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Sustainable Hospital Waste Management Practices in the Western Province of Sri Lanka: Problems and Prospects

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Abstract

Ensuring the sustainability of hospital waste management practices has become a burning issue. Due to the growing population coinciding with rapid urbanization and industrialization, practicing sustainable methods of medical waste management is an urgent requirement. Like other developing countries, Sri Lanka also faces various difficulties when dealing with high-risk hospital waste material, spreading diseases rapidly and making the environment unclean. Thus, moving towards sustainable hospital waste management has received urgent attention. The primary purpose of this study is to explore whether the existing hospital waste management practices are sustainable. Further, this study identifies weaknesses of the existing waste management practices and examines factors affecting Sustainable Hospital Waste Management (SHWM) in the Western province of Sri Lanka. Data were collected from 18 officers involved in waste management from 14 government hospitals in the western province. Both inductive and deductive thematic analyses were used to explore whether the hospital waste management practices are sustainable. The study revealed that most selected hospitals failed to achieve sustainability in waste management practices. Achieving sustainability of waste management practices has become a challenge to government

hospitals due to financial constraints, limited facilities and infrastructure, lack of social support, and poor management and administration. Patient mindset and health capacity, positive attitudes, knowledge, awareness, and experience, training on hospital waste management, availability of basic infrastructure and resources, financial facilities for hospital waste management, availability of rules and regulations, and intra and inter-organizational supports significantly affect sustainable hospital waste management. Exploring the sustainability of waste management practices using empirical data related to Sri Lanka is an initial attempt in the sustainable hospital waste management literature. Finally, policy measures are suggested for sustainable hospital waste management in Sri Lanka.

Keywords
Healthcare waste management; sustainability; Sri Lanka

1. Introduction

Hospital waste is a severe issue producing a high risk, causing people ill-health, spreading diseases quickly, and making the environment unclean. After radiation, healthcare waste is considered the second most hazardous waste globally as it includes various forms of waste, both dangerous and non-hazardous, such as sharps, human body parts, blood, chemical waste, pharmaceutical waste, and medical devices [1]. Improper handling of medical waste can hurt the environment, including wildlife and water quality, increasing the risk of spreading diseases [2].

Hospitals generate large amounts of wastewater, which is very complex and hazardous. Healthcare wastewater can pollute entire biodiversity systems, where such emissions into the sewerage systems of the cities and other water reservoirs can cause short and long-term adverse effects on public health. Over half the world's population is at risk from the health impacts of healthcare waste [3]. It is revealed that “high-income countries generate up to 0.5 kg of hazardous waste per hospital bed per day, while low-income countries generate on average 0.2 kg. However, healthcare waste is often not separated into hazardous or non-hazardous wastes in low-income countries, making the real quantity of hazardous waste much higher" [4]. There is an acute need for assessment and expansion of local healthcare infrastructure, and hospitals' lack of proper financial and environmental resources is another problem in developing countries. Adequate training of waste management personnel is another important factor that needs to be attended to [5]. The contemporary world faces severe challenges due to the growing medical waste. On the other hand, the prevailing situation is getting worse due to existing waste management practices such as improper disposable methods, lack of physical resources, and insufficient research on medical waste management, which are not sustainable. There is an urgent need at this moment for the sustainability of health care in the real sense of the world [6].

Healthcare is a high-risk sector with work related to injuries and diseases, and at the same time, hospital waste is dangerous as well. Management of healthcare waste in a safe and eco-friendly manner is the primary responsibility of health administrators. The absence of effective hospital waste management leads to the threat of a healthy environment. There is a gap in environmental knowledge between the younger and older generations in developing countries [7].

Inappropriate waste management practices in clinics can cause a variety of adverse impacts on communities. Lack of knowledge and attitudes on waste segregation, waste collection, and unsafe waste disposal methods due to a lack of awareness of related risks and financial constraints can cause waste mismanagement [8]. Unfortunately, waste segregation has received little attention in developing countries, and it is also caused by a lack of awareness, a weak regulatory framework, and a lack of economic incentives [9].

Improper waste disposal can be seen in many hospitals in Sri Lanka, leading to environmental hazards [10]. The responsibility for waste management in hospitals is assigned to the Director General as the Head of the Hospital. Infection Control Nurse/Medical Officer, Public health inspector, Infection Control Unit Administrative Officer, and waste management officer are the other responsible for hospital waste management [11]. Except for the National Hospital, waste management has not been satisfactory, and the provision of money for waste management has not been adequate in Badulla, Polonnaruwa, and Anuradhapura hospitals. A lack of awareness among patients on waste management is another major issue that could be seen in Polonnaruwa, Anuradhapura, and even in the Cancer Hospital, Maharagama [12].

The governmental healthcare services serve around 95% of the Sri Lankan population, and the private sector serves the rest [13]. Hospital waste can be segregated into hazardous waste (about 15%), which includes infectious, chemical, radioactive, pathological, sharps, pharmaceuticals genotoxic, and non-hazardous (about 85%), which is similar to the regular municipal waste, which is low risk when burned [14]. There are 1103 government hospitals; 49 are governed under the line Ministry, and the provincial councils govern the remaining 1054. Among them 34 government hospitals in the Western province, including national hospitals, teaching hospitals, district hospitals, base hospitals, and divisional hospitals [15].

The estimated total of infectious and sharp wastes generated from state sector hospitals (Divisional and Base hospitals) is 25.38 tons per day, and this includes 31% of radioactive waste, and 91% of laboratory chemical waste and state sector hospitals (Divisional and Base hospitals) reported 80.3% and 65.7% respectively for pharmaceutical waste [16]. National hospitals and Teaching Hospitals produce the most enormous quantity of hospital care waste. These top hospitals offer extensive medical and surgical services and typically have high bed strength and occupancy rates. Provincial hospitals, specialized referral facilities, and district general hospitals produce a similar range of transferable waste, less in quantity than national and teaching hospitals [17].

The national healthcare waste management program of the Ministry of Health and Nutrition and Indigenous Medicine mainly focuses on containing infectious waste and reducing risks to public health and the environment. Several steps to achieve this target include waste minimization, identification and segregation, recycling, adequate packaging, handling and storage, and proper treatment and disposal [18].

As per the National Environmental Act, no 47 of 1980, and National Environmental (Amendment) Act, no 53 of 2000, every hospital is legally responsible for adequately managing waste from the first process until its final disposal. In 2001, the Government of Sri Lanka drafted a comprehensive national policy on healthcare waste management (HCW) to cover an integral part of the management of HCW. The institutional mechanism for implementing the national policy is envisaged at central, provincial, and local levels [11].

The Master Strategic Plan 2016-2025 of the Ministry of Health in Sri Lanka promotes a green and clean environment as a solution for the issue of the non-conducive environment of hospitals in the

country. The National Health Policy promotes environmental sustainability in providing health care (safe disposal of wastewater from hospital settings, safe disposal of clinical waste, sustainable solar energy, ensuring green environment from air and chemical pollution) as a preventive health goal to strengthen the service delivery. These arrangements were made in 2016; however, the effectiveness of the plans needs to be investigated. The responsibility of waste management in hospitals is assigned to the Director - Infection Control under Volume IV of the National Health Strategic Master Plan 2016-2025. Generally, the Head of the Hospital, Infection Control Nurse/Medical Officer, Public Health Inspector, Infection Control Unit Administrative Officer, and waste management officer are other persons responsible for hospital waste management. The Office of Provincial Director of Health Services in the Western Province has started a well-organized hospital waste management system to solve many burning issues related to hospital waste. Accordingly, regarding hospital waste disposal, including clinical and regular waste, a waste management system has been established and planned to be developed further. Seven incinerators have been established in District General Hospitals and Base Hospitals in the western province for clinical waste management, and a system to dispose of small hospital's clinical waste has been developed [11]. Even before the COVID-19 pandemic, the regional government of Sri Lanka faced a waste management problem and did not have an effective medical waste disposal system. It is not sure that the existing medical waste management practices are sustainable. After the COVID-19 situation, the HWM has become more severe due to the enormous consumption of medical waste (face masks, gloves, sanitizer bottles), which caused a rapid increase in large-scale environmental hazards and health risks. However, as per [19], The UN Sri Lanka's Advisory Note on the socio-economic recovery from COVID-19 in Sri Lanka developed the country's recovery strategy and identified five strategic priorities. This includes protecting health systems during crises, providing social security and other essential services, providing economic response and recovery, promoting social cohesion and community resilience, and providing macro-economic response and multilateral cooperation. This UN Note has identified HCWM as a critical area under the first strategic priority, from both the health systems and environmental perspective(s), and highlighted that poor management of healthcare waste, in particular the hazardous components, potentially exposes healthcare workers, waste handlers, patients, and the community at large to infection, toxic effects, injuries, and risks polluting the environment.

Even though the government of Sri Lanka has made several efforts in Hospital Waste Management (HWM), many healthcare institutes need to adopt proper health waste management practices. Wastewater treatment and utilization are inferior in Sri Lankan state-sector hospitals [20]. Sri Lanka does not have a good attitude towards waste management. Still, many individual practices of poor waste segregation, recycling behaviors, open dumping, and open waste burning occur throughout the country [21]. Occupational safety measures taken during handling waste were not satisfactory as none of them was found wearing protective gloves, masks, or boots. Out of 10, 8 workers received only gloves on time and were not provided with boots, caps, or aprons [10]. Further, as per the author, out of 10 selected workers from the cleaning service, none of them had been given any training on waste handling from the hospital management or their employer, and inappropriately disposed mercury waste may end up in open dumping areas, and sanitary landfills or it may be burnt as regular waste. There is evidence that incineration or burning mercury waste causes a high density of atmospheric pollution. Disposing of mercury waste through such methods will ultimately end up in water reservoirs and human food sources [22]. On the other hand,

if all those institutions dispose of their garbage without a proper mechanism, it will become a massive problem affecting the entire country. Therefore, it is essential to have a strategically planned sustainable waste management system for the government hospitals in Sri Lanka. In this context, this study attempts to address the following research objectives:

1. To explore whether the existing hospital waste management practices are sustainable,
2. To identify weaknesses of the existing waste management practices and
3. To examine factors affecting Sustainable Hospital Waste Management (SHWM) in the Western province of Sri Lanka.

2. Sustainable Hospital Waste Management

Environmental sustainability is a growing concern and an essential aspect of the Sustainable Development Goals (SDGs). Sustainable healthcare waste management aims to reduce the consumption of natural resources through reuse, recycling, and recovering the materials before they have to be disposed of and dispose of such waste with minimal environmental impact [23]. Sustainable waste management ensures that any waste generated is kept to a minimum and disposed of to minimize ecological harm [24]. The four principles of sustainability in managing health care waste include the use of technology that is environmentally safe and does not harm public health, cost-effective and disposes of the waste by its economic value, socially acceptable and equitable to all local communities, and supervised meaningfully and consistently to ensure that sound environmental measures are followed over the long term [23].

Based on the literature, sustainable hospital waste management could be evaluated using four criteria: environmental desirability, economic effectiveness, social acceptability, and administrative diligence [23, 25]. The 3R practices (Reduce, Reuse, and Recycle) in waste management could be used similarly in handling hospital waste. The sustainable method should be compatible with a circular economy and the reduce-reuse-recycle approach [2]. Though sustainable management of healthcare waste is a complex process, implementing a cradle-to-grave approach is essential to understand, control, eliminate, or reduce the environmental and economic impacts of medical waste on society; hence, careful planning of stakeholders, research (both quantitative and qualitative) and substantial efforts are essential to promote sustainable healthcare waste management [26].

Sustainability could be achieved in developing countries through environmental attitude, awareness, and knowledge, which can be communicated to teachers and students through formal education [7]. Sustainable healthcare waste management practices can be achieved by integrating social responsibility within the waste policy, enhancing employee awareness, adding a training component, developing programs, and promoting sustainable practices' environmental and economic benefits [27]. Thus, as per the authors, sustainable healthcare waste management requires a holistic approach involving various parties, including policymakers, government and non-government organizations, and the community.

2.1 Theories and Approaches of Sustainable Hospital Waste Management

Healthcare waste (HCW) disposal techniques such as incineration, landfilling, and chemical treatments directly impact effective healthcare waste management in hospitals as their growing use negatively affects both the environment and, in turn, damages public health, thus contributing to a

global healthcare crisis [28]. Several theories and approaches have been evolved to explain sustainable hospital waste management, which will be discussed in the following section.

2.1.1 Incineration

Incineration is ranked the most preferable solution due to its ability to dispose of various medical waste types safely. When operated correctly, modern incinerators can efficiently burn medical waste at high temperatures, minimizing the risk of contamination and emissions. The method is considered adequate for medical waste disposal because it significantly reduces waste volume and can destroy pathogens and harmful chemicals [29]. However, modern incinerators running on sustainable and renewable energy sources such as biofuels are needed than conventional incinerators running on non-renewable energy sources [26].

The incineration process comprises waste storage and feed preparation, combustion in a furnace, producing hot gases and a bottom ash residue for disposal, gas temperature reduction, frequently involving heat recovery via steam generation, treatment of the cooled gas to remove air pollutants, disposal of residuals from this treatment process and dispersion of the treated gas to the atmosphere through an induced-draft fan and stack [30]. Effective monitoring and maintenance of the system, proper disposal of ash, and accurate record-keeping can be accomplished at the optimum level of incineration [31].

2.1.2 Transactional Cost Economics (TCE) Theory

The TCE theory describes hospital leaders' decision criteria in determining the appropriate waste management strategy for their organization based on their perceptions of each transaction's tangible and intangible costs. The decision to use a recycling, reuse, or disposal strategy, choosing and contracting the vendors or service providers, purchasing capital equipment, or structural changes within the hospital will all have different transaction costs and benefits hospital leaders will need to weigh. In addition, leadership must consider the costs associated with these strategies, such as staff education and training for the newly implemented protocols and procedural changes to the hospital's operational or infrastructure changes, should that occur [32].

2.1.3 Green Hospital Concept

Green Hospital is the one that is continuously upgrading public health by reducing environmental impacts and eventually by eliminating hospitals' roles in disease burden. Green Hospital officially recognizes and confirms the relationship between human health and the environment, indicating that we can understand it only through governance, strategy, and operations. It connects local needs to environmental actions and primary prevention methods through active participation in community and environmental health, justice in health, and green economy. Moving towards a green hospital includes reducing waste and energy and protecting the resources; besides, protecting the resources includes administrating the disposal of harmful factors, recycling, reprocessing reusable items and stuff, etc., and managing the protection of the product. To achieve Green Hospital's goals, sustainable healthcare waste management plays a fundamental role [33]. The term green purchasing is known as eco-procurement, sustainable procurement, and environmentally

friendly purchasing, which aims to reduce the risk to humans, animals, and the environment by integrating environmental factors at each level of the purchasing process [34].

2.1.4 Waste-To-Energy (WTE)

Waste-to-energy (WTE) conversion is another approach to sustainable waste management. Different WTE techniques are used to determine the waste's state and nature. On most occasions, the energy generated from the WTE process produces steam, which can produce electricity. Hence, healthcare waste contains over 99% explosive components, and WTE can be defined as an exciting alternative to landfilling. In countries like the US, WTE is classified as a renewable energy industry, and it has become one of the growing industries in the past three decades. This shows that WTE has the potential to be an alternative and reliable industry for healthcare waste treatment [26].

3. Factors Affecting Sustainable Hospital Waste Management

Sustainable Hospital Waste Management systems, depending on the type of hospital, have been identified as a critical factor that plays a vital role in sustainable hospital waste management [35]. Receiving training regarding medical waste management had a significant association with safe practice in healthcare waste management [36-38]. Providing personal protective equipment was an independent factor associated with adherence to proper healthcare waste management [39]. Personal protective equipment is also associated with waste management behavior [37]. Individuals with a knowledge of health care waste (HCW) management were likely to have satisfactory HCW management practices [38]. High knowledge and positive attitudes toward good practices can be vital factors in healthcare waste management [8]. Good attitudes towards HCWM are significantly associated with biomedical waste management practices in private hospitals [40]. The establishment of formal regulations on healthcare waste is mainly affected by successful hospital waste management [41, 42]. Proper waste segregation makes effective reuse, recycling, and recovery possible [9], and hospital waste storage methods significantly influence sustainable hospital waste management [35]. Similarly, financial facilities in HCWM significantly influence SHWM [25, 41]. Developing and implementing a sustainable healthcare waste management system requires a holistic approach that involves a range of stakeholders, including people from both internal and external environments in the organization [27]. Effective engagement of critical stakeholders will affect the development of a sustainable hospital waste management system [24].

4. Methods

This study was conducted on 14 selected government hospitals in the Western province facing waste handling problems. Three staff members, including the chief infection control officer, were interviewed from the selected two hospitals, which included large-scale government hospitals (Teaching Hospitals and National Hospitals). From the rest of the hospitals, one staff member from each hospital was interviewed. Accordingly, 18 officials were interviewed (both physically and through telephone and Zoom discussions), and a semi-structured questionnaire was used to collect data. Due to the fund constraints in the complex approval procedure, this study had to be limited to 14 government hospitals facing various waste management difficulties. Both inductive and deductive thematic analysis were used to analyze qualitative data. “Deductive coding uses the top-

down approach, which involves concerned themes based on existing theories and knowledge" [43]. The deductive thematic analysis explored whether the existing hospital waste management practices are sustainable. The sustainability of existing hospital waste management was analyzed through four dimensions: environmental desirability, economic effectiveness, social acceptability, and administrative effectiveness; these four dimensions were deducted from previous scholarly articles [25]. Moreover, Chauhan [44] proposed a decision support framework based on multiple criteria that provide a line of action for hospitals and waste disposal firms to effectively manage healthcare waste economically, environmentally, and socially sustainably in developing countries. The inductive thematic analysis involves allowing the data to determine the theme. The researcher used the inductive thematic approach to analyze the existing hospital waste management practices, problems and difficulties faced by the authorities in hospital waste management, and factors affecting sustainable hospital waste management in Sri Lanka. In-depth interviews were conducted to collect the data, and descriptive methods were used to analyze the data. To ensure the confidentiality and anonymity of the respondents and their hospitals, the hospitals were redefined under a particular code based on the hospital type and its relevant district.

4.1 Demographic Analysis

Most of the respondents were female nursing officers in infection control units. Others were public health inspectors and medical officers in the hospitals. All the respondents had at least a diploma or higher than a diploma as their educational qualifications, and most had more than 10 years of experience in their respective fields. The number of wards in the hospital and the number of staff in the infection control unit depends on the size of the respective hospital.

Hospital coding is done as follows.

TH- Teaching Hospitals	C- Colombo District
NH- National Hospital	G- Gampaha District
BH- Base Hospital	K- Kalutara District
DH- District and Divisional Hospitals	

E.g.: THC-01 -A teaching hospital from the Colombo District.

Hospital Coding is based on the type of hospital and the district located. Teaching and national hospitals deal with more significant amounts of waste than other hospitals; therefore, three staff members, including the chief infection control officer, were interviewed from these hospitals.

5. Analysis and Discussion

5.1 Existing Hospital Waste Management Practices in Sri Lanka

Under this section, the type and amount of waste gathered, treatment methods for infectious waste, and hospital water waste treatments will be discussed.

5.1.1 Types and Amount of Waste Gathered

The total amount of waste gathered from the hospitals differed from the type of hospital. Usually, national hospitals gather an enormous amount of waste daily, and base hospitals gather comparatively less than other types of hospitals.

"Hazardous waste includes only around 20% of hospital waste, mainly infectious waste, clinical waste, and sharps, and the remaining 80% belongs to Non-hazardous waste/general waste" (a Respondent from THC-02).

The total amount of waste generated by health care activities includes about 85% of general/non-hazardous waste compared to hazardous waste. Therefore, the remaining 15% of waste materials are considered infectious, chemical, or radioactive [4].

5.1.2 Treatment Methods for Infectious Waste Incineration

Most hospitals outsource their infectious and clinical waste to a private organization for incineration. It is hard to assess that outsourcing organizations incinerate waste according to the guidelines. Some hospitals have functioning incinerators for disposing of their infectious waste, but findings revealed that several shortcomings have occurred when incinerating waste.

"An incinerator needs to be established in an isolated area, and the chimney of the incinerator needs to be higher than the nearest building" (Respondent from NHC-01).

According to the International Basel Convention, the ash that remains after incineration is defined as hazardous waste because of its hazardous chemical contents and ability to cause harm. It should be disposed of through properly engineered hazardous landfill techniques [45]. Several hospitals failed to operate their incinerators according to the guidelines mentioned above.

Autoclaving/Steam Sterilization. Steam sterilization is also termed autoclaving. The component enters the autoclave device, which gets in contact with high temperature and pressure for a specific period, allowing the destruction of microorganisms and structural proteins in the waste component. After the required time is completed, the sterilized object can be removed from the device [46].

"After steam sterilization, we can dispose of infectious waste as general waste (a Respondent from THC-02).

Hazardous waste components can be removed as general waste after autoclaving, but they do not destroy waste components, such as incineration.

Open Pit Burning and Landfilling. For various reasons, some hospitals still practice outdated methods like open-pit burning and landfilling.

"After a considerable amount of clinical waste is gathered, we burn them in an open area, and we burn sharp waste with other clinical waste. However, sharps do not melt with this burning temperature, so we keep them in the burning pit" (a Respondent from BHK-01).

Burning hazardous and non-hazardous waste can be seen in many developing countries. This practice paved the way for releasing huge volumes of toxic, harmful gases into the atmosphere, which affects public health on a global scale [28]. They also keep their clinical sharps in the same waste pit without any particular treatment method deemed harmful to the environment.

5.1.3 Treatment Method for Radioactive Waste

"Radioactive waste will expire with its half-life; we store it separately until the half-life is over. (a Respondent from NHC-01).

It seems that keeping radioactive waste in a separate area until it expires is sufficient to treat radioactive waste. Medium-activity radioactive waste that has half-lives of less than a month may

be stored in a properly ventilated and sealed storage area. Then, the waste needs to be monitored appropriately until the required period is completed. Most of the low and medium-level radioactive hospital waste that has a short half-life is permitted to be disposed of through this method called "Delay and Decay" [47]. Hospitals' methods of treating radioactive waste would be favorable if those wastes were low-level and medium-level. Table 1 shows the existing waste management practices based on the types of garbage.

Table 1 Waste treatment methods based on the waste type.

Waste category	Type of waste	Treatment method
Hazardous waste	Clinical/Infectious waste	Incineration/open burning (limited hospitals)
	Clinical sharps	Incineration/Landfilling (limited hospitals)
	Cytotoxic waste	Incineration
	Chemicals	Maintaining separate pits and open dumping after mixing with water (absorbed by the land)
	Mercury	No unique treatment method yet, stored in a separate area.
	Radioactive waste	Keep it until the half-life is over.
Non-hazardous waste-biodegradable	Food waste	Composting/sending as animal food
	Leaves	Composting/Open dumping
	Coconut Shells	Composting/Recycling
Non-hazardous waste-non-biodegradable	Non-infected plastic Polythene Clean paper Cardboards Glass	Recycling/Open burning or landfilling (limited hospitals)

Source: Field Data, 2022.

5.1.4 Hospital Wastewater Treatment Methods

Hospitals in populated areas lack facilities to treat hospital wastewater; some hospitals must release their wastewater through the general line. Wastewater is released into the deep sea (approximately 1.5-2 KM from the ground). As per the authorities, releasing wastewater into the deep sea minimizes its negative impact, but protecting the marine-bio system would be questionable. *"We connect our hospital wastewater to the general sewerage system" (a Respondent from THC-01).*

Even though some hospitals maintain a proper system to treat hospital wastewater, using different wastewater pits, maintaining a wastewater plant, or sending it to a wastewater plant are excellent practices in wastewater management.

5.2 Sustainability of Hospital Waste Management Practices in Sri Lanka

This study explored whether the existing hospital waste management practices are sustainable using four dimensions: environmental desirability, cost-effectiveness, social acceptability, and administrative effectiveness. Some hospitals have made efforts to manage their waste correctly,

but most of them have failed to comply with the aspect of environmental desirability. Most hospitals (but not several Base and Divisional hospitals, as the government bears their waste management cost) failed to practice cost-effective waste management. Concerning social acceptability and social support toward (patients, hospital staff, and other external parties) hospital waste management is insufficient. Also, administrative support from governmental organizations is not sufficient to go along with hospital administration activities. Almost all hospitals have failed to achieve sustainability in all four dimensions of their waste management practices. Also, these hospitals have been unable to achieve sustainability, at least from one or more dimensions. The preceding sections discuss the above four dimensions' detailed analysis.

5.2.1 Environmental Desirability

Environmental desirability refers to the capability of waste management and technology options to safeguard public health and the environment [25]. The natural environment and public health must be protected to maintain environmental sustainability. To operate, every hospital must acquire two licenses from the central ecological authority. This license is called an environmental protection license (EPL) and schedule waste license. This two-license validity period is a one-year process. Upon completing the one year, the hospital must renew its license for the upcoming year. To acquire those licenses, hospitals need to fulfill several requirements in terms of environmental protection. Most hospitals acquire these two licenses, but when looking at some of their waste management practices (relatively environmentally undesirable), it would be questionable as the Central Environmental Authority (CEA) in Sri Lanka strictly follows those guidelines and requirements when granting the license.

Most hospitals engage in the given practices regarding environmental desirability in sustainable hospital waste management practices. Most hospitals are trying to start segregation of hospital waste from waste generation points according to the national color code, which would be helpful for waste recycling and reuse practices. Incineration is the most common method used by these hospitals when treating hazardous waste. Whether it is more sustainable than methods like open-pit burning or landfilling, incineration is not an environmentally friendly waste disposal method. Waste incineration contributes to air pollution in many forms. However, the damage can be reduced if it follows strict guidelines. However, based on the findings, it seems most of the hospitals that incinerate their waste failed to comply with those guidelines. Hospital wastewater management is another area that needs some development. Some hospitals outsource their recyclable and infectious waste to private parties. However, respondents do not have a clear idea about what method they use to treat the waste. Therefore, it is hard to identify whether those methods are environmentally desirable.

5.2.2 Cost Effectiveness

Economic effectiveness refers to the cost-effectiveness of each management and technology option in use, also considering the financial value of the waste [25]. Cost-effectiveness refers to hospitals maintaining waste management practices at the lowest cost by considering the economic value of the waste. Many hospitals face problems managing the cost of hospital waste management. Problems related to the cost factor have been rising with the prevailing economic crisis in the country. Hospitals that have incinerators struggle with the related cost of operating incinerators.

Primarily, the recent fuel price increases severely affect the hospital's waste management system. To overcome that, several hospitals tighten up their waste segregation procedures.

Most hospitals are aware of the economic value of the waste, and they sell recyclable waste to private sector organizations at a higher price. Reusing waste would also help reduce the cost of hospital waste management, but many hospitals have failed to achieve sustainability in terms of economic effectiveness. Some hospitals have even failed to practice their previous waste management practices due to cost limitations curtailing sustainability in hospital waste management practices.

5.2.3 Social Acceptability

Social acceptability and equity refer to the level of support and acceptance of the waste management and technology options in use by the local community, as well as the effectiveness of a community involvement approach in waste management [25]. Thus, it refers to the community's acceptance and support of waste management practices in hospitals. Most hospitals are complaining about the smoke coming from their incinerators. Therefore, hospitals that operate incinerators or burn their waste on the open ground need to be more considerate about their waste treatment methods. Apart from problems with incinerators, some hospitals are having community complaints about the odor from the pile of waste. This situation has occurred due to delays in waste collection.

There is a lack of support from patients regarding hospital waste management practices in several hospitals. Respondents from THC-01, DHG-03, BHC-01, BHK-03, and several other hospitals are not satisfied with the participation of patients and staff in waste management practices, especially in waste segregation. Still, many patients have not followed proper waste segregation practices in some hospitals. When considering local community awareness, most communities around hospital areas are not aware of the waste management activities in hospitals. However, people complain about any error in hospital waste management practices when it is visible or sensory (e.g., smoke coming from incinerators or the odor coming from a pile of waste when getting delays in collection). Several hospitals lack support from community members in hospital waste management, especially patients and their relatives/guardians who are not practicing hospital waste management, and the hospital staff are also not practicing hospital waste management practices. Hence, the social acceptability of hospital waste management practices is not satisfactory.

5.2.4 Administrative Effectiveness

Another important aspect is the ability and positive response of the administrator to carry out waste management practices in hospitals effectively. Administrative diligence refers to the administrative capability to ensure continuity in implementing suitable measures and policies that will be sustained in the long term [25]. Medical waste management should be collaborative with a committed government backup and a strong legislature [48]. Some hospitals have good support from the hospital administration, but the hospital administration has several constraints.

To reduce community complaints about the incinerators and the smoke, our administration decided to operate the incinerator at nighttime because smoke is not visible during the nighttime (a respondent from BHK-03).

Even though BHK-03 needs a considerable change in the hospital waste management system, the administrative solutions to the abovementioned problem are unacceptable. Changing the time they incinerate waste may limit complaints from the people, but the environmental effects and damage to public health will remain the same.

"*Government organizations support them in developing their waste management practices through specialized programs, and those organizations always share new information on new waste management practices through emails and Zoom sessions. This program has been introduced in all the governmental hospitals*" (*BHC-01).* However, other respondents did not mention it, and many of them were not satisfied with the government's support for hospital waste management due to fund shortages, delays in decision-making, lack of resource allocation, and lack of training programs. Some respondents did not even have a clear idea about whether they had good support from the government.

5.3 Problems and Difficulties Faced by the Hospitals in Waste Management

5.3.1 Waste Segregation Problems

Even though effective waste management depends on good waste segregation practices, many hospitals face problems regarding waste segregation. Jacob et al. [9] also noted that developing countries pay less attention to waste segregation.

5.3.2 Lack of Funds for Waste Management

Many hospitals are troubled with achieving cost-effectiveness due to the limited amount of money spent on waste management. Also, some hospitals have problems in terms of achieving environmental desirability, social acceptability, and administrative effectiveness due to fund constraints, e.g., incinerator breakdowns lead to more unsustainable waste disposal methods, incinerator repairing, delays in waste collection delays due to late payment, etc.

5.3.3 Prevailing Economic Crisis

"We had to reduce our cost for waste bags during this crisis. It affects the thickness of waste containers, but there are no other options" (a respondent from THC-02).

Some hospitals have prioritized medicines and food items during the economic crisis rather than acquiring waste management equipment. They reduced the usage of waste bags, affecting waste container thickness. However, the Sri Lankan economy has shown signs of financial constraints even before the Covid-19 pandemic. The situation went from bad to worse after the Covid-19 pandemic and the economic crisis.

5.3.4 Lack of Social Knowledge and Attitudes about Waste Management

People's knowledge and attitudes toward hospital waste management practices are not sufficient. Almost all the selected hospitals experience a lack of social support for waste management. Gunasiri & Senadheera [21] highlight this constraint.

5.3.5 Lack of Infrastructure and Essentials

Shortages of waste bags and bins also discourage proper waste segregation practices. Lacking essentials like personal protective equipment and kits and lacking proper training on waste management can harm the environment and safeguard public health. Jayawardena also highlighted these constraints [10].

Many hospitals lack waste infrastructure facilities such as proper waste storage areas. According to the Centers for Disease Control and Prevention (CDC), medical waste should be stored in labeled, leak-proof, puncture-resistant containers to prevent foul odors, and the storage area should be ventilated appropriately and accessible to pests [49]. Many hospitals failed to manage their waste storage areas according to the guidelines of the CDC.

Waste management activities of some hospitals were disturbed due to the limitations of trainee staff members and the absence of the required number of trained staff to handle infectious waste. The respondents were not satisfied with using cleaning staff members to handle hospital infectious waste who lack knowledge of proper waste management practices [10].

5.3.6 Failures in Waste Disposal Methods

"This incinerator is located on the lowest ground in the hospital, and it's not up to the standard even though there are some higher grounds near the hospital" (a respondent from BHK-03).

So, this hospital failed to place its hospital incinerator in a proper place. Similarly, several other hospitals also had the same failure during the waste disposal process, such as producing unnecessary smoke, breakdowns, problems with ash pits, temperature issues, and incompetent operators.

A proper disposal method for hospital mercury waste causes problems for several hospitals. Some government hospitals face this situation due to their increasing piles of mercury-contained waste, and there is no proper outsourcing party to collect mercury waste. The Epidemiology Unit [22] also highlighted the harm that could be created through improper mercury-contained waste disposal methods.

Hospitals in the Colombo area face difficulties when disposing of their hospital wastewater. The absence of proper treatment facilities for hazardous wastewater and a reusing system for non-hazardous wastewater is another issue that must be considered.

5.3.7 Absence of Proper Waste Recycling and Reusing System

Waste recycling and reusing are two essential components of sustainable hospital waste management. However, most respondents mentioned that there is no *correct method to recycle glass bottles, and they do not have a proper waste reuse system.* Several hospitals failed to practice proper waste recycling and reusing methods to manage their waste to the appropriate standards, leading them to unsustainable waste treatment methods.

5.3.8 Monopoly Created by the Waste Collecting Company (Clinical Waste)

These hospitals send their clinical waste to a private organization for incineration, and they also have to pay the private sector based on the weight and duration of waste collection, which is different from the waste amount gathered from the hospital. Due to the existence of one company,

hospitals are experiencing a lack of bargaining power, and the private sector maintains a monopoly in that area.

5.4 Factors Affecting Sustainable Hospital Waste Management

The following factors that affect sustainable hospital waste management are discussed briefly in the preceding paragraph.

5.4.1 Practical Training

Practical training on waste management practices is essential in developing people's knowledge and attitudes. This finding is revealed by Gizalew et al. [36], Dewi [37], Wafula et al. [38], and Karkil et al. [50].

5.4.2 Basic Infrastructure and Resources

Hospital waste management cannot be practiced appropriately without the basic infrastructure and resources. These findings were confirmed by Babirye et al. [39], Dewi et al. [37], Wafula et al. [38], and Kwikiriza et al. [51].

5.4.3 Knowledge Awareness and Experience

A person's knowledge, awareness, and experience of waste management affect sustainable hospital waste management, which is corroborated by previous research **(**Wafula et al. [38], Theofanidisa et al. [35], Kwikiriza et al. [51], and Pensiri et al. [8].

5.4.4 Favorable Attitudes

The attitude of HWM is a favorable factor towards Sustainable Hospital Waste Management, as highlighted by Mitiku et al.[40], Afriyanto [52], Chanpika, et al.[41], & Wassie [42]).

5.4.5 Financial Facilities

Cost-effective methods and proper financial facilities are also essential in waste management. This finding is confirmed by Wassie et al. [42], Chanpika et al. [41], and Yang et al. [25].

5.4.6 Rules and Regulations

There should be strict rules and regulations that need to be established as formal regulations on healthcare waste management. This finding was confirmed by Chanpika et al. [41], Yang et al. [25] & Wassie [42].

5.4.7 Support from Hospital Staff Members and Other External Organizations

To make hospital waste management practices sustainable, it is essential to have full support from hospital staff members and other external organizations. This finding is supported by Nouf et al. [27].

5.4.8 The Patient's Mindset and Their Health Capacity

If patients have positive attitudes toward the conservation of the environment and understand the risks of poor waste management and the benefits of proper waste management, that situation will lead to sustainable waste management in hospitals.

6. Policy Recommendations

Based on the findings, the following recommendations for sustainable hospital waste management are proposed:

6.1 Practicing Sustainable Waste Management Practices

As most of the selected hospitals retain biodegradable waste without any treatment or outsourcing it to a third party, they can use it to produce biogas and composting. It would be helpful to overcome the financial problems to some extent. An effective hospital wastewater management system should start from the generation point. Introducing wastewater plants for government hospitals would be sustainable. Onsite wastewater treatment would be more beneficial in preventing the release of hazardous waste materials into external sources and bringing reusable wastewater into the consumption cycle than potable water [20].

State-sector hospitals in Sri Lanka do not have well-defined waste recycling systems other than outsourcing or destroying them. No hospital properly practices waste reusing. Proper coordination between the medical sector and recycling industries is required, and new technologies must be adopted sustainably. Moreover, the waste used in the medical sector should be designed to make recycling and reusing possible [53]. These practices are consistent with the concept of Waste-to-energy (WTE) conversion. Furthermore, efficient medical waste management can be achieved by coupling new technologies with old ones, yielding better environmentally friendly and cost-effective results. These ideas coincide with the dimension of cost-effectiveness of SHWM.

6.2 Enhancing Knowledge, Awareness, and Attitudes of the Society

As achieving SHWM is a collective responsibility of the entire society, it is vital to maintain proper communication and coordination among all the relevant parties. Community participation in waste management is an essential factor that could be implemented through active involvement in the entire waste management process [54]. Educating society about the best waste management practices would be helpful to increase social knowledge and attitudes towards SHWM. If authorities can arrange training programs at a practical level, it would be more accessible to the community. Attitudinal changes in society are needed and should start at the school level.

6.3 Increasing Administrative Diligence

Waste management practices of state-sector hospitals in Sri Lanka have been downgraded due to a lack of resources, facilities, and financials. If the government can provide a proper intervention to this, hospitals would be able to follow waste management activities without any delays and backlogs. This idea is consistent with the dimension of administrative effectiveness.

The government should support hospitals with modern waste disposal systems, equipment, and human capital; the government should also properly implement an institutional waste management plan in the hospitals [55]. Administrative authorities need to be more cautious and diligent, and after the rules have been imposed, they need to monitor whether people are correctly adhering to them. Regulatory procedures need to be simplified, and bringing them to the global procedure is vital [56]. These ideas coincide with the dimension of SHWM's administrative effectiveness.

6.4 Addressing the Issue of Fund Constraints

Financial constraints are the most common problem faced by hospitals. Due to the prevailing economic crisis, the situation has gone from bad to worse.

"If we can get more donations from the government or the private sector, we can develop our waste management system further." - A respondent from DHG-03. These hospitals need adequate financial resources to develop waste management systems. As the government cannot handle economic issues, seeking public-private partnerships (PPP) and developing practical tools to attract the private sector for financial assistance would be better. Even though a company operates a hospital hazardous waste outsourcing as a public-private partnership project, these hospitals lack bargaining power due to their monopolistic nature. Hence, the government can call for a competitive procurement system instead of relying on a single organization. Sri Lanka would benefit from a combination of financing strategies that share a collective responsibility between consumers, producers, and the state [57]. Also, finding government or private donations to develop waste management is better.

6.5 Increasing Infrastructure Facilities

There are not enough incinerators to dispose of hospital hazardous waste, and relying on outsourcing organizations is not a sustainable solution. Every hospital does not have adequate space and facilities to install an incinerator. Therefore, it is better to construct one incinerator for several government hospitals in a proper place. Also, it must function under an adequate standard; otherwise, it will not be sustainable. This was corroborated by previous research **(**Wafula et al. [38], Theofanidisa et al. [35], Kwikiriza et al. [51], and Pensiri et al. [8]. Also, there is an acute need for essentials for waste management, like colored waste bags, waste bins, waste carts, etc. Some hospitals have limited infrastructure for waste management, such as dilapidated hospital buildings and limited storage facilities. There is evidence that these hospitals have no access to modern technology in waste management. Thus, adopting new technology to manage healthcare waste in environmentally safe and socially acceptable ways is necessary.

6.6 Organizing Training Programs

Training programs help to enhance knowledge and awareness of waste management. At present, only nurses in these hospitals participate in a 14-day training program offered by the government before being appointed as Infection Control Nursing Officers (ICNOs). Several ICNOs participate in that training program, but unfortunately, some officers lack training opportunities. Since waste management is a collective task, proper hospital waste management training must be provided to all hospital staff members and other stakeholders.

"In most instances, only 2-3 staff members represent those programs on behalf of our hospital, but if they can conduct online programs, we can attract more members." A respondent from DHK-01.

As hospitals face financial difficulties, online training programs could be conducted as they would be cost-effective. The programs need to be undertaken with the participation of all staff members. However, online programs might be problematic when providing practical training. It is important to conduct training programs regularly, and they need to reach every person in the hospital. At the same time, the training programs need to be evaluated on a time-to-time basis [58].

6.7 Introducing a New Legislative with Governance Practices

Sustainable hospital waste management needs to be formulated as a long-term goal because it needs collective participation from every individual in the country, and nationwide attitudinal change is required. Efficient medical waste management could be implemented with new technology to seek environmentally friendly and cost-effective results. It is expected that conventional incinerators running on non-renewable energy sources will be replaced with modern incinerators running on sustainable and renewable energy sources, such as biofuels, in the future. To ensure the sustainability of those new technologies, there is a need for a Sustainable Assessment of Technologies (SAT) [26]. Inconsistencies in the legislative framework can be overcome through merging the political will and organizational structure in terms of public engagement and multi-sectorial collaboration. Introducing new legislative institutions will pave the way for innovative initiatives that could lead the medical waste management process toward more sustainable performance [27]. To achieve sustainable hospital waste management, proper waste segregation, awareness of the people, recycling waste at a manageable cost, adherence to the guidelines and legal procedure of waste management, purification of hospital wastewater before release, and minimizing social problems are required. The country's existing waste management policy needs further development, such as more concern for zero waste or waste reduction and alternative waste management approaches like waste-to-energy and green hospital concepts [59].

7. Conclusion

This study revealed that the existing waste management practices were not on par with sustainability due to several weaknesses such as waste segregation problems, fund shortages, economic instability in the country, the lack of social knowledge, attitudes, and infrastructure, absence of proper waste recycling/reusing system, monopolistic nature in waste disposal company and other waste disposal problems. Several areas were identified as factors affecting sustainable hospital waste management, some of which have not been clearly described by previous studies. These factors include practical training, knowledge awareness and experience, favorable attitudes, financial facilities, rules and regulations, infrastructure and other facilities, support from hospital staff members and other external organizations, and patient mindset and health capacity. Practicing sustainable waste management practices, increasing and promoting awareness attitudes among people, increasing administrative diligence, addressing the issue of financial constraints, increasing waste management infrastructure facilities, organizing more comprehensive training programs, and introducing a new legislative with governance practices are proposed to overcome the weaknesses and improving sustainable hospital waste management practices in Sri Lanka.

8. Limitations and Further Research

This study is based only on fourteen government hospitals in the Western Province, which is one of the study's limitations. A similar study could be conducted, including hospitals in the country's other provinces. By using quantitative and deductive research methods, the findings of this study could be confirmed by enhancing their validity.

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Author Contributions

R. Lalitha S. Fernando: Conceptualization, Formal Analysis, Methodology, Project Administration, Supervision, Writing – Review & Editing. M.K.M Natharka Rushan: Data Curation, Investigation, Software, Validation, Visualization, Writing - Original Draft Preparation.

Competing Interests

The authors have declared that no competing interests exist.

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