Exploring Strategies for Minimizing Clinical and Medical Waste during the Covid-19 Pandemic with reference to the Colombo District, Sri Lanka

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Abstract

The COVID-19 pandemic seriously disrupted the waste management systems around the world and enhanced clinical and medical waste generation in most developing countries, including Sri Lanka. The present examines the upward trend in clinical waste of the Colombo District, contributed by prevailing practices, challenges, and environmental impacts stemming from poor waste management linked to the pandemic. A qualitative research methodology was adapted and, as population 63 Public and Private Hospitals in the Colombo District are included. Using purposive sampling technique nine In-Charge Officers and nine Overseers are selected as the sample. Accordingly, study sample comprising of 18 participants. Open-ended personal interviews and site visits are used as primary data collection methods. Secondary data is collected through research articles, journals, and custom department statistics, logbooks maintain by waste management department of each hospital. Studies have documented an increase in clinical waste by approximately 35% compared to the pre-pandemic era and infectious waste increased by 60%, inclusive of Personal Protective Equipment (PPE) such as masks, gloves, and gowns. Hazardous plastic waste surged 45%, partly due to single-use medical products. The majority of hospitals had conventional ways of managing the wastes, while more than 70% of facilities faced problems while adhering to guidelines pertaining to segregation at the source and waste disposal. In addition, only 30% of hospitals could show specific premises for waste treatment, as a result, up to 50% of medical waste was subjected to incineration without filtration or landfills, which increased the pollution burden. The study concludes with dire needs of practices that ensure sustainable waste management with proposals such as biodegradable personal protection equipment and reusable containers. To this end, this paper concludes that without new strategies, COVID-19 waste will leave behind a legacy that has a long-term impact on the environment. It is thus recommended that further studies in the area be carried out to expand the scope beyond the hospital's setting by incorporating quantitative analyses that bear on improved understanding and policy.

Keywords: Clinical Waste, Corona Virus, Covid-19 Pandemic, Medical Waste, Strategies

1. Introduction

There have been a number of pandemics around the world in the last century, and Ebola Virus, Middle East Respiratory Syndrome (MERS), Swine Flu, Zika Virus are just a handful of the outbreaks which have caused disruption in the world. When comparing the above-mentioned pandemics with the pandemic that the world is facing today, it can be said that COVID-19 seems to be posing a much greater threat, and it affected all parts of our society and waste management is no exception.

There is significant increase in waste accumulation due to the stockpiling of gloves, gowns, masks and other personal protective clothing and equipment and unusual production of medical waste from both households and health care facilities. The personal protective equipment, testing kits, surgical masks, and nitrile gloves are the major contributors to waste volume.

Due to COVID-19 waste production shifted from industry and commercial centers to residential areas and this has caused an increase in medical waste up to 40% (Kalantary et al., 2021). As the world grappled with the COVID-19 pandemic, water pollution worsened due to the surge in plastic waste, further endangering aquatic ecosystems already under threat before the crisis.

Sri Lanka, already facing inadequate waste management practices due to technical, practical, and financial constraints, has been particularly vulnerable to waste management challenges during the pandemic. Therefore, the proper disposal of medical and clinical waste is urgently required to reduce the risk of pandemic spread and ensure the sustainable management of environmental hazards.

In the months of March and April 2020, a significant number of disposable face masks and gloves were disposed of by households under home quarantine. Most of the waste generated during that period primarily consisted of face masks, gloves, and similar items.

In this context, this study tries to answer the following research question.

What are the effective strategies for minimizing the generation and managing of clinical and medical waste in Colombo District during the COVID-19 pandemic?

Thus, the objectives of the study are:

1. To identify current strategies of managing Medical and Clinical under COVID-19 pandemic situation in Colombo District in Sri Lanka.
2. To identify issues relating to managing medical waste during the COVID-19 pandemic situation in Sri Lanka.
3. To identify the impacts of medical wastes generated during the Covid-19 pandemic situation.
4. Proposing sustainable solutions and alternative strategies for the management of exponentially increased medical waste over a short time (strategies for minimizing clinical waste).

This research makes the reader aware of why Clinical/ Medical waste should be treated using the special methods without using traditional methods during this COVID-19 Pandemic. Most importantly, this study helps everyone to adopt the "new normal" post-COVID-19 with sustainable strategies.

Most importantly, findings of this research study propose policy measures as some sustainable strategies to minimize medical waste and that will be easy to implement in real world in any situation, especially in developing countries like Sri Lanka.

2. Literature Review

According to World Health Organization (WHO) guidelines reports (WHO, 2022) clinical waste can be defined as, all the waste generated by health-care establishments, research facilities, and laboratories, and also this comprises the waste that are originating from "minor" or "scattered" sources, such as that produced in the course of health care take on in the home (dialysis, insulin injections, etc.).

2.1. Current Practices of Clinical/ Medical Waste Management in Developing Countries in Asia

Medical/ Clinical waste in a developed country is segregated into color coded and labeled bags or containers (Jang et al., 2006). Developing countries also require the local standards to source segregation of different waste streams into labeled and color-coded waste bags or containers (Ali et al., 2017).

There are several issues with regard to the proper segregation of clinical/ medical waste in developing countries and, these include, lack of proper source segregation, lack of color coding and lack of records pertaining to waste composition and quantity and as a result of that some waste components such as pharmaceutical and domestic waste are mixed together (Ali et al., 2017).

Developing countries require a regular training for all persons who are engaged in waste management activities pertaining to the medical waste management (Ali et al., 2017). Most of the time poor waste management happens due to the bad economic conditions of the developing countries and as a result of that governments of those countries are unable to provide sufficient funds or support for the clinical waste management (Da Silva et al., 2005).

Usually in developed countries, clinical waste is segregated at source and temporarily stored in storerooms which are properly labeled and moreover, there exist legal provisions for site decontamination and spillage control (Ali et al., 2017).

Mostly in developing countries there are no properly labeled waste containers and storerooms for managing the clinical waste and there is poor condition of the containers and there is a lack disinfection as well (Ali et al., 2017).

In order to transport the collected waste a proper procedure is required. Medical waste transportation in European countries regulated by international regulation of the carriage of dangerous goods by road, commonly known as ADR (WHO, 2015). Developed countries like Korea use an online tracking system to monitor medical waste transportation and within that system all the information regarding waste characterization, generator, transporter and the treatment facility is duly recorded (Jang et al., 2006).

There are several issues reported with regard to the transportation of clinical waste in developing countries and they include, lack of personal protective equipment (PPEs) for waste transporters, lack of proper push carts/trolleys which could cause leakages and accidents and transportation in unsuitable vehicles passing through residential areas (Khan, 2016).

Many technologies are used in developed countries for medical waste disposal and they include thermal, biological, mechanical, irradiative and chemical methods such as incineration, autoclaving, land filling, recycling, electron beam technology, bioconversion, etc. or a combination thereof (Ali et al., 2017).

For decades developing countries have been facing difficulties in managing clinical waste in a proper way. Mostly in developing countries waste is burned in open land fill sites or thrown on the roadsides and such sites are accessible to stray animals and sometimes lie in close proximity to residential areas (Ferronato & Torretta, 2019). In most cases, pharmaceutical and chemical wastes are drained in the sewage systems, which can cause the breakdown of natural eco systems and cause environmental pollution (Fatta et al., 2011).

2.2. Managing Clinical (Infectious) Waste for Final Disposal during the COVID-19 Pandemic

COVID-19 in outpatient treatment areas directly generates hazardous waste and these wastes should be separated from the general wastes as soon as possible, packaged, and then stored and collected for transportation to the hospital for final disposal (Sangkham, 2020).

Waste should be collected on a daily basis and must never be allowed to accumulate where it is produced and a daily collection program, and collection round must be planned, and each type of waste must be collected and stored separately with different known signs on the containers (Ugom, 2020).

There should be an additional vehicle with a non-absorbent, sealed loading area, which should be locked, disinfected, and separated from the main vehicle. (Sangkham, 2020)

In most of the developed and developing countries, medical waste is treated by using incineration and secure landfilling. Under this COVID-19 pandemic, situation priority is given to high-temperature incineration to dispose of clinical/ medical waste (Sangkham, 2020). While incineration remains the dominant method, the introduction of plasma gasification technology, which converts waste into clean energy offers a sustainable alternative to minimize environmental impact (Anyaegbunam, 2013).

During the COVID-19 pandemic, the disposal capacity of medical waste is seriously inadequate, because the use of protective masks has greatly increased the possibility of carrying pathogens (Sangkham, 2020). Therefore, some medical waste buckets with obvious mark points are placed in the public areas of hospitals and communities to collect abandoned masks (Sangkham, 2020). They are packaged in double-layered medical waste bags and treated as general medical waste (United Nations Environment Programme, 2020).

The clinical/ medical waste generated by clinics, wards, specialized examination rooms and medical laboratories should be regarded as clinical or medical waste related to COVID 19 and should be labelled as ‘COVID-19 infectious waste’ and this label should be attached by the relevant person during the packaging phase (Sangkham, 2020). As per the author, this waste is placed into double yellow or red medical waste bags and 0.5% (5000 ppm) chlorine disinfectant is sprayed on the surface of these bags before placing the clinical/medical waste in a bucket for temporary storage on site.

For general environmental disinfection at 0.1% (1000 ppm) chlorine-based products can be used as an alternative and, however, chlorine solutions at lower pH have much shorter shelf lives, thus, chlorine solutions (0.1% or 0.5%) should ideally be freshly prepared every day (WHO, 2020). After isolation and packaging this waste put it in another double-layered medical waste bag, and again a chlorine rich disinfectant is sprayed to disinfect the waste (Sangkham, 2020).

Under the COVID-19 pandemic situation most of the countries generated excessive amounts of clinical/medical waste and therefore they have to evaluate their waste management systems to properly incorporate medical waste disposal.

The most common method that was used to dispose medical waste is incineration and it is a biologically safe and suitable method to destroy traces of the virus with high furnace temperature, and the incineration temperature and duration should be set to 1100 °C for 3 min (Kanemitsu & Sangkham, 2020).

Autoclave is another technique that is used to treat the clinical waste before sanitary landfill. This method has been used for more than a century to sterilize medical instruments, and for several years they have been adapted for the treatment of hazardous waste (Tsukiji et al., 2020). An autoclave comprising of a metal vessel designed to withstand high pressures, with a sealed door and an arrangement of pipes and valves through which steam is introduced into and removed from the vessel (WHO, 2020).

Microwave is another technique that can be used to treat clinical waste before secure land filling. This is essentially a steam-based process where treatment occurs through the action of moist heat and steam generated by microwave energy (Tsukiji et al., 2020).

Residual waste remaining after any of the above treatment options is mostly disposed of on land and this should be in a controlled or sanitary landfill, if available. During the COVID-19 pandemic the overall capacity for medical waste disposal is seriously inadequate and for instance, landfills used as one of the most common medical waste disposal options in developing countries in Asia such as India, Bangladesh, Thailand, Indonesia, Myanmar, Malaysia etc. (Kulkarni, 2020).

2.3. Best Practices of Clinical and Medical Waste Management

2.3.1. Cradle-to-Grave COVID-Waste Management in South Korea

COVID waste should not be stored for more than 24 hours, and it should be incinerated on the same day of collection. The household waste generated by self-quarantined persons would also be treated as COVID-waste and the waste generated

by the home-quarantine patients are stored in dedicated color-coded bags and containers after the disinfectant spray (Jun ho et al., 2021).

2.3.2. Utilization of Resources for Efficient Handling of COVID-Waste in Catalonia (Spain)

In Spain collection of COVID-waste is directed along with the Municipal Solid Waste (MSW), however, there is very clear instruction to double-seal the waste-containing bags and to keep it separate by the home-quarantine persons themselves to avoid mixing with common household waste (Ilyas et al., 2020).

2.3.3. On-Site Treatment of COVID-Waste in China

In order to minimize the risk of infection of medical waste, bigger spaces in outer areas of hospitals (usually in the parking space) have been temporarily assigned for the storing, disinfectant spraying, and their smooth transportation to the treatment facility (Lakhouit, 2020).

The performance of clinical waste management measures varies across regions and is based on availability of resources, enforcement by laws, and advancements in technology. Studies have determined the efficiency of segregation of wastes, frequency of collection, and treatment in reducing environmental and health risks. According to Medromi et al. (2009), integrated waste management practices that combine high-temperature incineration with sterilization techniques have proved to yield improved results in minimizing contamination. Furthermore, the application of electronic tracking systems for medical waste has increased monitoring and compliance levels (Pamucar et al., 2020).

Apart from that, comparative studies indicate that decentralized waste treatment, like in China, reduces logistical inconvenience and simplifies waste disposal. Centralized incineration, like in South Korea, is efficient in total pathogen destruction but requires massive infrastructure outlays (Pamucar et al., 2020). These findings highlight the need for context-specific waste management strategies that balance efficiency, cost, as well as environmental impact.

3. Methodology

In this present study, a qualitative research method and an inductive research approach have been followed to address the research objectives. The study population consists of public and private hospitals, amounting to a total of 63 hospitals in the Colombo District. Studying the whole population will not be practical, hence, a purposive sampling technique was utilized to select two public hospitals and one private hospital, namely, Colombo National Hospital, Sri Jayewardenepura General

Hospital, and Nawinna Medicare Hospitals (Pvt) Ltd. These hospitals were selected based on the key criteria of volume of medical waste generated, availability of a separate department for waste management, and a variety of hospital units such as Outpatient Department (OPD), Emergency Treatment Unit (ETU), and Intensive Care Unit (ICU).

For comprehensive understanding of the practices of waste management, a total of 18 respondents were selected, comprising 9 In-Charge Officers from OPD, ETU, and Surgical ICU units, along with 9 Overseers responsible to oversee healthcare and waste management activities. The participants in this study will be selected on the basis of their direct involvement in the handling of clinical wastes, long experience in the management of hospital wastes, and being able to give information on challenges and practices in waste disposal.

To delve deep into the clinical waste management practices, the primary data collection methods involved open-ended personal interviews and site visits. Primary data will be obtained from in-depth, open-ended personal interviews in a face-to-face setting. Each interviewee will be asked questions based on a semi-structured approach, this offers latitude to pursue further new insights, challenges, and perspectives regarding the subject of medical waste management.

Thus, the areas it will try to cover are as follows.

- Background of the medical waste management system
- Number and location of disposal sites
- Methods of waste transportation and treatment
- Following the guidelines in the management of waste
- Problems healthcare workers face in waste management

To be sure that the answers would be consistent and deep, an interview guide had been prepared in advance, mapping out the core themes and questions. The interviews last approximately 45 minutes, and data is recorded by audio recording or note-taking, with prior informed consent obtained from each participant. Participants will be guaranteed data coding, ensuring confidentiality so that they will be free to talk without any doubt about being identified.

Most of the interviews are conducted in Sinhala for better understanding and to make the conversations easier. Meanwhile, the interview guide is also prepared in English to make sure that clarity is maintained if participants face difficulties in comprehension. All interview recordings will be transcribed verbatim and later translated into Sinhala for ease of analysis.

Secondary data include research articles, journals, conference papers, Customs Department statistics, and hospital management logbooks displaying the records of waste management where the sources utilize the findings deduced from the primary data through providing more contextual information.

Content analysis was used to identify key patterns, challenges, and emerging trends in clinical waste management during the COVID-19 pandemic. This approach will help the study present a comprehensive and experience-based understanding of waste disposal practices and their environmental impacts. Based on the research objectives, interview questions were designed, and three main themes were developed to address the research objectives.

1. Current strategies and measures of clinical waste management system under COVID-19 pandemic.
2. Issues relating to waste management practices.
3. Impacts of improper management of clinical/medical waste management under COVID-19 pandemic situation.

4. Analysis and Discussion

The findings of this study are presented primarily under three themes as outlined. Data was collected and analyzed according to those three themes.

4.1. Current Strategies and Special Measures of Clinical Waste Management System under COVID-19 Pandemic

The clinical waste management system has faced significant challenges due to the increased generation of waste during the COVID-19 pandemic. This section discusses the current strategies and special measures employed by hospitals to manage clinical waste during this crisis, categorized under the following sub-themes.

4.1.1. Increased in Clinical Waste Generation

The COVID-19 pandemic has led to a noticeable increase in clinical waste generation. Hospitals have reported an increase in infectious waste, as well as an overall rise in the daily amount of waste produced.

"Prior to COVID-19, hospital staff did not use Personal PPE such as face masks, gloves, etc. on the hospital premises, except in emergencies and necessary situations. The wearing of face masks, gloves, etc., especially by those coming from outside the hospital, was not seen before the COVID-19 pandemic" (OPD 01– In-Charge Officer, Selected National Hospital).

4.1.2. Waste Segregation and Categorization

Hospitals have adopted strict waste segregation policies, and waste is classified and separated according to its nature, particularly infectious waste and COVID-19 waste. Waste is divided into different categories and treated accordingly.

"Before Covid-19, we categorized waste into four categories: infectious, sharps, recyclable, and general waste. Because of the pandemic, we categorized waste into Covid-19 infectious waste, infectious waste, sharps, recyclable, and general waste, and we have a separate color-coded binning system" (OPD 03– In-Charge Officer, Selected Private Hospital).

4.1.3. Personal Protective Equipment (PPE) for Waste Handlers

With the pandemic, clinical waste handlers and external visitors now have to use Personal Protective Equipment (PPE) as a measure of precaution when handling clinical waste. It was not something they were doing before the pandemic.

"Prior to the pandemic, gloves and face masks were hardly ever worn, except in an emergency. The use of PPE became a requirement with the rise of infectious waste during the COVID-19 pandemic" (OPD 01– In-Charge Officer, Selected National Hospital).

4.1.4. Special Waste Packaging and Storage

Hospitals have adopted distinctive packaging protocols for COVID-19 related clinical waste. Waste is placed appropriately inside double-layered yellow or red medical waste bags for safety, following the hospital's guidelines regarding waste management. Special temporary storage units have also been installed for pandemic-generated waste.

" At the packaging phase of the infectious COVID-19 waste gathered, the waste is loaded into the double layered yellow or red color medical waste bags based on the hospital's waste management guideline" (OPD 03– In-Charge Officer, Selected Private Hospital).

"Due to the poor ability of the temporary storage area, there were other independent storage units established during the pandemic to hold the surplus waste'' (OPD 02– In-Charge Officer, Selected National Hospital).

4.1.5. Increased Frequency of Waste Disposal

Disposal of clinical waste has been made more regular, and hospitals are now required to dispose of waste daily, without any storage. This is to prevent the buildup of potentially dangerous material and allow quick disposal.

"Waste is burnt at the end of the day. Waste accumulation is not feasible under the current pandemic scenario" (ICU OV 02– Overseer, Selected General Hospital).

4.1.6. Temporary Storage of Waste

Hospitals have created temporary waste storage facilities for clinical waste to ensure that the waste is securely stored until the time of disposal. These storage facilities are created primarily to cope with the additional amount of clinical waste due to the COVID-19 pandemic.

"Hospitals created additional temporary storage spaces to contain the increased amount of waste generated during the pandemic" (OPD 02– In-Charge Officer, Selected National Hospital).

Though most of the practices and strategies followed by hospitals nowadays are based on traditional ways, the specific measures and guidelines followed during the COVID-19 pandemic, such as PPE wearing, segregation, and increased disposal, are a modification that is necessitated by the challenges caused by the epidemic.

4.2. Issues Relating to Clinical and Medical Waste Management Practices

Even though there are guidelines for the classification of waste and pretreatment of waste most hospitals practically do not adhere to those guidelines.

"Mostly, the collected waste is not put into the color-coded double layered bags and waste handlers forgot to disinfect the collected waste by spraying chlorine" (OPD 01– In-Charge Officer, Selected National Hospital).

Another major issue was that the hospitals introduced new separate bin systems to dispose of the waste and they procure a lot of plastic bins and polythene bags to segregate those wastes. Ultimately, this caused a huge generation of plastics and will cause environmental pollution.

There are obstacles to the safe disposal of waste due to improper collection of waste as well as improper transportation.

"There is a lack of a separate vehicle for transporting the clinical waste, PPEs for waste transporters, and proper push carts. And also, in some instances highly infectious waste is transported through residential areas as well" (OPD OV 01– Overseer, Selected National Hospital).

As a method of disposal of waste, primarily incineration of waste under high temperatures causes to generate toxic gases and has a significant adverse effect on the environment as well as on personal health.

4.3. Impact of Improper Management of Clinical and Medical Waste Management under COVID-19 Pandemic Situation

Improper management of clinical and medical waste during the COVID-19 pandemic has had widespread health, environmental, and economic consequences. The increased volume of hazardous waste, along with unsafe disposal practices, has escalated risks to both the environment and public health. The subsequent sub-themes describe these consequences, guided by hospital staff observations and current literature.

4.3.1. Health Risks to Waste Handlers and the General Public

One of the most immediate impacts of suboptimal waste management is an increased risk of infection and health hazard to hospital staff and waste handlers. Exposure to improperly disposed infectious waste greatly accelerates the risk of disease transmission, particularly in a pandemic scenario.

"During the COVID-19 pandemic condition period, one of our garbage handling workers got COVID-19 infected" (ETU OV 01– Overseer, Selected National Hospital).

"There were also instances where workers encountered inappropriately disposed face masks and gloves inappropriately, which increased their risk of infection." (ICU OV 02– Overseer, Selected General Hospital).

The proof is that if infectious waste is not handled the right way, occupational exposure to pathogens increases. According to Chartier et al. (2014), both waste handlers and health workers incur a high infection risk in the event of non-adherence to safety standards as required. The lack of PPE, improper waste segregation, and even more are added as increased risks of occupational hazard (Brooks & Windfeld, 2015).

Further, the entire population is at risk due to incorrect methods of disposal, and they could pollute water resources and food webs. WHO (2020) reemphasizes that health wastes need to be disposed of and treated properly in order not to experience further secondary infection cases.

One of the costs of poor waste management is the increased risk of infection and health hazards for hospital staff and waste handlers. Exposure to improperly dispose of infectious waste significantly raises the risk of disease transmission, particularly in a pandemic scenario.

"During the COVID-19 pandemic situation, one of our waste handling workers got affected by COVID-19." (*ETU OV 01– Overseer, Selected National Hospital).*

"There were instances where staff members were exposed to improperly discarded face masks and gloves, increasing their risk of infection." (*ICU OV 02– Overseer, Selected General Hospital).*

Studies confirm that improper handling of infectious waste increases the risk of occupational exposure to pathogens. According to Chartier et al. (2014) healthcare workers and waste handlers are at high risk of contracting infections if safety protocols are not strictly followed. Similar findings were reported by Windfeld & Brooks (2015), who highlighted that inadequate personal protective equipment (PPE) and poor waste segregation heighten occupational hazards.

Furthermore, the general public is also at risk due to improper disposal practices, which may lead to contamination of water sources and food chains. WHO (2020) emphasizes that medical waste must be treated and disposed of safely to prevent outbreaks of secondary infections.

4.3.2. Environmental Impacts of Hazardous Waste Disposal

Clinical waste incineration is a standard procedure in every hospital. But when not incinerated in the right way, it contaminates the environment. High-temperature incineration of medical and clinical waste releases dioxins and furans as toxic gases that have long-term effects on health of the people and environment.

"WHO guidelines and clinical waste management policy suggest eliminating waste through high-temperature incineration, which contributes to environmental pollution." (OPD 02– In-Charge Officer, Selected National Hospital).

"We observed greater ash and smoke emission from the hospital incinerators during the pandemic peak period, and air pollution was a concern." (ICU OV 03 - In-Charge Officer, Selected Private Hospital).

Similar findings reveal that incineration without proper emission control can lead to severe air pollution (Giusti, 2009). Improper management of medical waste during the COVID-19 pandemic significantly contributed to environmental contamination, particularly in urban areas where there is negligible waste treatment infrastructure (Singh, 2021).

The other considerable environmental impact is water and soil contamination due to the uncontrolled landfilling of untreated clinical waste.

"Due to the waste overflow, temporary outdoor storage for containing some of the clinical waste was introduced, leading to leakage and contaminating the ground space." (ETU OV 01– Overseer, Selected National Hospital).

Illegally dumped medical waste can release heavy metals and pathogens into groundwater, posing a long-term environmental risk (Hossain et al., 2011).

4.3.3. Economic Consequences of Improper Waste Management

The economic impact of mismanaged medical and clinical waste extends beyond the hospital budgets to affect public health costs and environmental clean-up charges. The waste mismanagement cost burden increases significantly, particularly in a public health crisis situation.

"If there is a crisis being caused by improper handling of the waste, there is another cost incurred in its rectification. Especially if it is an incident of such an epidemic, much would be spent in repairing it if there is a negative impact." (OPD 01– In-Charge Officer, Selected National Hospital).

"Our waste disposal cost increased significantly since we had to use external facilities for the disposal of waste that had accumulated." (OPD 03– In-Charge Officer, Selected Private Hospital).

The economic impact of the lack of proper waste disposal is widely reported in previous research. Mismanagement of COVID-19 medical waste resulted in an estimated 400% increase in waste disposal expenses in some developing countries as a result of the need for emergency waste treatment facilities (United Nations Development Programme, 2021). In addition, (Wilson et al., 2012) highlighted that ineffective waste management systems increase the cost of healthcare due to outbreaks of diseases, increased mortality rates, and the cost of cleaning up the environment. Moreover, indirect economic losses include the loss of tourism and operations of businesses in the affected areas where there is poor waste disposal.

"Tourists and visitors reported that medical waste was dumped in open areas, which negatively impacted the reputation of our health centers and the associated businesses." (ICU OV 02– Overseer, Selected General Hospital).

Improper waste management deters investment in the economy and affects local economies, particularly those based on eco-tourism and public health safety regulations (Kumar et al., 2023).

4.3.4. Broader Societal and Psychological Impacts

In addition to health, environmental, and economic concerns, poor medical waste management has broader social implications. Public exposure of biomedical waste in open areas has the potential to instill fear and psychological trauma among communities, particularly in the event of a health crisis like COVID-19.

"People were afraid to even visit the hospital when they saw discarded used PPE kits and masks outside in open bins." (OPD 02– In-Charge Officer, Selected National Hospital).

"Some patients complained about hospital hygiene and even postponed their treatments fearing infection." (ICU OV 03– In-Charge Officer, Selected Private Hospital).

Public loss of confidence is documented in a study by (Mohandas & Capoor, 2021) that says that, where biomedical waste has been indiscriminately dumped during the time the pandemic was happening, public trust in hospitals declined. Loss of confidence tends to lead to compromised healthcare-seeking behavior, thus widening health emergencies.

In addition, inefficient handling of medical waste may result in legal consequences and regulatory sanctions against hospitals since governments implement stricter regulations for waste management. (WHO, 2021) has reaffirmed the necessity of integrating legal systems to hold healthcare facilities accountable for noncompliance with waste management rules.

"The government issued warnings to a number of hospitals for not complying with waste disposal guidelines, further complicating hospital work." (OPD 01– In-Charge Officer, Selected National Hospital).

Inadequate clinical and medical waste management amid the COVID-19 pandemic has resulted in significant health, environmental, economic, and social impacts. Hospitals have attempted to cope with the increased amount of waste, but inadequacies in segregation, disposal, and treatment have yielded dire consequences. Such outcomes align with global studies, further necessitating improved waste management policy and green waste treatment practices.

5. Conclusion and Recommendations

The results from this present study have shown a significant generation of clinical wastes from the COVID-19 pandemic, most of which were from personal protective equipment like face masks, gloves, and face shields. Indeed, increases in medical waste produced as a result of more stringent safety protocols in response to the public health crises are in line with previous literature (Jayasinghe et al., 2023).

It highlighted changes in the waste management mechanisms of selected hospitals, though those changes were primarily geared toward compliance with WHO

guidelines, rather than strategies to reduce waste. This is also supported by available literature where (Omran et al., 2021) identify that while hospitals across the world have improved their waste handling mechanisms, most lack concrete initiatives on minimizing waste at the source. Moreover, this study confirms that most of the literature evidence indicates staff training gaps, inappropriate disposal practices, and lack of viable alternatives for managing the waste generated (Silva et al., 2021).

The unsolved, long-term environmental and health risks from unsustainable clinical waste disposal remain a challenge. Previous studies (Klemes et al., 2020) indicated that unregulated PPE waste can precipitate secondary crises, which include increased pollution and the potential for disease transmission. While using less PPE may not be possible, it would seem from the findings that the use of biodegradable alternatives, an improvement in segregated waste, and better disposal methods could protect against such risks.

This study reinforces the increasing demand for hospitals to take seriously the need for sustainable waste management practices. Besides, health facilities can make a great contribution to minimizing environmental hazards by going beyond mere short-term compliance with health guidelines and integrating innovative strategies for waste reduction. Failure to do so now may lead to increased health and ecological challenges in the future and thus calls for proactive action.

The below mentioned solutions are the sustainable strategies to handle the waste.

5.1. Encourage to Produce and Use Biodegradable Masks

Masks that are made from non-woven material such as polypropylene and gloves which are made from latex can be substituted with masks and gloves which are made from cellulose fabric. Cellulose fabrics are fabrics that are made from fibers obtained from any plant-based material such as wood, leaves, and bark. Although, masks produced from fabric material are available in the market today, most are not biodegradable, hence not sustainable. Therefore, this solution differs from already available fabric masks as cellulose fabric is not only biodegradable, but sustainable as well. As Sri Lanka is famous for the Sugarcane Industry and for the cultivation of plantains, the residue of sugar cane (Bagasse) and banana fiber can be used as raw materials for the production of cellulose fabric. Lignin Carbohydrate complexes act as anti-viral agents. As Bagasse and banana fiber consist of 25% Lignin, 39% Cellulose and 5-10% Lignin and 60-65% Cellulose respectively, fabric produced from these fibers will act as a good filtering system for COVID-19 virus.

Production of cellulose fabric may seem to be accompanied by environmental degradation as it requires plant materials as raw products. However, as we suggest

producing cellulose fabric with already available waste residue from different industries, the effect on nature is curtailed. Thereby, it helps achieve the targets of Responsible Consumption and Production which are to achieve the efficient use of natural resources and substantially reduce waste generation.

5.2. Replace Sanitizer Bottles with Biodegradable Sanitizer Wipes

Sanitizer bottles can be replaced by sanitizer wipes that are biodegradable. With the shift from the use of sanitizer bottles to sanitizer wipes, the consumer wastage of sanitizer gel and bottles will significantly reduce, thus making it an economically viable solution.

Biodegradable sanitizer wipes can be made from organic cotton which is readily available in Sri Lanka. They are compostable as well, thus being of multi-use. One of the key issues in relation to substituting sanitizer bottles with sanitizer wipes is the non-biodegradable packaging, which is produced of plastics such as polythene. However, these packaging materials can be replaced by packaging which is made of starch (starch films). As Sri Lanka is active in the cultivation of corn and paddy, corn starch and rice starch can be used to produce biodegradable and water-resistant packaging for sanitizer wipes. These solutions are not only sustainable but also comply with the United Nations Sustainable Development Goals (UNSDG) categories of Clean Water and Sanitation, Responsible Consumption and Production and Life- below Water.

5.3. Substitute Reusable Plastic or Glass Bottles

Bottles of sanitizer and hand wash can be replaced with reusable plastic or glass bottles. Reusable plastics are manufactured from High-Density Polyethylene (HDPE), which stands for High-Density Polyethylene. One of the major advantages of HDPE is that they are comparatively cheaper and recyclable. Substituting single-use plastics with reusable and recyclable plastics might be one of the sustainable options, since it rests in line with the categories of UNSDGs such as Clean Water and Sanitation and Responsible Consumption and Production.

5.4. Adoption of a Circular Economy Model for PPE Waste

The single-use PPE would be much better off if recycling systems for medical waste were available in a closed-loop form: collected used PPE, sterilized either by plasma-based systems or UV-C light decontamination methods, and remade into new protective gear or medical supplies. Advanced polymer separation technologies could extract valuable components from discarded masks, gloves, and gowns for reprocessing. This is indeed in collaboration, development, and progress with active material science companies and research institutions on new, biopolymer-based PPE

that would remain protective but also fully recyclable. This option follows UNSDG Goals 9 (Industry, Innovation, and Infrastructure) and 12 (Responsible Consumption and Production).

5.5. Develop Nano-Coated Antimicrobial PPE for Extended Use

Adoption of nano-coated antimicrobial masks, gloves, and gowns would decrease dependency on disposable PPE. Nanoparticles of metals such as silver and copper, and graphene oxide, exhibit powerful antimicrobial properties and hence will lower the chances of contamination. In this regard, PPE is reusable multiple times before its appropriate disposal. For example, the masks with graphene-based filters possess self-cleaning and virus-inactivating properties that increase their use cycles and will have a major implication in decreasing medical waste. This may hence involve research collaboration with experts in nanotechnology to ultimately develop biodegradable nano-coated PPE that, even at the end of the product life cycle, will still maintain sustainability. This strategy supports UNSDG goal 3 (Good Health and Well-being) and the goal 9 (Industry, Innovation, and Infrastructure).

5.6. Adopt to AI-Powered Waste Segregation and Smart Disposal Systems

The two major concerns regarding medical waste management practices in the present day are inappropriate exclusion of hazardous wastes and hazardous waste contamination. AI-powered waste sorting and disposal systems can be fitted within hospitals for better efficiency and sustainability. Automatic bins fitted with AI-driven sensors and machine learning algorithms categorize the medical waste rightly into biodegradable, recyclable, and hazardous categories. Moreover, blockchain-based tracking of generated wastes could present data analytics related to the quantity generated, efficient methods for proper disposal, and subsequent follow-ups needed to advance in improving their environmental sustainability performances. In addition, organic clinical waste can be transformed, utilizing arisen AI-driven waste-to-energy innovations, into biofuels or renewable energies to supply a hospital.

As discussed so far, Sri Lanka must take decisive short-term and long-term measures to mitigate the impact of medical waste. Immediate actions should focus on proper waste segregation and disposal, while long-term strategies must emphasize sustainable waste management solutions to prevent lasting environmental damage.

6. Limitations and Further Research

Several limitations must be borne in mind so that the work will have credibility. It will be restricted to hospitals within the Colombo District and does not extend to other facilities that generate clinical waste, such as clinics, maternity centers, medical centers, laboratories, etc. Thus, the results cannot be generalized for all healthcare

facilities. The small sample size of 9 In-Charge Officers and 9 Overseers from only three hospitals may limit the depth of analysis due to a purposive sampling method as a result of time constraints. The small sample size reduces the representativeness and generalizability of results. A larger sample of respondents would give a broader understanding of clinical waste management practices.

Data collection also presented several challenges. Some of the waste handlers and hospital officers lacked appropriate knowledge concerning the health risks from clinical waste, which might affect the response outcome. There were participants who were unwilling to provide information for fear of professional or personal repercussions. The site visits during the pandemic presented a high health risk, making it difficult to witness waste management practices on-site. Moreover, interviews with hospital staff faced the problem of heavy workloads, hence time constraints in most cases, making fewer comprehensive data collection probable.

The other limitation is the availability of secondary data. There were very few previous studies related to clinical waste management in Sri Lanka. Hospitals mainly burn medical wastes, and hardly any documentation regarding waste measurement and segregation are made, hence accessible records are not available. Moreover, responses were different from different participants due to their social status, cultural backgrounds, and religious beliefs, and may affect the data collected.

Further, policy, financial, and infrastructural impediments practically hinder the introduction of proposed waste management policies in Sri Lanka. So far, management practices in hospitals have concentrated on safeguarding healthcare workers and the public from infectious diseases rather than on environmentally friendly waste managing procedures. Therefore, the current approaches to the treatment of generated wastes lack related arrangements that minimize generation of waste and ensure environmentally friendly methods of disposal.

It also forms the ground for future studies that could synthesize qualitative and quantitative methodologies and an analytically profound, empirical work on similar clinical waste management issues. It enlarges the scope of studies that hitherto were restricted to hospitals within the Colombo District by incorporating various kinds of health-based facilities like clinics, maternity facilities, and laboratory services. This generally enhances its valid generalization or validity to other circumstances. Future studies may take a critical position on the effective working of the present waste management framework, explore potential systemic inefficiency, and understand globally recognized systems of sustainable management of wastes whose principles can be applied to Sri Lanka. Further scholarly research into clinical waste

management in Sri Lanka would, therefore, contribute to the knowledge useful to policy makers, health administrators, and people in the profession of waste management for the better formulation of more effective, evidence-based, and eco-friendly methods of waste disposal.

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