

Mechanisms for Recycling Healthcare Waste and Their Role in Achieving Sustainable Development

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Abstract:

The purpose of this research article is to shed light on the actual processes of recycling healthcare waste and their importance in achieving sustainable development. Healthcare waste is among the most hazardous types of waste due to its infectious and toxic nature, and society deals with it daily. It includes all waste generated by medical practices or activities associated with healthcare institutions. Hence, we aim to highlight the mechanisms through which healthcare institutions dispose of their medical waste, and whether these mechanisms are based on scientific foundations or merely stem from necessity. Given the limited practical experience in potentially conventional methods, our primary conclusion is that there are alternative methods to treat and recycle as much healthcare waste as possible. Several aspects must be taken into consideration when selecting appropriate solutions, many of which depend on local conditions such as health and safety standards and waste disposal options. It is also necessary to impose measures on any health institution that does not comply with regulated systems of healthcare waste disposal, while also honoring institutions that take the initiative in implementing public projects in this regard to encourage and motivate others to contribute to sustainable development.

Keywords: healthcare waste, recycling healthcare waste, healthcare waste recycling mechanisms, sustainable development.

JEL Classification Codes : Q 01, Q28, Q42, Q56, Q57, C42

ملخص:

يهدف هذا البحث إلى تسليط الضوء على واقع عمليات إعادة تدوير نفايات الرعاية الصحية وأهميتها في تحقيق التنمية المستدامة. تعد نفايات الرعاية الصحية من أكثر أنواع النفايات خطورة بسبب طبيعتها المعدية والسامة، ويتعامل المجتمع معها بشكل يومي. وهي تشمل جميع النفايات الناتجة عن الممارسات الطبية أو الأنشطة المرتبطة بمؤسسات الرعاية الصحية. لذا، حاولنا تسليط الضوء على الآليات التي تتخلص بها المؤسسات الصحية من نفاياتها الصحية، وما إذا كانت هذه الآليات مبنية على أسس علمية أم أنها مجرد نتيجة للضرورة. ونظراً للخبرة العملية المحدودة فيما يخص الأساليب التقليدية المحتملة، فإن الاستنتاج الرئيسي الذي توصلنا إليه هو أن هناك أساليب بديلة لمعالجة وإعادة تدوير أكبر قدر ممكن من النفايات الصحية. هناك العديد من الجوانب التي يجب مراعاتها عند اختيار الحل المناسب، ويعتمد الكثير منها على الظروف المحلية، مثل معايير الصحة والسلامة وخيارات التخلص من النفايات. ومن الضروري أيضاً اتخاذ إجراءات ضد أي مؤسسة صحية لا تلتزم بنظام التخلص من النفايات الصحية، مع تكريم المؤسسات التي تأخذ زمام المبادرة في تنفيذ المشاريع العامة في هذا الصدد لتشجيع وتحفيز الآخرين على المساهمة في التنمية المستدامة.

كلمات مفتاحية: نفايات الرعاية الصحية، إعادة تدوير نفايات الرعاية الصحية، آليات إعادة تدوير النفايات الصحية، التنمية المستدامة.

تصنيفات JEL: س 01، س 28، س 42، س 56، س 57، ج 42.

1. Introduction

Humans strive daily to improve the level of healthcare institutions. The more advanced and diversified these institutions are, the more positively they reflect on public health and life expectancy. The rapid development of healthcare institutions across various specializations leads to increased amounts of medical waste, exacerbated by rapid population growth. Medical waste generated by healthcare institutions is among the most dangerous due to its content of fast-spreading microorganisms, sharp tools, patient residues, and hazardous chemicals that cause various diseases. If not handled using scientific methods and modern technologies, this waste could pose a significant threat to the environment and public health. It constitutes a real threat constantly faced by health sector professionals, which requires cautious and scientifically studied handling to avoid the transmission of diseases and infections and to mitigate its danger to the environment. Negligence in handling infected waste could result in the spread of diseases such as various types of hepatitis, blood-related diseases, HIV/AIDS, or others—posing fatal consequences. The risks extend beyond healthcare workers to include the general public, especially with the expansion of home healthcare services and field vaccination campaigns, particularly in educational institutions and private care outside hospitals.

Based on the above, there is an increasing focus and interest in the environmental risks of healthcare waste, which has become a subject of interest to many researchers regarding how to treat and manage it and avoid its dangerous effects.

Research Problem

Healthcare waste is among the most hazardous categories of waste handled by the public daily due to its abundance and diversity. Visitors, employees, and cleaning staff in healthcare institutions are particularly vulnerable to its dangers. Some institutions do not handle medical waste scientifically, which worsens the issue. Additionally, most citizens lack sufficient awareness of how to handle medical waste.

Research Objectives

1. Raise awareness among citizens and healthcare managers about the dangers of mishandling medical waste.
2. Guide society, particularly healthcare institutions, toward benefiting from medical waste (e.g., expired medications and solutions), and encourage waste volume reduction.
3. Identify safe disposal methods for medical waste in accordance with the regulations and instructions of the competent authority.

4. Contribute to providing a safe environment for patients, staff, and visitors in healthcare facilities.
5. Participate in preserving the environment from pollution caused by improper handling of especially hazardous healthcare waste.

Research Significance

1. To shed light on the mechanisms by which healthcare institutions dispose of their medical waste, and whether these mechanisms, with their various methods and means, are relatively sound.
2. To determine whether the mechanisms for recycling healthcare waste are based on scientific foundations or have emerged as a response to necessity and as a result of practical and limited experience using possibly traditional methods.
3. To attempt to identify any role played by the relevant authorities in providing technical and material assistance to healthcare institutions in disposing of their waste.
4. To Raise awareness among the public and healthcare workers regarding the magnitude of the medical waste problem, with the aim of preserving health, reducing the waste of human and natural resources, and preserving the environment for future generations.

2. Healthcare Waste and Its Recycling

Health and environmental departments, as well as researchers in this field, began to pay attention to medical waste around the world in the late 1980s. This was due to the growing global awareness of the dangers of what is known as medical waste, as a result of the development of modern technologies used in all forms of health care. It was necessary to understand how to manage and dispose of this waste and avoid its harmful effects on individuals and the environment.

2.1 Basic Concepts Related to Healthcare Waste

2.1.1 Definitions of Healthcare Waste

There are multiple definitions of healthcare waste, including the following:

- Healthcare waste is defined as: all waste generated from medical practices or activities related to healthcare facilities, including waste from patient care or isolation rooms, sterilization and disinfection waste, blood and serum waste, waste from

operating rooms such as fluids resulting from surgeries and autopsies, and used instruments such as medical syringes and scalpels, in addition to some medical waste resulting from pharmaceutical industries and expired or non-compliant drugs (خالد محمد بالنور، 2015، ص 3).

- Healthcare waste is also defined as: materials or infectious biological items which, although considered “municipal” waste, are in fact contaminated. This includes infectious items such as textiles, dressings, syringes, and other objects that may transmit infection through contact with patients. It also includes surgical implants and other tools used during (WHO, 2004).

2.1.2 Types of Healthcare Waste

Healthcare waste can be classified as follows (خالد محمد بالنور، 2015، ص 3-4):

- **Non-hazardous healthcare waste:** Resembles domestic waste (e.g., packaging, paper, metals, organic kitchen waste). It comprises about 75–80% of all medical waste and poses minimal risk to health or the environment.

- **Hazardous healthcare waste:** These are materials that cannot be disposed of in public landfills or sewage networks due to their hazardous nature and harmful effects on the environment and the safety of living beings. They require specific means of handling and disposal. It includes:

- . Infectious waste: Waste contaminated with infectious agents (e.g., blood-contaminated materials, body fluids, materials used by patients with infectious blood diseases, lab samples that could transmit diseases to humans or animals). This type constitutes 15% to 20% of total healthcare waste.

- . Sharps: Used sharp objects including needles, syringes, scalpels, and blades. Since these can puncture skin and are often contaminated with blood or other infectious body fluids, they pose serious transmission risks and account for about 1% of total healthcare waste.

- . Surgical and therapeutic waste: Waste containing disease-causing agents for humans or animals, including blood, mucus, anatomical parts or tissues removed during surgery or autopsy, and specimens used in laboratories. These also include anatomical waste such as amputated limbs, which require special disposal for ethical reasons. These represent around 1% of total healthcare waste.

- . Chemical and pharmaceutical waste: Includes chemicals used in sterilization and cleaning procedures, expired and unused medications, contaminated pharmaceuticals, vaccines, and items used in drug preparation like vials. These account for about 3% of chemical waste.

. Radioactive waste: Results from diagnostic, therapeutic, and research activities involving radioactive materials. Examples include radioactive isotopes, sealed radiation sources, and anatomical or biological waste from patients undergoing radiotherapy, as well as dry solid waste like gloves, paper towels, and device parts containing low radiation levels. Most healthcare radioactive waste is considered low-level radioactive because the isotopes used have short half-lives.

Healthcare waste can also be classified according to healthcare activities and the materials used in them as follows (WHO, 2018):

- Infectious waste: Includes waste contaminated with blood and other bodily fluids, laboratory waste, waste from patients in isolation wards, and contaminated medical equipment. Such waste is suspected to contain disease-causing organisms like bacteria, viruses, parasites, or fungi in quantities or concentrations sufficient to cause disease.
- Sharp tools (needles, blades): Sharp objects capable of cutting or penetrating the skin, including syringes, needles, scalpels, blades, saws, broken glass, and nails. These can transmit infections directly into the bloodstream.
- Pathological waste (blood, organs, tissues): This category consists of human tissues, organs, bodily fluids, body parts, fetuses, and contaminated animal carcasses that may harbor dangerous or infectious agents.
- Pharmaceutical and chemical waste (expired drugs, disinfectants): Includes chemicals used in laboratory formulations, disinfectants, heavy-metal batteries, and other hazardous substances.
- Genotoxic and carcinogenic substances: Includes extremely hazardous and carcinogenic waste.
- Radioactive waste (used in diagnostic and therapeutic procedures): Includes radioactive diagnostic materials or substances used in radiotherapy.
- Non-Hazardous Waste: Waste that does not pose any biological, chemical, radiological, or specific physical danger.

2.1.3 Characteristics of Healthcare Waste

Healthcare institutions aim to protect, preserve, and promote public health through their operations, which in turn generate waste with the following characteristics (WHO, 2018):

- Non-hazardous waste generally accounts for 85% of the total waste generated by healthcare activities;
- The remaining 15% is considered hazardous material that can transmit infections or be toxic or radioactive;
- Approximately 16 billion injections are administered annually worldwide, but not all used syringes and needles are disposed of safely;
- Healthcare waste is incinerated, producing toxic and air-polluting emissions;
- Major sources of healthcare waste include hospitals, laboratories and research centers, autopsy centers, animal research and testing laboratories, blood banks and sample collection services, and nursing homes.

2.1.4 Effects of Healthcare Waste on Individual Health

Healthcare waste contains microscopic organisms that may be harmful and can transmit infections to patients in healthcare facilities, healthcare professionals, and the general public. The health hazards associated with healthcare waste include (WHO, 2018):

- Burns caused by radiation exposure;
- Injuries resulting from sharp-object pricks;
- Poisoning and contamination through pharmaceutical products, especially antibiotics and cytotoxic drugs;
- Poisoning and contamination through sewage and waste incineration;
- Infectious waste transmits certain germs and diseases, and waste containing expired medications, cancer drugs, radioactive materials, may cause pneumonia and other chronic illnesses;
- High-income countries produce on average about 0.5 kg of hazardous waste per hospital bed per day, while low-income countries produce about 0.2 kg per bed per day. However, in low-income countries, healthcare waste is often not segregated, meaning the actual quantity of hazardous waste is likely much higher.

2.1.5 Effects of Healthcare Waste on the Environment

The treatment and disposal of healthcare waste may pose indirect health risks through the release of pathogens and toxic pollutants into the environment. These risks include the following (WHO, 2018):

- Occupational hazards due to contamination of landfill sites if they are not properly constructed and maintained, and the disposal of waste not properly designed, managed, or maintained;
- Widespread and improper incineration of waste releases pollutants into the air, along with toxic ash residues and substances such as lead and mercury. Incinerated materials containing chlorine can produce dioxins and furans, which are carcinogenic to humans and harmful to health;
- Only modern incinerators operating at temperatures between 850°C and 1100°C and equipped with special gas-cleaning devices can comply with international standards for dioxin and furan emissions. Alternatives to incineration include high-pressure autoclaves, integrated steam treatment with internal mixing, and chemical treatment.

2.2 Recycling of Healthcare Waste

2.2.1 Concept of Healthcare Waste Recycling:

Before defining the concept of healthcare waste recycling, we deemed it necessary to present a general definition of waste recycling. Waste recycling is defined as the process of re-manufacturing and reusing waste, whether domestic, industrial, or agricultural, in order to reduce the impact and accumulation of such waste on the environment. This process is carried out by sorting and separating waste based on the raw materials it contains, then re-manufacturing each material separately (Research on Waste Recycling, 2017).

Healthcare waste recycling is defined as the mechanism concerned with the processes of separation, collection, transportation, storage, and disposal of medical waste in a scientifically and hygienically safe manner. It also involves reducing its volume and re-manufacturing and reusing these wastes to benefit from some of their components for various purposes (Medical Waste: Definition, Classification, Treatment and Disposal Methods, 2021).

2.2.1 Objectives of Healthcare Waste Recycling

The purpose of healthcare waste recycling is reflected in achieving the following (WHO, 2004):

- Reducing the risk of harm to healthcare workers, the population, and the environment;
- Reducing the quantity of healthcare waste;

- Ensuring the collection and segregation of healthcare waste;
- Establishing appropriate waste collection sites within healthcare institutions;
- Establishing proper on-site waste transportation pathways;
- Maximizing the recovery of waste as much as possible;
- Disposing of healthcare waste in a hygienic and environmentally friendly manner;
- Preserving natural resources.

3. Sustainable Development

In the second section, we will discuss sustainable development in terms of its concept, characteristics, principles, and dimensions, in addition to its measurement indicators.

3.1 Definition of Sustainable Development

The idea of sustainable development has been widely accepted in its broadest sense and was officially endorsed after 1987. However, translating this idea into practical goals, programs, and policies has proven to be a difficult task due to the influence of capitalist forces on the United Nations, which are reluctant to give up their environmentally destructive modes of production. The International Conference on Environment and Development held in Rio de Janeiro in 1992, also known as the Earth Summit, marked the global and explicit emergence of the term “sustainable development.” According to the third principle of the conference, sustainable development is defined as: the need to achieve the right to development in a manner that equitably meets the developmental and environmental needs of present and future generations (بوخاري فاطمة، 2020، ص 98).

3.2 Characteristics of Sustainable Development

According to Boyce and Dunlap, the characteristics of sustainable development are determined by the following (عمر علوني، 2019، ص 121):

- Decentralization control of resources;
- Autonomy by relying on local technologies appropriate to the local environment;
- Environmental adaptation;
- Community participation;
- Harmony with nature ;

- Biodiversity ;
- Balancing the quadruple paradox: “use - needs - environment - generations”;
- Good governance, transparency and social responsibility.

3.3 Principles of Sustainable Development

Sustainable development is based on a set of principles that constitute the foundation of its strategies aimed at achieving development and the well-being of current generations without compromising the ability of future generations to meet their needs. The most important of these principles are (صيد تونس، 2018، pp. 114–115):

- Precautionary Principle: Act even in the absence of full scientific certainty about the effects of planned activities;
- Participation: Stakeholder involvement in decision-making;
- Integration: Environmental and social factors considered in development planning;
- Polluter Pays Principle: Those who pollute must bear the cost.

3.4 Dimensions and Indicators of Sustainable Development

Sustainable development includes three dimensions according to (صيد تونس، 2018، ص 115):

- Economic: Per capita GDP, investment ratio, energy consumption, debt, aid.
- Social: Poverty rate, unemployment, life expectancy, literacy, urbanization.
- Environmental: Water resources, arable land, deforestation, fertilizer use, preserving biodiversity, using clean technology, maintaining adaptive capacity, and achieving ecological balance as a regulatory framework for natural resources.

3.5 Indicators of Sustainable Development

Thinking in terms of sustainability has led to the development of tools for measuring development, which were previously limited to observing economic growth rates. Sustainable development indicators were formulated in the early 1990s and encompass environmental, social, economic, and institutional dimensions. These indicators are classified into four main types (حسين بن الطاهر، 2012، ص 457):

3.5.1 Economic Indicators:

- **GDP per capita:** This indicator is one of the driving force indicators of economic growth, as it measures total production and its volume. Although it does not fully measure sustainable development, it represents an important element of quality of life. GDP per capita is calculated by dividing the gross domestic product at current market prices in a given year by the population, and it is usually measured in US dollars;
- **Gross investment to GDP ratio:** This indicator refers to expenditure on additions to the economy's fixed assets as a percentage of GDP. It measures the ratio of total investment to production and is expressed as a percentage;
- **Per capita energy consumption:** This refers to the annual energy consumption per person. The indicator measures the amount of energy consumed per capita in a given country;
- **Current account balance as a percentage of GDP:** This is the ratio of the total net exports of goods and services, net income, and transfers to GDP. It is an indicator that reflects a surplus or a deficit and shows how quickly the economy is affected, it is expressed as a percentage;
- **Total external debt as a percentage of GDP:** This is the ratio of total external debt (given or received) to GDP, expressed as a percentage. It is an indicator that measures the level of a country's indebtedness and helps assess its debt sustainability;
- **Net official development assistance as a percentage of GDP:** This includes official development assistance in the form of grants or loans provided by the public sector to certain countries and territories with the aim of promoting development or social services under concessional financial terms. This indicator measures the levels of concessional assistance.

3.5.2 Social Indicators:

- **Human Poverty Index:** Measured by long and healthy life, knowledge or literacy, and access to economic means;
- **Unemployment:** Measured by the percentage of unemployed individuals to the total labor force;
- **Quality of life:** Represented by life expectancy at birth for those who are not expected to reach the age of forty;
- **Education:** Adult illiteracy rate and the percentage of people over the age of 15 who are illiterate;
- **Population growth rate:** Measures the annual population growth rate and is expressed as a percentage;

- Percentage of urban population: This is the percentage of the population residing in areas classified as urban.

3.5.3 Environmental Indicators:

- Water resources;
- Arable land per capita;
- Amount of fertilizers used;
- Desertification;
- Change in forest area.

3.5.4 Institutional Indicators:

- Main telephone lines per 100 inhabitants;
- Mobile phone subscribers per 100 inhabitants;
- Personal computers per 100 inhabitants;
- Internet users per 100 inhabitants.

5. The Contribution of Healthcare Waste Recycling to Achieving Sustainable Development

Healthcare waste problems stem from a lack of awareness of the health risks associated with medical waste, a lack of training in proper waste management practices, the absence of waste management and disposal systems, and a lack of financial and human resources. Accordingly, mechanisms for recycling healthcare waste have been proposed to mitigate its negative impacts on individual, community, and environmental health, as part of achieving sustainable development.

5.1 Fundamentals of Healthcare Waste Management

5.1.1 Healthcare Waste Management

Proper healthcare waste management is crucial to reducing the disease burden linked to poor practices, including exposure to infectious and toxic substances. The following methods have been suggested to improve the management of healthcare waste (WHO, 2018):

- Establishing a comprehensive system that defines responsibilities, allocates resources, and governs waste handling and disposal according to international standards;

- Raising awareness of the risks associated with healthcare waste, promoting safe practices, and encouraging environmentally friendly and safe decision-making to protect individuals involved in the collection, handling, storage, transportation, treatment, or disposal of waste.

5.1.2 WHO Mechanisms

The World Health Organization (WHO) has issued the first global and comprehensive guidance document on healthcare waste management titled “Safe Management of Wastes from Health-Care Activities”. It addresses regulatory frameworks, planning issues, waste minimization and recycling, and options for handling, storing, transporting, treating, and disposing of waste, as well as training. This document targets hospital administrators, healthcare facility managers, policymakers, public health professionals, and waste management directors.

WHO also developed a set of training modules on best practices in healthcare waste management, covering all aspects from waste identification and classification to disposal considerations using strategies such as incineration or other methods. The modules include guidance for national plan development, monitoring tools, and cost estimation for healthcare waste management (WHO, 2022, p.2).

5.2 Waste Management and Recycling Techniques

The mechanisms and technics used in healthcare waste management can be summarized as follows (2023 تصنيف النفايات الطبية):

- **Incineration:** Most common method of disposing of hazardous medical waste worldwide. It involves burning the waste and treating the resulting emissions. But criticized for high capital and operating costs, incomplete destruction toxic cells, significant emissions of air pollutants such as black smoke and fly ash, ineffective destruction of heat-resistant chemical and pharmaceutical compounds, emission of toxic gases and unpleasant odors.
- **Chemical Disinfection:** Used in healthcare facilities to eliminate microorganisms on medical instruments, walls, and floors, and to treat liquid and solid medical waste by destroying or neutralizing pathogens. But requires strict conditions and safety protocols, improper disposal of chemically disinfected waste is harmful to the environment, hazardous materials require comprehensive safety procedures, ineffective treatment of pharmaceutical, chemical, and some types of infectious waste and high cost of chemical disinfectants and the disinfection process.

- **Wet Thermal Treatment (Autoclaving):** Uses steam to sterilize waste, this method involves shredding the waste and exposing it to high-pressure, high-temperature steam. It resembles autoclaving due to its temperature and contact time parameters, effectively inhibiting most microorganisms. Sharp tools must be crushed or ground to enhance disinfection efficiency. But criticized for ineffective for chemical or pharmaceutical waste, inappropriate for anatomical waste, animal carcasses, and materials that resist steam penetration and effectiveness depends on operational conditions.
- **Microwave Irradiation:** Widely used in many countries, this method uses microwave energy to destroy pathogens and infectious agents. Waste is first shredded, then moistened and transferred to a radiation chamber with microwave generators for 20 minutes. Afterward, the waste is compacted and transferred to municipal waste streams. But criticized for Relatively high cost, Operational and maintenance risks, Inability to process metals and potential side effects from microwave radiation.
- **Land Disposal:** Considered an acceptable solution in the absence of pre-treatment options. When hazardous and untreated medical waste accumulates in healthcare facilities, the infection risk becomes much greater than if carefully disposed of at a landfill site. But criticized for risk of pathogen spread through air, soil, and water, leading to severe pollution and fire hazards, danger to sanitation workers due to unregulated dumping in open landfills and Increased risk of infection transmission to individuals or animals exposed to active pathogens via wounds, inhalation, ingestion, or indirectly through disease vectors or the food chain.

Healthcare waste landfills are preferable to regular landfills if the following conditions are met: geological isolation of waste, engineered specifications for waste acceptance, and regulated site operations by trained staff. Such landfills prevent soil, surface water, and groundwater pollution, reduce air pollution and odors, and limit human contact with waste.

- **Solidification/Stabilization Treatment:** This is particularly suitable for pharmaceutical waste and incinerator ash with high metal content. It reduces the risk of toxic material leaching into surface or groundwater by mixing waste with cement and other substances before disposal. The process involves removing packaging, placing the waste into the ground, and adding a mixture of water, lime, and cement to create a uniform mass poured into molds for transport to storage sites. This method is relatively inexpensive and does not require sophisticated technology.

There is no universal solution for healthcare waste treatment. Choices should be based on minimizing health and environmental impacts considering local conditions and resources.

6. Conclusion

Healthcare waste includes solid and liquid materials generated from prevention, diagnosis, treatment, and research related to human diseases. It is divided into hazardous and non-hazardous waste. Hazardous waste results from medical activities and, due to its quantity, concentration, or chemical, physical, or biological properties, poses a threat to human health and environmental safety during handling, storage, transportation, treatment, and disposal. Examples include infectious waste, chemical waste, genotoxic waste, sharps, heavy metals, radioactive waste, and pressurized gases. Non-hazardous healthcare waste, by contrast, consists of kitchen and office waste from healthcare institutions, such as food remains, paper, and wood waste.

Medical waste poses both health and environmental risks. Health risks arise from infectious waste, which contains large and varied quantities of disease-causing microbes (e.g., dermatological microbes, reproductive tract pathogens, tuberculosis bacteria, intestinal pathogens), as well as chemical pharmaceutical waste, genotoxic substances, and radioactive materials. Environmental damage results from pollution caused either by unregulated activities and negligence in waste management programs or by the aggressive disposal practices of some dominant societies. For instance, powerful countries often dump their hazardous waste in developing nations, turning their lands into toxic dumping grounds. Environmental damage includes harm to essential life systems and aesthetic degradation.

Several proper methods for disposing of hazardous waste are mandated in many countries and implemented in healthcare institutions. These begin with waste segregation, followed by collection and internal transport, storage, and finally, disposal through incineration, burial, steam sterilization (autoclaving), microwave or radiation treatment, or chemical treatment.

Proper healthcare waste management has social, economic, and environmental benefits:

- Socially, it reduces health sector burdens.

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- Economically, it creates jobs and wealth.
- Environmentally, it minimizes pollution.

To protect natural resources for future generations, all stakeholders, whether individuals or institutions, must take responsibility for medical waste disposal and adhere to national waste management regulations.

To support healthcare institutions and achieve effective waste management for sustainable development, we offer the following proposals:

- Establish practical rules for effective healthcare waste management aligned with legal frameworks and WHO recommendations;
- Allocate financial resources for healthcare waste management and develop plans for their use and evaluation;
- Enhance awareness activities on the dangers of general and medical waste and its effects on health and the environment;
- Regulate disposal procedures, particularly for chemical and toxic healthcare waste;
- Educate the public through seminars, lectures, and publications about the risks of mishandling home-generated medical waste (e.g., needles, syringes, medications, antibiotics) and the dangers of disposing of such waste with general household garbage;
- Ensure that treatment processes are environmentally sound, protecting individuals and ecosystems by guaranteeing safe, sanitary storage and disposal;
- Emphasize sorting, collection, and transportation procedures, regular disinfection of trucks and storage rooms, personal hygiene, and emergency measures in case of accidents;
- Operate and maintain treatment and landfill sites properly;
- Adhere to international agreements regarding new methods and technologies in healthcare waste management;
- Sustain continuous efforts for success, including professional training and rewarding achievements;
- Educate healthcare workers on the dangers of handling medical waste, and provide necessary equipment and tools to enable safe disposal, while enforcing standard safety procedures to reduce exposure risks;
- Require healthcare institutions to accept community-generated medical waste for proper disposal;
- Regularly inspect healthcare institutions, both scheduled and unannounced, to ensure compliance with safe waste disposal standards;

- Penalize non-compliant institutions and reward those that actively support national waste management initiatives, encouraging further participation.

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