




Review

Beyond the Frontlines: Assessing PPE Waste Disposal in Lahore's Major Public Hospitals During COVID-19 and its Environmental Consequences

Muhammad Khaleeq uz Zaman¹, Naeem Abbas^{2*}, Muhammad Irfan², Muhammad Hammad Khan², Farah Deeba², Khuram Shehzad Khan¹

¹University of Education, Lahore, Pakistan

²Center for Environment Protection Studies, Pakistan Council of Scientific and Industrial Research, Lahore, Pakistan
E-mail: naeemchemist@gmail.com

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Abstract: The COVID-19 pandemic spread around the world like fire in a forest. Many preventative measures were suggested, among which one was the use of PPE. PPE was already being used in hospitals to prevent the spread of contagious diseases. The current pandemic led to an enormous increase in PPE usage, both in hospitals and domestic circuits. However, it has been observed that PPE waste is not being handled and administered appropriately in some major hospitals in Lahore, Pakistan. This mishandling can lead to the rapid spread of diseases, more specifically, the current pandemic, COVID-19. Our study aimed to describe the management of PPE waste in public hospitals. The data was collected by direct and indirect observations of staff in the hospital, including the ones in administration, and the way they managed the waste. The condition of infectious waste in the waste depots of hospitals was also observed and noted. It was observed that not all the hospitals were following the guidelines provided by the WHO about PPE waste. Segregation, storage and transportation were below Pakistan's biosafety rules for 2015 and WHO standards. It could lead to many health and environmental problems. Our study highlights the need for staff training regarding segregation and the proper storage and disposal of hospitals' waste. Certain recommendations in this regard have also been reported to put a stop to the issue of PPE waste and its drastic consequences for the environment.

Keywords: PPE, COVID-19, preventative measures, environmental impact of PPE

Nomenclature

COVID-19	Coronavirus disease
HCWs	Healthcare workers
ICU	Intensive care unit
LGH	Lahore General Hospital
LWMC	Lahore Waste Management Company
PP	Polypropylene
PPE	Personal protective equipment
SARS-CoV-2	Severe acute respiratory syndrome coronavirus 2

1. Introduction

The current study endeavors to inspect the effects of PPE waste on the environment and its management in major public hospitals in Lahore during the COVID-19 situation. It explores the challenges that hospitals face in managing PPE waste and examines effective strategies for minimizing the ecological impact of PPE waste while ensuring the safety of HCWs. The study also investigates the current PPE waste management practices in public hospitals in Lahore and identifies gaps in the management of PPE waste that need to be addressed.

The study also examines the economic impact of PPE waste management in public hospitals, with a focus on the cost of disposing of PPE waste. The study's results will be useful for public health professionals, hospital administrators, and policymakers in Pakistan, and more specifically, Lahore, and will provide valuable insights into the management of PPE waste during the COVID-19 pandemic to reduce the environmental effect of PPE waste while ensuring the safety of HCWs. It will also be relevant to other countries and regions facing similar obstacles in dealing with PPE waste during the COVID-19 outbreak.

1.1 COVID-19: A global pandemic

The novel coronavirus, scientifically known as SARS-CoV-2, became the reason for a global pandemic known as COVID-19 and shook the whole world. The virus broke out in the Eastern Chinese city of Wuhan, with a population of around 11 million, in December 2019. Despite initial efforts to contain the outbreak, the virus quickly spread to other parts of Asia and eventually became a pandemic [1].

To reduce the spread of the virus, the WHO has recommended several preventive measures. These measures include maintaining physical distance, frequently washing hands, and wearing PPE like masks, gloves, and gowns [2].

Proper usage of PPE is crucial in preventing the spread of the virus, as it helps to protect both HCWs and patients from exposure to the virus. PPE is particularly important in high-risk settings where the risk of exposure to the virus is highest, such as hospitals and other healthcare facilities [3].

It must be kept in mind that only the use of PPE is not sufficient to prevent or halt the spread of the virus [4]. It must be used along with other preventative measures as well, such as physical distancing, frequent hand washing, and other infection control practices. It is a collective effort of all sectors, individuals, and the government to reduce the spread of the virus and protect the masses from the pandemic [5]. With many preventative measures suggested by the WHO [6], this study will focus on the proper usage of PPE.

1.2 Introduction to PPE

PPE, including items like masks, gloves, and safety goggles, plays a critical role in minimizing the risk of infectious diseases and workplace injuries [7]. Using PPE is not only important for personal protection but also for preventing the spread of diseases. To ensure its effectiveness, PPE should be used alongside other protective measures [8]. Several factors, such as availability, clear usage guidelines, risk awareness, and comfort, influence the effective use of PPE [9-11].

Employers and governments hold the responsibility of protecting employees during their work, including providing clear PPE guidelines and training for HCWs [12-14]. Proper PPE use is crucial, as misuse can endanger HCWs' lives. In the past, PPE was mainly used in healthcare facilities, but global pandemics, like the one leading to widespread isolation [15], have extended its use to households. This has caused a shortage of PPE worldwide and generated hazardous waste in homes and healthcare settings [16].

The WHO recommends single-use PPE due to contamination risks, except for safety goggles and face shields that can be reused with proper disinfection [17]. Managing and environmentally disposing of this waste is now a pressing challenge.

1.2.1 Disposal and recycling of PPE in the environment

The disposal and recycling of PPE during the COVID-19 pandemic have emerged as critical concerns due to increased usage, resulting in higher PPE waste generation [16]. This waste can contain microplastics and other pollutants harmful to the environment, posing risks to waste handlers and the community if not managed correctly [18]. Proper PPE waste management is essential to reducing its environmental impact and infection risks [19]. Safe disposal methods, including specialized PPE disposal bags and decontamination, must be employed [18]. Segregation of PPE waste from other types is also crucial to prevent contamination [20].

Recycling is another aspect of PPE waste management [21], helping reduce landfill contributions and conserve resources. However, it must be done safely to avoid environmental and health risks [22]. The sustainable management of PPE is a global concern. The lack of international coordination in PPE management and waste handling threatens several United Nations SDGs, including good health and well-being (SDG 3), clean water and sanitation (SDG 6), economic growth (SDG 8), and climate action (SDG 13) [16].

Disposable PPE, such as face masks and gloves made of PP, is non-biodegradable and can take up to 450 years to degrade [23]. Recycling hospital-used PPE is challenging due to its complex chemical composition and contamination risks for handlers [24].

1.2.2 Impact of PPE on the environment

The increased use of PPE due to the pandemic has generated a significant amount of PPE waste, which, if improperly disposed of, can harm the environment. Research by Kampf et al. [25] indicates that the coronavirus can survive on surfaces like plastic, metal, and glass for up to nine days, raising concerns about disease transmission through mishandled PPE. The virus's ability to persist on surfaces is alarming, with survival times of up to 72 hours on plastic and 48 hours on steel surfaces [26]. Even a slight delay in collecting used PPE, as short as 72 hours, can pose risks to waste workers [4, 27].

Another concern is the degradation of plastic PPE waste into microplastics, which can enter the food chain and harm marine life, eventually impacting human health [28]. Microplastics ingestion can affect birds and wildlife, disrupting ecosystems when reaching the ocean [29]. Improper PPE disposal strains waste management systems, resulting in increased litter that harms wildlife and the environment [30].

To address these concerns, proper PPE waste management is essential, including effective segregation, collection, and disposal methods. Awareness campaigns and educational programs can play a crucial role in promoting responsible PPE disposal.

1.2.3 Disposal of PPE

Recent years have witnessed an enormous increase in the utilization of single-use plastic. In fact, it has multiplied by a significant amount during the current pandemic. The improper management of such massive quantities of waste is causing it to accumulate in the oceans and on land. By 2040, the environmental disposal of plastic is estimated to exceed 710 million metric tons [31]. According to Parker [32], the amount of plastic waste flowing into oceans is expected to increase by threefold by 2040.

Given the limited availability of comprehensive data in developing nations such as Pakistan, we shall examine the city of Wuhan, the epicenter of the coronavirus pandemic. The hospitals in Wuhan produced six times more daily waste during the peak of COVID-19. It was on average 40 tons per day, as compared to the previous 6 to 7 tons. As the amount of PPE waste generated in hospitals increased dramatically, neither waste management processes nor plastic recycling increased; as a result, the plastic could have ended up in landfills [28]. During this pandemic, PPE waste production across the globe has produced great downstream plastic waste disposal in both developing and developed countries [33].

1.3 Categorizing hospital waste according to WHO

WHO classifies hospital waste into two main categories: non-risk waste and risk waste [34]. Non-risk waste includes materials like general refuse, paper, plastics, and cardboard, which pose no significant threat to health or

the environment. This waste can be disposed of in a manner similar to regular household or commercial waste [35, 36]. Conversely, risky waste presents potential dangers to both human health and the environment [20]. It comprises materials contaminated with chemicals, pathogens, or radioactive substances, such as sharps (e.g., needles, scalpels), medical gloves, gowns, PPE, and laboratory waste. Proper handling, storage, and disposal methods are necessary to mitigate these risks [20, 37].

WHO recommends that hospitals establish systems for segregating and disposing of risky waste to safeguard public health and the environment [38]. This can involve using color-coded bins or containers for various waste types and providing staff with training on appropriate procedures for managing risky waste. Segregation should occur at the point of waste generation.

In addition to segregation and disposal, hospitals must have protocols for storing, transporting, and disposing of risky waste [39]. Measures should prevent the release of viruses or chemicals into the environment, including using leak-proof and puncture-proof containers and ensuring staff and public safety during handling and transport through the provision of PPE [40]. WHO also advises hospitals to collaborate with local waste management authorities and stakeholders to ensure responsible waste handling and disposal. This entails identifying suitable disposal methods, like incineration or autoclaving, and ensuring secure waste transportation to disposal sites [41].

Hospitals must strictly adhere to national and local waste disposal laws and regulations. They should also implement a robust waste management plan, including regular inspections, audits, and monitoring. This ensures compliance with guidelines and minimizes risks to health and the environment.

2. Waste from hospitals in Lahore

This study was carried out in Lahore, the capital of the most populated province, Punjab [42]. PPE waste management is a concerning problem in developing countries like Pakistan. There are already limited resources among the hospitals to properly tackle the waste. The outbreak of COVID-19 has worsened the situation even more as it led to the production of medical waste in such volumes that it needs desperate waste management, though it appears to be a largely ignored affair.

In hospitals, there are insufficient methods and a lack of awareness regarding PPE waste disposal. It was observed that the waste was categorized into two categories only and was being handled in that regard. It can be classified as general waste or infectious waste.

2.1 General waste

As per regulations, there was no record of general waste. Specific bins were placed in wards and different areas of hospitals for general waste. Waste was collected by the waste pickers and transported by LWMC from the general waste depots of the hospitals on a daily basis. However, a concerning observation was the improper disposal of used face masks by some individuals into general waste bins, potentially contributing to the risk of virus transmission.

Examining the reasons behind individuals discarding used face masks in general waste bins could reveal critical insights into disposal behavior, possibly due to a lack of awareness or inadequate disposal facilities. Additionally, investigating the implications of improper disposal, such as virus transmission risks, emphasizes the urgency of comprehensive solutions.

2.2 Infectious waste

In the hospitals visited for this study, all waste materials were classified as infectious waste that came into contact with the patient. It included all PPE used in hospitals, including masks, gowns, goggles, head covers, gloves, shoe covers, and face shields. Additionally, it included items like blood bags, syringes, needles, urine bags, vials, and bodily fluids. Quantifying the volume and composition of infectious waste generated in these hospitals provides a more comprehensive view of waste management challenges. Analyzing specific hurdles, such as the absence of incineration facilities, offers insights into the need for improved infrastructure. Furthermore, exploring the potential health risks tied to improper infectious waste handling emphasizes the importance of effective protocols. The two color-coded bins used

are yellow for infectious waste and white for general waste, as shown in Figure 1.



Figure 1. Specific bins for infectious and general waste used in LGH

From each ward, the infectious waste was carried to the waste depot or infectious waste room. According to the WHO, the increased amount of PPE waste will require additional efforts to manage this toxic waste. There will be a need for high-temperature incinerators in hospital cities. In countries like Pakistan, the situation of hospital infectious waste handling is already diminishing; only a few hospitals have the capacity to autoclave the waste. There are no incinerators in public hospitals as well. So, it further challenged the administration to handle such large amounts of healthcare waste.

Figure 2 shows PPE waste collected from a local hospital in Lahore during the pandemic. It was determined that the management and segregation of PPE waste were inadequate. The collected waste was indiscriminately disposed of in the hospital's waste depot without proper consideration for its potential harm to the environment or public health. It is important for hospitals to have proper protocols in place for the handling and disposal of PPE waste in order to ensure the safety of both hospital staff and the broader community. According to WHO recommendations, all such waste must be preferably treated on-site and then safely disposed of through an autoclave mechanism or by incineration [43]. To further analyze the issues shown in Figure 2, quantifying the extent of inadequate PPE waste management provides clarity. Investigating contributing factors, such as resource constraints or training deficiencies, deepens understanding. Moreover, assessing potential environmental and public health consequences underscores the importance of implementing WHO-recommended protocols.



Figure 2. Improper disposal of PPE utilized during COVID-19

Figure 3 shows the waste management strategy. PPE waste management requires careful collection, segregation, and disposal of the PPE waste.

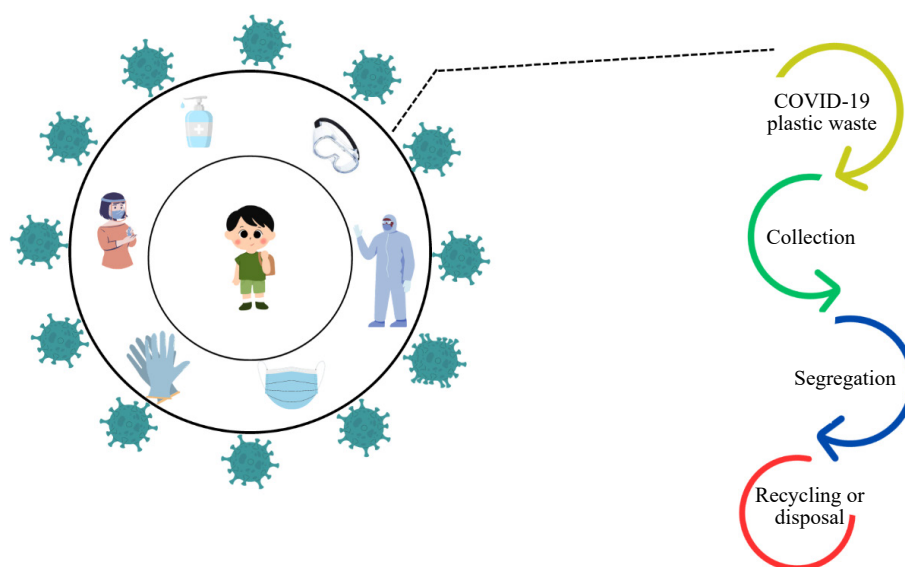


Figure 3. Waste management strategy

During the course of the study, some major public hospitals in Lahore were visited. The total production of waste was investigated. The study involved assessing the total bed capacity, daily infectious waste generation, and COVID-19 ward waste production. Additionally, we gathered data on waste management authorities and their disposal methods to gain a comprehensive understanding of the situation. The data obtained is presented below in Table 1.

Table 1. Waste production from hospitals in Lahore

Hospital	Beds capacity	Infectious waste (kg/day)	COVID-19 ward waste (kg/day)	Waste management authority	Waste disposal mechanism
LGH	1,600	550 to 600	20 to 30	3RWM	Incineration
Sheikh Zaid Hospital	1,030	330 to 350	15 to 20	Self-management	Autoclave
Jinnah Hospital	1,650	500 to 550	20 to 25	ATWM	Incineration
Sir Ganga Ram Hospital	830	250 to 270	10 to 15	ATWM	Incineration
Services Hospital	1,200	370 to 400	18 to 22	ATWM	Incineration

Note: 3RWM = reduce, reuse and recycle waste management; and ATWM = Ali Traders Waste Management

It was observed that infectious waste management in LGH was satisfactory. Infectious waste, including PPE, was enclosed in specified yellow boxes and temporarily kept in the infectious waste room, demonstrating a meticulous approach to containment and risk mitigation. This effective handling of infectious waste is further emphasized by the hospital's partnership with the 3R waste management company, responsible for its transportation and disposal at an incineration plant on a daily basis. Incineration is widely recognized as the most suitable method for biomedical waste disposal [44]. Figure 4 shows the infectious waste room with waste enclosed in yellow bags.



Figure 4. Infectious waste room of LGH

Sheikh Zaid Hospital Lahore, one of the most advanced hospitals in the city, has an on-site autoclave mechanism for treating infectious waste. This advanced process involves melting, shredding, and finally crushing the waste materials, ensuring thorough and secure disposal within the hospital premises. This commitment to innovative waste management solutions not only minimizes risks but also contributes to a cleaner environment. Following the comprehensive treatment, LWMC efficiently manages the waste, exemplifying a well-structured waste management ecosystem that encompasses both treatment and disposal.

In Jinnah Hospital, a private company (CIADS Marketing Services) transported the waste materials from the hospital wards up to the waste depot. The condition of the waste depot was not satisfactory as the waste was not managed properly, raising concerns about the need for improved waste handling protocols and infrastructure, as shown in Figure 5. The authorities mentioned that AT-Waste Management holds the contract for waste disposal at its incineration unit. The same company was holding the contract for waste disposal at Sir Ganga Ram Hospital and Services Hospital, Lahore, as well.

To offer a more comprehensive assessment of waste management practices at Jinnah Hospital, an exploration of the specific challenges leading to the unsatisfactory condition of the waste depot can shed light on areas for improvement. Moreover, investigating the contractual arrangements and performance indicators between the hospital and AT-Waste Management provides a deeper understanding of their partnership's dynamics. This insight allows for a more comprehensive evaluation of waste management efficiency and effectiveness.



Figure 5. Waste depot at Jinnah Hospital, where infectious waste is not being managed properly, potentially posing a serious threat to the spread of various diseases

It was observed that hospital staff were not properly trained regarding healthcare waste management, highlighting a critical area of concern that needs immediate attention. There was no proper segregation of waste in hospitals. All types of waste were being collected as infectious waste except general waste, which was treated subsequently. This lack of waste segregation and adherence to recommended disposal routes, as shown in Figure 6, underscores the importance of implementing comprehensive training programs and protocols for healthcare waste management.

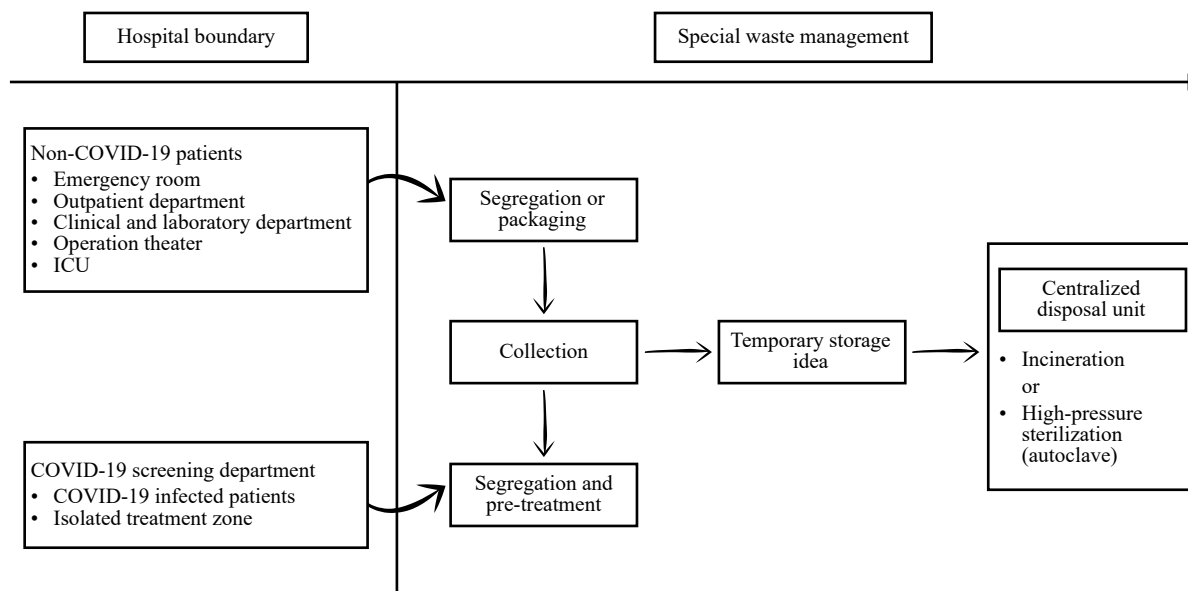


Figure 6. PPE waste management strategy

3. Conclusion

The usage of PPE in hospitals has significantly increased over the years, and this trend has been amplified during the current COVID-19 pandemic. It has brought a significant increase in the amount of PPE waste generated, presenting a major challenge for its management. In many public hospitals in Lahore, Pakistan, PPE waste is either disposed of in landfills, incinerated, or treated through autoclave methods. One of the major issues with PPE waste management in hospitals is the lack of proper segregation of waste. This not only increases the risk of disease transmission but also poses significant environmental problems. In order to address this issue, it is essential for hospital staff to be trained on the proper handling and segregation of PPE waste. Along with staff education, a critical requirement is to adjust the strategy for managing medical waste in response to the pandemic. This must include proper disposal procedures to reduce the chance of the virus spreading to the surrounding area. It is also crucial to establish a regular monitoring and checking system to guarantee that hospitals comply with the set guidelines for managing PPE waste.

Moreover, it is important to remember that PPE is made of plastic, and it takes hundreds of years to degrade. Improper disposal of such plastic can lead to pollution and harm to the environment. Therefore, it is important to make sure that PPE is disposed of properly to avoid environmental pollution.

In conclusion, the increase in PPE use during the COVID-19 pandemic has highlighted the need for effective and sustainable PPE waste management strategies in hospitals. Proper segregation of waste, staff training, and adherence to established guidelines are essential to minimize the risk of disease transmission and environmental pollution.

4. Recommendations

- 1 Hospital waste management rules and compliance:
 - Hospitals are obligated to adhere to the Hospital Waste Management Rules [45] with respect to proper waste management practices.
 - Continuous monitoring and supervision systems should be established to ensure compliance with healthcare waste management regulations and protocols.
- 2 Safe waste disposal:
 - Proper segregation of waste should be performed at every hospital before incineration or waste treatment takes place.
- 3 Staff training and dedicated personnel:
 - Proper training of staff and waste pickers must be conducted for proper segregation and disposal of PPE waste.
 - Each hospital should be staffed with dedicated and motivated personnel for this activity.
- 4 Waste transport and contracts:
 - A designated catchment area should be established and a dependable transport system for waste treatment and disposal should be put in place.
 - Private companies with incinerator plants that have received approval from the Punjab Environmental Protection Department are required to maintain a contract for waste disposal.
- 5 Environmental focus:
 - An eco-friendly and economical waste management strategy must be the first priority of hospitals.
- 6 Public awareness:
 - Flow sheet diagrams and signboards, explaining the proper disposal of PPE, should be placed inside hospitals at various locations to educate the general public who visit the hospitals daily.

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Conflict of interest

There is no conflict of interest for this study.

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