diseases in recent years (Torres Munguía et al., 2022), such as SARS-CoV-2 in 2019, SARS-CoV in 2003 (Heymann, 2004), and influenza A (H1N1) in 2009-10 (Viboud & Simonsen, 2012). Therefore, the guidelines and practices of medical waste removal need to be updated regularly. Otherwise, the environmental damage and the health risks for all living organisms, including animals and humans, would be severe due to the pollution of air, water, and lands (Manzoor & Sharma, 2019). In the discipline of environmental biotechnology, biological processes are used to reduce pollution, restore the environment, and promote sustainable growth. It has shown promise in lessening the negative effects of medical waste on the environment (Selvasembian et al., n.d.). Based on this, the review paper offers a recent comprehensive overview of medical waste management and the role of environmental biotechnology in reducing the negative impact of medical waste on the environment. It covers various aspects of waste management, including generation, segregation, collection, transportation, treatment, and disposal, and highlights the importance of environmental biotechnology at each stage. Furthermore, the review examines different environmental biotechnologies that can be employed for managing medical waste, such as composting, anaerobic digestion, microbial fuel cells, and

phytoremediation. It delves into the advantages, drawbacks, and potential uses of each technology. It also explores the social and economic implications of using environmental biotechnology to manage medical waste. Overall, this review discussed using environmental biotechnology to reduce medical waste's environmental impacts and examines current management practices and biotechnology's role in solving this issue.

2. Impact of medical waste on the environment

If handled improperly, medical waste, which includes any kind of waste produced by healthcare facilities like hospitals, clinics, and laboratories, can have a substantial negative influence on the environment. The following are some ways that medical waste may harm the environment (Lenzen et al., 2020; Wei et al., 2021) -

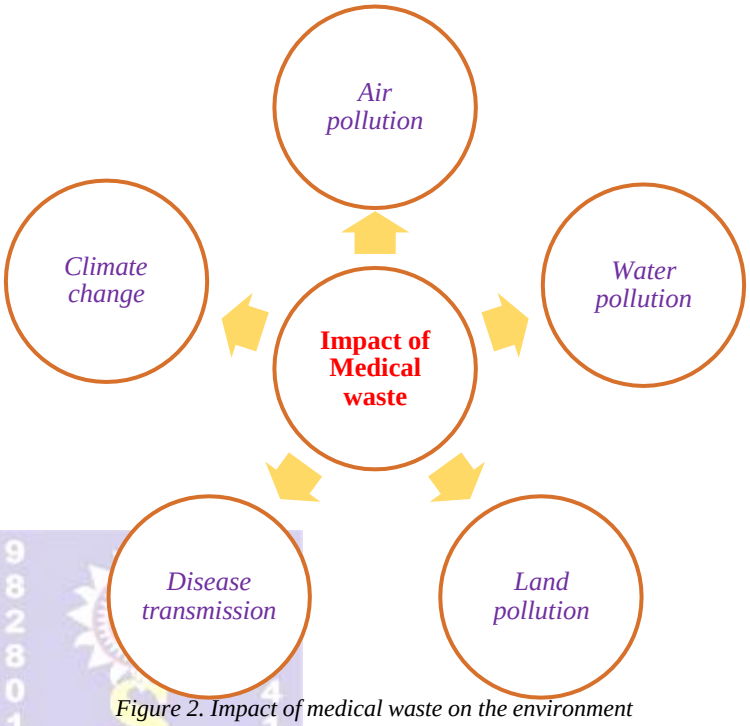

Figure 2. Impact of medical waste on the environment

Air pollution: When medical waste is burned, hazardous chemicals like dioxins, furans, and mercury can be released into the atmosphere, causing air pollution, and perhaps endangering the health of adjacent communities (*Health-Care Waste*, n.d.; Manisalidis et al., 2020).

Water pollution: If medical waste is not properly disposed of, it may contaminate water sources, posing major health dangers to both humans and wildlife (*Health-Care Waste*, n.d.).

Land pollution: Medical waste can contaminate the soil and landfills, endangering the environment and endangering human health (Manzoor & Sharma, 2019).

Disease transmission: Infectious agents including viruses, germs, and parasites can be carried by medical waste and spread illness to both people and animals (Das et al., 2021; Rajak et al., 2022).

Climate change: By releasing greenhouse gases that cause global warming, improper medical waste disposal can exacerbate climate change (*From Managing Medical Waste to Measures to Mitigate Impact of Climate Change, Ms Napapan Shows the Way*, n.d.; Raila & Anderson, 2017).

3. Biotechnology in managing medical waste.

Biotechnology is the application of organisms, cells, or molecular analogues for products and services. Among various applications, one of its promising uses is in waste management, where biological methods can treat and dispose of different types of waste, such as infectious, chemical, pharmaceutical, or radioactive waste (Englande & Jin, 2006). These methods can also reduce the environmental and health impacts of waste by preventing the emission of harmful substances, such as dioxins, furans, and heavy metals, into the air, water, and soil. However, biotechnology in waste management is not without challenges and limitations, such as ethical, social, economic, and regulatory issues (Parmieka, 2020).

3.1. Bioremediation:

3.2. Composting:

Medical waste can be managed naturally and sustainably via composting. It involves the microbial breakdown of organic waste products to create a nutrient-rich soil amendment that may be applied to agriculture and gardening. Composting can be utilized to manage a range of items when it comes to medical waste, including food waste from hospitals, clinics, and labs, as well as outdated pharmaceuticals and other organic waste products. By producing an environment that is perfect for microorganisms to grow, composting works. Microorganisms such as bacteria, fungi, and actinomycetes are in charge of decomposition. The organic material is broken down by these bacteria into less complex substances including carbon dioxide, water, and organic acids. The heat from the procedure also aids in killing any germs that could be present in the waste (Sufficiency et al., 2022). Bacillus subtilis is one type of bacterium used in composting. This bacterium can degrade a wide range of organic substances and is frequently found in soil. It is frequently used in composting to hasten decomposition and create high-quality final products (Duan et al., 2020; Mahapatra et al., 2022). Another illustration is the fungus *Aspergillus niger*, which is frequently employed in the pharmaceutical and food industries due to its capacity to manufacture enzymes. *A. niger* can aid in the composting process by reducing complex organic molecules like lignin and cellulose into less complex ones that are more easily utilized by other bacteria in the compost pile (Searca et al., 2022). Composting medical waste can reduce the quantity of garbage that is dumped in landfills and create an important soil amendment that can be utilized to enhance the fertility and health of the soil. When done properly, it is a secure and organic method of treating medical waste that can help stop the discharge of dangerous toxins into the environment (Taiwo, 2011).

Cellulase is one type of recombinant enzyme that can be utilized in the composting of medical waste. One of the main ingredients of medical waste including bandages, gauze, and cotton swabs is cellulose, which is broken down by the enzyme cellulase. Cellulase use can hasten the decomposition process, reducing waste volume and producing nutrient-rich compost in the process (Khan et al., 2016). Lipase is another illustration. This enzyme breaks down the lipids and fats in medical waste such as soiled bandages and surgical drapes. By using lipase, these materials can decompose more quickly, which reduces their volume and the risk of environmental pollution (Patel et al., 2019). In addition to lipase and cellulase, protease is a third enzyme that can be employed to digest proteins in medical waste, including biological fluids like blood. Protease usage can aid in the breakdown of these substances and lower the risk of infection (Semarang, 2018).

4. Conclusion

Environmental biotechnology offers a promising way to lessen the harm that medical waste causes to the environment. This study has demonstrated that a variety of technologies, including microbial treatment, composting, and phytoremediation, can effectively treat medical waste and lessen its impact on the environment. Further enhancing the efficacy of environmental biotechnology in waste management is the use of biodegradable materials and the adoption of sustainable practices in healthcare facilities. It is critical that stakeholders in the healthcare sector, decision-makers, and researchers work together to develop more creative and long-lasting solutions to the problem of managing medical waste. We can lessen the negative effects of medical waste on the environment and safeguard public health by using environmental biotechnology solutions.

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