

COMPARISON OF MEDICAL WASTE MANAGEMENT IN POLAND AND IN INDIA – LITERATURE REVIEW

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Purpose: The aim of the article is to provide objective research about a comprehensive comparison of medical waste management procedures in Poland and India. It examines the legislative frameworks, waste generation figures, treatment techniques, and environmental consequences in both countries.

Design/methodology/approach: The basic research methods were the analysis of literature on the medical waste management in Poland and in India. The article focuses on the comparison of produced waste, their type, type of their classification and their impact on the environment.

Findings: The comparative analysis enables bringing critical observations on how to manage such type of wastes in different settings. Both examples show that stringent regulatory frameworks and advanced technologies can lead to positive outcomes. It is shown by the research that proper disposal of medical wastes, aiming at guaranteeing public security and preservation of nature must consider peculiarities of local environment to be implemented effectively.

Research limitations/implications: In the future, research will be continued in the field of statistical comparison of medical waste management in both countries.

Practical implications: The findings emphasize the importance on not only technological and legislative solutions for medical waste management but socio-cultural factors, involving stakeholders, and awareness. The comparative nature of study contributes to making a useful reference to policymakers, healthcare professionals, and waste management practitioners as it provides better practices of medical waste management anywhere in the world.

Originality/value: Medical waste management in the case of global health emergencies such as COVID-19 pandemic should be a potential research focus in the future. The knowledge of these impacts can help to develop more dynamic and adaptable waste management systems that are ready to cope with the quick increase in volume of the wastes. In addition, cross-country studies will promote international collaboration to share best practices innovations, and experiences. It can spread more integrated and efficient global strategies on the medical waste management that would result in better health outcomes and environmental stewardship.

Keywords: medical waste management, techniques, strategies, safety.

Category of the paper: Literature review.

1. Introduction

Medical waste management is a critical issue of both environmental and public health; this has different approaches in various nations. The comparative approach in this research between Poland and India offers an alternative angle to viewing the different strategies for such a challenge. Poland, as a country with the functioning health care system must comply to EU policies on medical waste. EU method is based on compliance, safety and sustainability which will reduce the rate of wastes generation as well encourages recycling. The Polish approach is a technology-focused (Halkos, 2021). However, in the case of India, there is a vast population to deal with making it more complicated when disposing medical waste. The nation suffers from issues due to its high level of waste production and varying process in its states associated with the faint law enforcement. Despite the fact these are issues that India is facing, innovative technologies and cost-efficient methods of waste management seem to grow in this country (Barma, 2022).

Both countries have an evolutionary waste management medical history. The evolution has been driven by European standards with changing healthcare requirements due to developing cum improved waste management system in Poland. In contrast, India's path shows rapidly increased urbanization and healthcare sector however leaving behind the provision of basic infrastructure for solid waste management. The classification of the medical waste, which is hazardous and non-hazardous also, complicates its control measures. Waste collection management is made worse by the extent and nature of waste produced in India, as well poor segregation practices. Contrastingly, the Polish system of waste separation has a simpler process as it possesses better infrastructure and compliance with regulation (Hag, 2022).

The influence of healthcare infrastructure and population structure on the number of medical wastes generated and managed is high. In India's heavily populated areas, the overwhelming numbers of wastes exceed established infrastructures while Poland has population densities that are more manageable despite their potential waste quantities. The modern technology has greatly transformed the system of waste management. In terms of waste treatment and recycling, Poland derives benefits from European innovations, while India is gradually investigating cost-effective and replicable methods. Environmental and health effects of improper management of medical wastes are prevailing in both countries, however much more acute in India because inconsistent waste assistance practices (Hag, 2022, Vlachokostas, 2020).

Both countries' policy and regulatory issues demonstrate the struggles in dealing with medical waste. By following EU directives, Poland leads to more homogeneous but a harsher regulatory environment. This regulatory framework is changing in India, but this change can be seen with varying value of implementations and enforcements across the states. The appropriate waste management practices are formulated based on stakeholder engagement

and public understanding. Visibility of public awareness improved, and the stake is high in Poland; on India's end visible improvement needs to act as motivation for intensity checking participation since it helps with better waste management. As this comparison between Poland and India, however, does not only reveal the statistical features for medical waste management but also shows the overall context as well including global practices and opportunity (Franco-Garcia, 2019).

2. Materials and Methods

This study is based on a structured literature review and data analysis of the legal acts from both countries – Poland and India. Additionally, statistical data analysis and semi-structured expert interview, documental and legal analysis, policy documents and scientific articles were analyzed to identify system-level deficiencies. Comparative analysis was used to highlight management of medical waste in both countries.

The aim of this study was to identify systemic challenges in infectious medical waste management in Poland and in India and show some differences in regulatory framework. Research objectives were indicated:

- **Research objectives:**

- Focus on the structure, efficiency, and regulatory compliance of medical waste management systems in Poland and India.
- Examine the specific challenges faced in managing medical waste in Poland and India and identify effective practices that could be implemented in similar contexts.
- Evaluate the influence of socio-economic, cultural, and geographical factors on the medical waste management strategies in both countries.
- Provide actionable recommendations for improvements in medical waste management, drawing on the insights from the comparative analysis.

- **Research questions:**

1. What are the structural and operational differences in the medical waste management systems of Poland and India?
2. What challenges are unique to Poland and India in the context of medical waste management, and how are these challenges being addressed?
3. How do socio-economic and cultural factors impact medical waste management practices in Poland and India?
4. What improvements can be recommended for both Poland and India based on the comparative analysis?

This study focuses on a comparative analysis of medical waste management in Poland and India. It includes the examination of legislative frameworks, waste management strategies, and literature review regarding waste generation and disposal. The study aims to identify challenges for both countries, considering the influence of various socio-economic and cultural factors. The findings aim to provide insights and recommendations for policymakers, healthcare facilities, and waste management authorities in both countries.

3. Results

3.1 Medical waste management in Poland

The Waste Act of 2022 defines the concept of medical waste as "waste generated in connection with the provision of health services and conducting research and scientific experiments in the field of medicine" (Dz.U., 2023). Therefore, medical waste will appear in hospitals (general, psychiatric), rehabilitation sanatoriums, addiction centers, hospices, medical and educational facilities, care and educational facilities, clinics, health centers, clinics, and individual medical and nursing practices. Medical waste can be divided into 2 groups: hazardous waste (infectious waste, special waste) and non-hazardous waste. These wastes may occur as solid substances (syringes, needles, limbs), liquid substances (blood, plasma, vomit) and gaseous substances. Since medical waste encounters the patient's blood and secretions, it may be dangerous to human health. Primarily because the patient may be a carrier of various types of diseases or pathogens such as viruses, bacteria or fungi that may cause AIDS, hepatitis C or the plague (Topolska, 2017).

Hazardous medical waste is generated at virtually every stage of a medical facility's operations. During the admission and diagnosis of a patient, medical waste may appear, such as: dressing materials, surgical gloves, sponges, cotton swabs, sticks, spatulas, pharmaceuticals, syringes, and needles. At the stage of conducting research, including laboratory tests, medical waste appears in the form of e.g., needles, pipettes, human tissues, or blood. Most hazardous medical waste occurs during surgery. During and after surgery, waste such as used surgical equipment (needles, scalpels, etc.), human remains and tissues, and blood are generated (Zalewska, 2019).

To classify waste, not only medical waste, an online waste database (BDO) was established and launched in 2018. Its main goal was to seal the waste management system. The main tasks of BDO are (BDO, 2023):

- collecting information on packaging and products in packaging introduced in Poland,
- collecting information on the achieved levels of recovery and recycling of waste from packaging and products,

- obtaining information on cross- border movement of waste,
- waste classification,
- keeping waste records based on submitted reports,
- control of the waste management market.

The waste catalog is a collection of all waste divided into groups, subgroups, and types of waste, depending on the source of their generation. Additionally, the catalog lists hazardous waste that poses a particular threat to human health and life and the environment, marked* (Dz.U., 2020, item 10). According to the waste catalog, medical waste is classified in group 18 and subgroup 01 (waste from diagnosis, treatment, and medical prevention).

Types of medical waste (Mesjasz -Lech, 2019, Zdęba-Mozoła, 2022):

1. Infectious waste: This group consists of materials that are contaminated with blood and other bodily fluids such as used dressings, bandages, and swabs. It also encompasses objects like discarded gloves, gauze and other used medical equipment that has got into contact with infectious materials.
2. Sharps waste: This category includes used needles, syringes lancets and other sharp medical tools. The importance of disposal of sharps waste properly to prevent injuries and hence the risk assessments pathogens associated with blood borne is significant.
3. Pathological waste: This category encompasses human tissues organs and body parts that are removed during surgeries autopsies or other therapeutic procedures. Pathological waste disposal helps to stop the development of infections spread and also preserves dignity with respects for the deceased.
4. Pharmaceutical waste: This type includes expired, unused, or contaminated medications and pharmaceuticals that require disposal. Right managing of waste from pharmaceutical is required for the purpose to avoid contamination due to environmental pollution in addition using medications improperly.
5. Chemical waste: This classification features different substances and dangerous agents used in medical operations, treatments, laboratory works. The proper treatment and well placement of chemical waste is also very important in the process to reduce environmental impact as well protecting public health.
6. Radioactive waste: Under this group come materials as are contaminated with radioactive substances for use in radiation therapy, nuclear medicine, and research activities. Here radioactive waste is managed and disposed of under strict regulation to avoid the exposure from radiations as well as contamination on environment.
7. General waste: This group includes non-toxic waste produced by medical organizations, including paper, cardboard food scraps and other infectious materials. Segregation and disposal of general waste, which are not considered a medical waste, need to be done properly for overall management of the wastes in hospitals.

The nature of medical waste is hazardous waste: these comprise of infectious garbage, pathological waste products, knives, pharmaceuticals, and physical cleansers. The breakdown of the percentages within each category is highly dependent on various types of medical activities that are observed in a particular centre.

The second group is in general non-hazardous waste: in most cases, more than 80% is not hazardous like domestic wastes. It can be distinguishing special category of waste like some operational units may produce certain categories of special waste such as radioactive waste that calls for specific treatment and management methods.

The specific nature of the work of medical facilities is related to constant contact with hazardous substances. Improper contact with blood or surgical waste may pose a risk of infection. Improper storage or transport of medical waste, or even worse, a complete lack of proper management of this type of waste, may lead to the release of potentially hazardous substances into the environment and, consequently, to contact with them by unaware third persons. In the event of improper storage of waste (e.g., in a common garbage container), hazardous compounds may spread even through animals, such as rats or cats, which is why it is so important to properly handle waste at the stage of storage. Due to the potentially dangerous impact of medical waste on the environment, it should be properly segregated and stored at the initial stage of its production. This is the first and very important step in the entire process of safe transport and waste disposal.

In the case of medical waste, its initial segregation and - more importantly - proper protection against the environment mainly concern waste such as:

- used dressings, syringes, surgical tools,
- waste from treatment and operating rooms,
- used and expired medicines.

To store medical waste (depending on the type of waste) plastic bags or hardened containers may be used. What type of container should be used depends primarily on the characteristics of individual medical waste. In the case of waste with sharp edges, e.g., needles or scalpels, hardened containers should be used. The proper selection of the agent and method of storage allows you to minimize the risk of potentially dangerous situations for the environment or for people who have direct contact with the waste, e.g., during its storage or transport. Hardened containers are resistant to most mechanical damage, moisture, and certain chemical reactions. Containers and bags for medical waste are delivered in different colors, depending on the target type of waste to be stored in them. Figure 1 shows examples of bags and containers for storing and transporting medical waste.



Figure 1. examples of bags and containers for storing and transporting medical waste.

Source: www1.

The following types of containers can be distinguished (Regulation of the Minister of Health of October 5, 2017, on the detailed method of dealing with medical waste (Dz.U., 2017; EKOMED, 2023):

- **red containers** – intended for collecting waste like residues from feeding people from infectious disease wards, blood, waste containing toxins or microorganisms,
- **yellow containers** – intended for collecting waste like chemical reagents – containing dangerous substances, cytotoxic drugs,
- **different colour containers e.g., blue** – intended for collecting waste like surgical and treatment tools, dressings, including plaster casts, bedding.

It is important to note that the containers are not designed with reusability. After filling, each container should be tightly closed in a way that prevents it from being opened again without leaving a clear trace. Professional containers used by companies are created in such a way that once closed, the container guarantees the waste producer that it cannot be reopened by unauthorized persons. Containers should be filled with no more than $\frac{2}{3}$ of their volume - this allows them to maintain appropriate properties of containers and resistance to damage, which is crucial for the safety of the waste producer due to his responsibility. An equally important element is the proper marking of the container or bag with waste – each of them should have an appropriate marking containing, among others: waste code or time of its closure.

It is worth remembering that the choice of a reliable company dealing with the transport and disposal of medical waste, which can provide and provide appropriate means of transport, is crucial for the safety of outsiders and the waste producer, because he is responsible for the waste generated (Ekomed, 2023, Przydatek, 2022).

Challenges and issues in medical waste management are related to:

1. **regulatory compliance:** adhering to the complicated and dynamic medical waste management regulations and policies can be difficult for healthcare facilities as well water managers themselves, regulators;
2. **infrastructure and facilities:** timely and enough regulations on infrastructures or facilities for the collection, separation of storage treatment as well as medical waste disposal is necessary. One of the challenges in promoting appropriate waste

management infrastructure in healthcare facilities, particularly those located outside urban areas;

3. **segregation and handling:** it is necessary to make proper segregation between different types of medical wastes in the generation point. On the other hand, difficulties in practice can occur while placing emphasis on training of healthcare personnel and provision them with equipment for segregation and safe & effective treatment of medical waste;
4. **transportation:** the transportation of medical waste from the healthcare facilities to treatment and disposal facility must be safe and compliant. Challenges may be associated with availability of specialized transport services and preservation of integrity waste containers during transportation;
5. **treatment and disposal:** choosing the right treatment method and mode of disposal for medical waste is not always an easy task. This may also involve certain alternative facilities such as autoclaving, incineration and chemical treatment which must be cleared by the relevant authorities;
6. **environmental impact:** managing the environmental effects of medical waste does not come easy for especially in terms of emissions, wastewater, and contamination. When it comes to ensuring that the process and methods of treatment and disposal are environmentally friendly;
7. **public awareness and education:** raising awareness among health workers, waste management personnel and the population in general on importance of correct handling and disposal medical wastes is also necessary;
8. **resource allocation:** effective implementation of medical waste management should be made possible by proper resources. Healthcare facilities and waste management companies may also face difficulties due to budget limitations and resource allocation.
9. **monitoring and enforcement:** close monitoring and control of the medical waste management regulations also need to be implemented. It is a challenge to be assured that regulatory authorities are provided with the capacity of compliance monitoring and where necessary, enforcement.

The realization of these challenges demands coordinated involvement between the healthcare institutions, waste disposal firms, regulatory organizations, and different stakeholders to formulate crucial procedures for medical announcement within Poland.

3.2 Medical waste management in India

Medical waste, also known as biomedical waste, refers to any waste solid or liquid that contains infectious or potentially infectious materials from medical, laboratory, or research activities such as diagnosis, prevention, and treatment of diseases. This waste poses a higher risk of infection and injury to healthcare workers, patients, and the surrounding community. It encompasses human anatomical waste, animal waste, microbiology and biotechnology waste,

waste sharps, discarded medicines and cytotoxic drugs, soiled waste, liquid waste, incineration ash, and chemical wastes (Datta, 2018).

Common generators of medical waste in India include hospitals, clinics, medical and veterinary colleges, blood banks, mortuaries, autopsy centres, biotechnology institutions, research laboratories, home healthcare facilities, and funeral homes. Hazardous chemicals and radioactive waste, although non-infectious, also require proper disposal (Kandasamy, 2022).

In India, the management and handling of biomedical waste are regulated by the Biomedical Waste (Management and Handling) Rules of 1998, along with subsequent amendments. These rules are presented in six schedules – types of biomedical waste, colour coding and container sizes, labels for biodegradable bags or containers for medical wastes, transport labels: standards of treatment and disposal; detailed indications on the organization's incinerator autoclaves including microwave systems. Biomedical waste classification- categories, treatment, processing and disposal options are shown in Table 1. Operating standards such as combustion efficiency and emission specifications are also outlined (Rules, 1988).

Appropriate handling of medical waste is important to avoid the risk associated with infection diseases since there are several germs which can cause harm to individuals while making it dangerous and hazardous for public health as well as environment.

Table 1.

Biomedical waste classification- categories, treatment, processing and disposal options (Datta, 2018)

Category	Types of waste	Colour and type of container
Yellow	Human anatomical waste, animal anatomical waste, soiled waste, discarded or expired medicine, laboratory waste, chemical waste, chemical liquid waste	Yellow colour non chlorinated plastic bags; thickness ≥ 50 microns or containers
Red	Contaminated waste (recyclable)	Red colour non chlorinated plastic bags; thickness ≥ 50 microns or containers
White	Waste sharps including metals	White colour translucent, puncture proof, leak proof, temper proof containers
Blue	Glassware, metallic body implants	Cardboard boxes with blue coloured marking or blue coloured puncture proof, temper proof containers

Types of medical waste in India (Rules, 1988; Datta, 2018):

1. general waste: this category includes non-hazardous waste from healthcare facilities, such as paper, packaging and food waste. While not inherently hazardous, proper disposal is still essential to prevent environmental pollution and maintain hygiene standards within the facility. The general type of medical wastes should be categorized into a different section and managed with the regulations municipal garbage management systems;
2. pathological waste: the pathological waste can be defined as tissues, organs, body parts and bodily fluids generated from surgery or autopsy laboratories. This kind of waste is dangerous from the point of view disease spread and require additional special care in

dusting. Thus, this waste should be stored in non-porous and puncture proof containers and treatment procedures like burning or autoclaving guarantees the pathogen elimination;

3. infectious waste: the types of waste that fall within this category include the wastes containing blood, body fluids or any other infectious material including used bandages and swabs. Complete segregation, packaging and treating the material is required to minimize chances of infections. The infective wastes should be stored in colour coded leak-proof containers and decolorized or decontaminated through process like incineration or autoclaving before they are finally dumped;
4. sharps waste: sharps waste includes needles, syringes, scalpels, and any other item that might cause injury or infection. It should be gathered in sharp-proof receptacles that will help to prevent the needle sticks and injuries. Sharps waste is usually dealt with through autoclaving or other approved sterilization method so that they do not cause further harm;
5. pharmaceutical waste: these types comprise of medications that have expired, drugs and contaminated medication as well as vaccines. Proper waste disposal is necessary to prevent pollution and avoid illicit use. The disposal of pharmaceutical waste seeks to adhere to the segregation and management employed by such a measure with secure storage, return into manufacturer or incinerating it at high temperature;
6. chemical waste: harmful chemicals used in the medical field, namely disinfectants, solvents and reagents should be managed and properly discarded to ensure people's life is protected as well as that of all nature. Hazardous waste management guidelines require that chemical wastes be collected, stored, and disposed of in a manner involving treatment or incineration at licensed sites;
7. radioactive waste: materials containing radioactive substances used in diagnostic and therapeutic procedures should be treated with special consideration on their handling as well as disposal to avoid radiation exposure or contamination of environment. The proper disposal of the waste must comply with regulations that include provision and use of shielding, containment within licensed radioactive facilities for treatment;
8. pressurized containers: this group contains aerosol cans, gas cylinders and various other pressurized containers utilized for the medical procedures. These materials should be de-pressurized and safely disposed of to avoid accidents or hazards. It is necessary to arrange the proper depressurization, and disposal means for the safe handling of pressurized containers.

In the case of India, medical wastes have also been becoming significant concerns in terms with respect to their quantity and composition due to increasing health care sector. Each year, the country produces approximately 484 tons of medical trash daily-a number that has been increasing over time as new facilities are developed. This waste is a mixed variety of both hazardous and non-hazardous substances. About 15-20% of total waste is classified as

hazardous and potentially infectious, which may compromise the health of people and nature. The remainder, between 80-85%, is non-hazardous just like municipal waste. Medical waste from major metropolis comprises of a larger proportion since the healthcare facilities are concentrated in these urban centres. The word 'toxic' refers to materials such as used syringes, contaminated gauzes expired drugs discarded surgical instruments and chemical wastes. These aspects are especially worrisome since if mishandled and discarded carelessly they can transmit diseases such as the human immunodeficiency virus (HIV), hepatitis among other infections (Devi, 2019).

The composition of medical waste in India also depicts the plurality of traditional systems and quality variation in health care services. In advanced cities filled with higher-level medical facilities, the content of complex items such as chemical and pharmaceutical residues cytotoxic drugs, radioactive materials are high. On the contrary, wastes from rural areas where is more basic healthcare services produce non-hazardous waste but with a lower percentage of infectious and hazardous. Nevertheless, even non-hazardous waste can be contaminated and become hazardous. There is the poor segregation of waste at source by mixing hazardous and non-hazardous wastes which makes management processes cumbersome. Additionally, there is a rising trend of disposable medical devices and plastics in the health industry leading to an alarmingly high rate at which wastes are generated. This case highlights the importance of sustainable waste management policies and practices (Gowd, 2021; Kaur, 2022).

With the rapid development of its health care industry, India has seen a sharp rise in medical waste creation over the past several years. This rise is due to various factors such as increasing population, higher prevalence of chronic diseases and improving accessibility to healthcare facilities. According to the recent data, India produces around 500 tons per day of medical waste, and this figure remains increasing with the growing number of hospitals, clinics diagnostic centres or laboratories (Sharma, 2020). The largest contributors to this growth are the urban centres, particularly metropolitan cities in which healthcare facilities have high population concentrations. In addition, medical waste has become different from the type of trash production. The amounts also increased on hazardous materials such as sharps, pharmaceuticals, chemical solid and liquid wastes among other infectious substances which are a major health threat resulting in losses of billions. However, this transformation partially arises from the current development in medical devices and techniques that frequently involve increased use of sophisticated surgical tools. Increases in biomedical waste during normal time were already increasing, and the COVID-19 pandemic massively accelerated this trend: largely due to personal protective equipment (PPE) masks and gloves highlighting challenges of rapid increases in volume for adequate management (Kothari, 2021).

The trends in medical waste generation in India also show the changing pattern of healthcare practices and consumer behaviour. Single-use disposable medical products are becoming prevalent focusing on the patient safety and infection prevention. This trend, however necessary to cut off cross contamination issues has led to mounting plastic-based wastes creating immense

environmental challenge. The incomplete separation of wastes at the source is still one of main problems, as hazardous and non-hazardous waste becomes mixed prior to collection. Moreover, there is an uprising understanding of environmental and health consequences of incorrect medical waste management creating stringent rules and policies. Both government and different environmental organizations are now pushing the direction for better ways of garbage management emphasizing dumping, recycling, and responsible disposal methods. On the other hand, implementation has huge differences regionally with many urban centres recording better management systems in comparison to rural areas. In the Indian context, with more advancements taking place in generation of medical waste over time demands for better strategies including education policy, strict regulations as well as adoption of eco-friendly disposal methods is pronounced than ever (Manzoor, 2019).

4. Discussion

The medical waste disposal in Poland and India illustrates several very different approaches which are related with the infrastructure of health care, the regulating system, as well as social-economic environment. The healthcare system in Poland is liberal, and the operations of the system fall under the regulations set by Europe Union regulation that promotes compliance with orders, safety and sustainability. This route has resulted in a functional, sophisticated, and integrated waste management paradigm that utilizes leading-edge technology to minimize wastes generation while fostering recycling.

Contrastingly, India has issues that are very complicated due to the demography and their large population of heterogeneous origin, but they produce lots of waste differently at state level. It comes based on the demand for more rigorous law enforcement and has taken an active step towards modernized efficient and cost-effective waste elimination practices. Despite this unattractive perspective, the situations of medical waste management in India continue to improve, an indicator of its urbanization and development of the health system.

The following countries have also made very significant progress in their approaches to medical waste management strategies. The Polish one also could be viewed as a reflection of the European standards, and reforms that is necessary for Indian health care was unavoidable many times not able meet increase in number. The variation in hazardous and non-hazardous waste among the two countries is associated with intricate strategies of management.

Finally, the provided analysis identifies the contextual connections that frame up medical waste management in Poland and India thereby giving an image of global operations with regards to possible cures. It shows that medical waste management systems used by these two countries are formed by healthcare infrastructures, characteristics of population demographics, technological advancements, and policy settings all which have played a critical role.

In Poland, the medical device is governed by European Union directives and national laws that similarly enact high standards of safety and quality. The law enacted on April 7th2022, Medical Devices, which seeks to harmonize the EU's MDR and IVDR imposes extensive pre-marketing criteria aimed at gaining market access for publicly funded health markets. Furthermore, Polish laws on the promotion and advertising of medical equipment as well as products of life sciences instruct to consider ethical standards and prohibit misleading advertisements. In addition, Poland's plastic waste and packing policy with implications for medical waste can be defined as the highly controlled environmental preservation practices that involved bans on several disposable plastics products and costs for single-use plastic garbage dealing.

However, India's regulatory framework for medical waste management is elaborate, stipulated to decrease risks arising from handling or disposal. These regulations are based on the Biomedical Waste Management Rules, initially notified in 1968 and amended in 2016 and 2018. A number of these regulations establish tough standards for segregation, transportation, storage, treatment, and disposal of biomedical waste; the decontamination wastes are classified depending on their hazard level and particular handling methods are provided for each specific group. To this end, hospitals and medical facilities in India should get the necessary sanction from their State Pollution Control Boards (SPCBs) or Pollution Control Committees (PCCs) regarding generation, management, and disposal of biomedical waste. Likewise, CPCB is very crucial in developing standards and the biomedical waste management guidelines to be used across the entire country. The 2016 revision of the rules changed much, such as a polar plan for chlorinated plastic bags and barcoding systems that served better waste tracking. However, the effective realization of such rules is not that easy process even in towns and rural districts due to informative deficiency and shortage of resources.

These differences reflect different strategies of waste management in Poland and India. Poland's regulatory environment, in line with the EU standards, is also safety and quality driven where medical devices as well as waste management have severe rules. Instead, although India's structure is rather comprehensive, its efficient implementation with difficulties in rural and backward areas manifests a broader lack of public awareness insufficient infrastructures and stricter control.

5. Conclusions

The research conducted in this article provides an analysis of the medical waste management systems in Poland and India. Through the comparison of these systems, the study emphasizes major dissimilarities in waste management practices that are based on different socio-economic, cultural, and regulation backgrounds. The Polish approach also influenced by

the European Union regulations gives evidence of the high standardization, efficiency and technology. This is useless for India's system, facing challenges because of its size and heterogeneity, but also demonstrates resilience and slow but steady progress towards reform. This comparative study does not only focus on the current situation of medical waste management in both countries but has also shed some light on the worldwide phenomenon of waste management practices.

The results of this study are important in terms of understanding the impact of medical waste disposal and its effects on public health and the environment. The comparison of Polish and Indian systems provides pivotal principles in terms of adaptability, resource accommodation, and innovative approaches to the healthcare challenges that are currently altering with pandemics like COVID-19.

Using a comparative analysis of medical waste management in Poland and India enables bringing critical observations on how to manage such type of wastes in different settings. Both examples show that stringent regulatory frameworks and advanced technologies can lead to positive outcomes, while the emerging scheme in India is relatively simple – it touches upon innovation and flexibility under resource shortages. It is shown by the research that proper disposal of medical wastes, aiming at guaranteeing public security and preservation of nature must consider peculiarities of local environment to be implemented effectively.

The findings emphasize the importance on not only technological and legislative solutions for medical waste management but socio-cultural factors, involving stakeholders, and awareness. Coherent solutions in the management of both wastes are fully dependent on this complex range of aspects. The comparative nature of this study contributes to making a useful reference to policymakers, healthcare professionals, and waste management practitioners as it provides a sort of roadmap for better practices of medical waste management anywhere in the world. The scope is limited to the analysis of existing data and does not include primary research or experimental interventions in the field. The findings aim to provide insights and recommendations for policymakers, healthcare facilities, and waste management authorities in both countries.

The case of Poland and India is not isolated, but representative of broader challenges in middle- and high-income countries with fragmented oversight. These results justify the need for the development of best-practice models and case-based solutions, especially in some crisis like COVID-19 pandemic.

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