# Public hospital waste segregation practices: A scoping review

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## Abstract

Healthcare waste segregation (HCWS) is a cornerstone of effective healthcare waste management (HCWM), ensuring the safe handling, disposal, and minimisation of environmental and health risks. This dissertation implemented a scoping review methodology to investigate HCWS practices in public hospital settings providing tertiary care. It focused on mapping segregation methods, guideline adherence, environmental impacts, and the research methodologies employed in the included studies. The review included 10 studies conducted across diverse contexts, primarily in lower-middle and upper-middle-income countries, where HCWM challenges are often most acute. The findings revealed significant variability in segregation practices, influenced by infrastructure, training, and adherence to international and national guidelines. While some hospitals demonstrated high compliance with colour-coded systems and effective waste stream separation, others struggled due to resource limitations and inconsistent enforcement of policies. Improper segregation was linked to increased hazardous waste volumes, pollution, and occupational risks such as needle-stick injuries. Conversely, best practices, including segregating at the point of waste generation, compliance monitoring and efficient training, were associated with improved segregation outcomes. Methodologically, the reviewed studies utilised a mix of quantitative, qualitative, and mixed-method approaches, with field observations, questionnaires, and interviews being the most common data collection tools. However, the reliance on cross-sectional designs and the limited application of longitudinal studies constrained the ability to evaluate long-term segregation impacts. This review highlights the need for standardised HCWM guidelines, enhanced training programmes, and infrastructural investments to address identified challenges. Future research should explore innovative monitoring technologies and expand the scope to include diverse healthcare settings. Finally, the evidence this dissertation provides is actionable insights for improving HCWS practices

globally, contributing to safer healthcare environments and sustainable waste management.

**Keywords:** Healthcare waste, segregation, public hospitals, tertiary care

# Table of Contents

## Abbreviations

HCF – Healthcare Facility

HCI – Healthcare Industry

HCW- Healthcare Waste

HCWHE – Healthcare Without Harm Europe

HCWM – Healthcare Waste Management

HCWS – Healthcare Waste Segregation

HIC – High-Income Countries

JBI - Joanna Briggs Institute

LMIC – Low and Middle-Income Countries

MIC – Middle-Income Countries

MCDA – Multi-Criteria Decision-Analysis

MOH – Ministry Of Health

NGO – Non-Governmental Organization

NHS – National Health Service

PCC – Population, Concept, Context

PRISMA - Preferred Reporting Items for Systematic Reviews and Meta-Analyses

PRISMA-ScR – PRISMA for Scoping Reviews

SDGs - Sustainable Development Goals

UN – United Nations

WHO – World Health Organization

# Chapter 1 Introduction

## Background Information

Over the years, environmental care awareness has been gaining more and more popularity due to pressures from the detrimental effects of climate change on the key stakeholder, our planet. Ossebaard and Lachman (2021) pressure that these detriments, such as global warming and water pollution, are already causing enough health diseases and increasing mortality rates. A global health authority pillar, the World Health Organization (WHO) (2023), highlights how climate change is causing respiratory illnesses and spreading vector-borne diseases among other issues. However, Ossebaard and Lachman (2021) warn that sooner rather than later not just our physical health will be suffering the consequences of climate change, but our complete holistic health will be affected, from mental health illness to social health problems. Consequently, the WHO (2023) predicts that just between the years 2030 and 2050 a total of about 5 million people would have died because of climate change. Moreover, it also expects that by 2030 about US$2-3 billion will be required to cover the costs related just to direct health damages.

Despite this, Ossebaard and Lachman (2021) hold the healthcare industry (HCI) accountable as it has only had minimal action on environmental care. Additionally, it is the HCI itself which is contributing to climate change through waste, air, and pharmaceutical pollution. Even though, as Voudrias (2018) identifies, the HCI is one of the largest in the world, it still needs to strengthen its actions on climate change. Thus, Ossebaard and Lachman (2021) suggest that this industry should start by investigating its own carbon footprint to act on climate change and care for our earth.

Hence, HCWM has been identified as a critical component of public health and environmental sustainability by the HCI (Chartier et al., 2014). Amongst the various aspects of HCWM, the WHO finds HCWS as one of the foundations for effective and safe

management of healthcare waste (HCW). However, the degree of HCWS implementation varies significantly across regions.

In public hospitals, Chartier et al. (2014) find that improper HCWS not only poses public health and environmental detriments but also increases the risk of occupational hazards for healthcare workers, such as needle-stick injury-acquired infections.

**Personal Interest**

As a nurse working in the only acute hospital in Malta, which is also the only public entity providing tertiary care, I have encountered first-hand experiences of incorrect techniques, poor education, and limited guidelines of HCWS. Moreover, its detriments were also encountered such as needle-stick injuries, loss of recycling opportunities, waste of resources from mistreating non-hazardous waste as hazardous, and backloading the incinerator with high volumes of incorrectly segregated waste. Unfortunately, studies on HCW in Malta are very scarce. Thus, any information, such as statistics, reports, and guidelines, is neither made readily available to the public nor considerably found. Overall, HCWS practice and its importance are still emerging in Malta. Hence, this dissertation is very significant to me as environmental care has been at heart from a young age, and I hope that maybe one day it will assist the HCI towards more focus on environmental care and saving our planet.

**Rational**

After a very extensive search through Google Scholar and OAR@UM, as already mentioned, HCW research in Malta is very scarce. Only one study was found, which is a bachelor's degree dissertation investigating the knowledge, attitudes, and practices of Mater Dei hospital nurses (Attard Bason, 2015). Hence, this dissertation will follow the recommendation of Ossebaard and Lachman (2021) to start at the root of the problem and focus on the involvement of the HCI in waste pollution. After an inspection of literature from

the databases of Google Scholar, Scopus, and Hydi, and the journal publishing scoping and systematic reviews about healthcare “Joanna Briggs Institute (JBI) Evidence Synthesis” (JBI, 2023), none resulted in a scoping review on hospital waste segregation until now. Thus, this dissertation aims to be the first.

Unlike systematic reviews that narrowly focus on evaluating intervention effectiveness, scoping reviews allow for the mapping of key concepts, research methods, and practices across diverse contexts (Peters et al., 2020). Hence, a scoping review is suitable for this dissertation, due to the fragmented and varied nature of existing studies on HCWS.

**Research Question**

This study sought to answer the following research question…

*“What are the current healthcare waste segregation practices in public hospital settings?”*

…through a scoping review to reach the aims of this dissertation. This question has been based on the Population, Concept, Context (PCC) framework, suitable for exploring the broad subject, as stipulated by the JBI (Peter et al., 2020). This framework has been discussed further in the third chapter of this dissertation. The question aimed to map the literature for the current methods and best practices of hospital waste segregation. Furthermore, this dissertation aimed to be a stepping-stone towards prompting studies on HCW in Malta and be a precursor to systematic reviews on HCW segregation.

Hence, to attempt to achieve these aims the research question has been answered through the following objectives in the format of supplementary research questions (R).

R1. What are the current categories and methods of hospital waste segregation?

R2. What guidelines are in place for appropriate hospital waste segregation?

R3. To what extent and with what effects does the proper or improper segregation of hospital waste impact the environment?

R4. Which research methods are commonly employed in the study of hospital waste segregation?

**Dissertation Outline**

This chapter discussed the scope and rationale for this dissertation, where a scoping review methodology is implemented to answer the main research question and its objectives through supplementary questions. This dissertation has been structured into five chapters. ‘Chapter 1’ above introduced the dissertation. Secondly, ‘Chapter 2’ gave a review of the literature relating to HCWS. Following, ‘Chapter 3’ presented the methodology involved in attaining the studies for review, while ‘Chapter 4’ presented the results with discussions to answer the research question. Finally, ‘Chapter 5’ concludes this dissertation, identifying its limitations, and giving recommendations for future research.

# Chapter 2 Literature Review

HCWS is a critical component of effective HCWM. Proper segregation practice not only ensures the safety of healthcare workers and patients but also minimises environmental detriments and complies with regulatory standards such as the United Nations (UN) Sustainable Development Goals (SDGs). This chapter will define HCW, explore its classification and production, and analyse HCWS practices and challenges. Lastly, local and international segregation standards will be explored.

## Defining Healthcare Waste

In 1999, the WHO was the first to publish a global manual on HCWM (Chartier et al., 2014). However, HCW generation requirements have evolved, and new management methods have been discovered, leading to the publishing of the present second edition guidance in 2014, “Safe management of wastes from health-care activities”. From this manual, the prevalent definition of HCW was introduced as any waste generated through healthcare activities. These activities arise from sources such as the HCI, for example, hospitals and medical laboratories, or households such as from insulin administration (Chartier et al., 2014). The former is a major source of HCW (Chartier et al., 2014). Furthermore, the WHO classifies HCW into two main categories: non-hazardous general waste and hazardous waste.

Regardless of having a definition from the global guidance, a scoping review by Hangulu (2018) still mapped several different nomenclatures of HCW from around the world. The most common nomenclature used by high-income countries (HIC) was ‘medical waste’ followed by equal occurrences of ‘healthcare waste’ and ‘hospital waste’. On the contrary, low and middle-income countries (LMIC) more commonly use the term ‘biomedical waste’, with ‘healthcare waste’ being the second most used, followed by the term ‘medical waste’. However, the term ‘biomedical waste’ was one of the least used by HIC. Other

nomenclatures found include ‘clinical waste’, ‘hazardous waste’ and ‘hazardous healthcare waste’. Nonetheless, the review took into consideration that the majority of the studies gathered were from LMIC (Hangulu, 2018). Thus, the discrepancies between nomenclature use were more prominent. Although Hangulu (2018) observed that HIC and LMIC used different nomenclatures of HCW, it was also observed that they both define, categorise, and classify HCW in alignment with the WHO guidance.

However, the discrepancies in HCW nomenclatures along with other factors are eliciting improper segregation practices (Ali et al., 2017; Hangulu, 2018). The WHO highlights that about 75-90% of HCW produced by healthcare facilities (HCFs) is general domestic waste, making it non-hazardous. Non-hazardous HCW consists of municipal waste such as plastic from sterile packaging waste, paper from administrative departments, and food from kitchen works (Chartier et al., 2014). Therefore, only 10-25% of HCW is left to be deemed as hazardous and imposing environmental and health dangers. Such waste is from infectious, chemical, pathological, biologically harmful pharmaceuticals, or cytotoxic agents, used or unused sharps, and radioactivity natures (Chartier et al., 2014).

## Healthcare Waste Classification

As previously indicated, HCW is classified into non-hazardous and hazardous waste. Below is a further classification of the two groups extracted from the WHO manual, which enables segregation to provide better HCWM practices (Chartier et al., 2014).

### Hazardous Waste

As previously mentioned, hazardous waste originates from different natures, this sets the basis for classifying different hazardous waste. Ultimately, classification aids in steering towards proper HCWM, thus ensuring safety for stakeholders and the environment.

#### *Sharp Waste*

The first and most probably the most apparent hazardous waste is sharps, which are

items that can cause puncture wounds or cuts. These are deemed as highly hazardous HCWs, irrespective of being infectious or not. Some examples of sharps include needles, an infusion set's spike, scalpels, and broken glass (Chartier et al., 2014).

***Infectious Waste***

According to Chartier et al. (2014), this waste originates from materials suspected to contain a sufficient concentration of pathogens, including bacteria, and parasites, to cause disease in receiving hosts. The key term here is 'sufficient concentration'. This means that a ball of cotton wool with a drop of blood, from a non-isolated patient, is not infectious waste but categorised as domestic waste. Furthermore, this can be compared to household behaviours where diapers are disposed of as domestic waste in the black waste bin. Infectious waste can range from waste heavily soiled with blood or body fluids such as blood transfusion bags and tubing or blood-soaked gloves, lab cultures and stocks such as urine microbiology samples, and any waste materials or equipment which were in contact with known infected people or animals such as heavily excreta soiled clothes.

***Pathological Waste***

Pathological waste also known as anatomical waste is sometimes segregated with infectious waste. However, it is more commonly classified as a separate hazardous waste. This HCW is produced through the need for disposing of both healthy or infectious human and animal body parts or fluids. These can originate from surgeries and autopsies for medical procedures or research (Chartier et al., 2014).

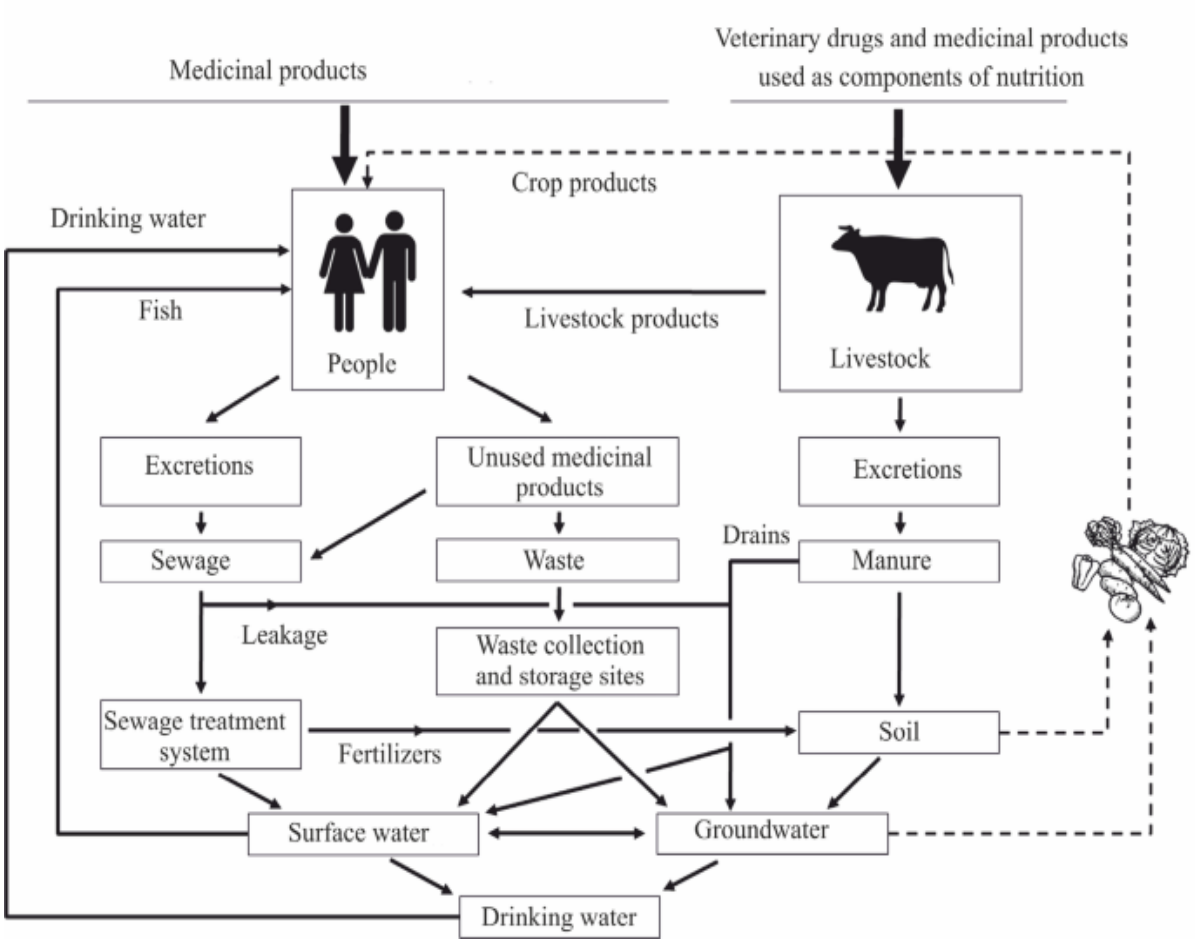
***Pharmaceutical Waste***

Pharmaceutical waste is a global environmental problem due to its broad and multiple sources of pathways into the environment, mainly from disposal and excretion. It is crucial to dispose of this waste appropriately because it is not only an antecedent to environmental and human health damage, but its persistent lifecycle makes it difficult to eradicate as interpreted

in Figure 1 by Kuznetsov (2004) (as cited in Frumin, 2022). As a type of HCW, the WHO describes pharmaceutical waste as any expired, contaminated or unused drug, vaccine or serum which can pose serious risks due to its chemical or biological nature (Chartier et al., 2014). Additionally, heavily pharmacologically contaminated items, such as antibiotic vials and connecting tubing, are also considered pharmaceutical waste.

**Figure 1**

*Environmental pathways of pharmaceutical waste (Kuznetsov 2004)*




The WHO manual adds that this category does not only include tablet, antibiotic, or vaccine drugs but also genotoxic and cytotoxic substances, primarily used in cancer treatments. Genotoxic waste is dangerous to deoxyribonucleic acid, where it may induce genetic mutation, cause defects to the foetus in pregnancy, or cause cancer (Chartier et al.,

2014). This is produced from cytostatic drugs which suppress cellular growth and multiplication. On the other hand, cytotoxic waste kills or stops the growth of body cells. It is generated from chemotherapeutic and antineoplastic drugs used for cancer and organ transplant treatments. Additionally, Chartier et al. (2014) explain that both genotoxic and cytotoxic waste are produced from bodily fluids like urine, vomit, and faeces of patients receiving these treatments which may contain hazardous amounts of these drugs for up to a week after administration. Contaminated drug vials, syringes, and other materials are also toxic waste forms posing significant risks to healthcare workers and the environment. Thus, pharmaceutical waste is deemed as highly dangerous and a global threat, impeding the SDGs. Proper disposal methods, such as incineration or specialised treatment, are critical to prevent contamination of water supplies, soil, and air, thereby protecting both human health and the ecosystem.

***Chemical Waste***

Chemical waste in healthcare arises from substances used in laboratories, sterilisation processes, and cleaning agents (Chartier et al., 2014). This waste includes solvents, disinfectants, and reagents, which could be hazardous due to their toxicity, corrosiveness, flammability, oxidising, and explosive, water or shock reactivity. Hazardous chemical waste includes substances like formaldehyde, which is used for equipment disinfection, specimen preservation and disinfecting liquid infectious waste. Photographic solutions from X-ray departments are also hazardous. Halogenated and non-halogenated solvents, such as chloroform and acetone respectively, are another form of hazardous chemical waste. Additionally, organic and inorganic chemicals, such as insecticides and bleach, are used in various hospital departments. Mercury is sub-categorised as a heavy metal hazardous chemical waste, primarily generated from broken clinical equipment, though its use is decreasing with its replacement by mercury-free instruments such as a digital thermometer.

Other heavy metals like cadmium and lead are also found in HCW, such as discarded batteries and radiation shielding panels. Additionally, gases stored in pressurised containers, such as oxygen cylinders, require careful disposal to prevent explosions from incineration or accidental puncturing.

However, Chartier et al. (2014) distinguish that if chemical wastes lack the above properties they are deemed as non-hazardous, such as sugars, folic acid pills, and albumin transfusions (Stanford University, n.d.). Therefore, it can be noted that not all drugs are pharmaceutical waste. These can be distinguished where the latter contains dangerous compounds, while the former consists of substances with minimal to no harmful effects.

***Radioactive Waste***

Radioactive waste in the WHO manual consists of materials contaminated with radioactive substances, often generated from diagnostic and therapeutic procedures in nuclear medicine and oncology. This waste can originate from either unsealed sources, typically liquid radionuclides applied directly in medical procedures, or sealed sources, which are encapsulated in unbreakable or impermeable devices like needles. The majority of radioactive HCW contains radionuclides with short half-lives, where radioactivity diminishes rapidly within hours or days. However, certain therapeutic procedures use radionuclides with longer half-lives, thus remain radioactive for extended periods and require special handling. These are usually small objects used on or within patients and can be sterilised and reused on other patients. Sealed sources typically have higher radioactivity but are produced in small volumes. These are generally returned to the supplier and are not disposed of in regular waste streams, ensuring the safe management of radioactive materials in healthcare (Chartier et al., 2014).

***Non-Hazardous Waste***

Chartier et al. (2014) refer to non-hazardous HCW as general waste that is not a sharp

hazard and has not been in contact with any infectious, pathological, pharmaceutical, hazardous chemical, or radioactive waste. Therefore, it is deemed non-hazardous as it does not pose a risk to human health or the environment. This waste includes food scraps, paper, packaging materials, and other municipal waste. Historically, domestic waste was either discarded in landfills or incinerated. However, increasing environmental awareness has changed waste management approaches, where the majority of non-hazardous waste can be recycled or composted, such as sterile tubing packaging and food waste respectively. Additionally, Chartier et al. (2014) suggest that a reusing approach can also be applied to certain goods such as furniture and printer cartridges. These approaches promote more sustainable HCWM practices thus adhering to the SDGs.

## Healthcare Waste Production

### Sources of Healthcare Waste

HCW is generated from various sources within HCFs, including major and minor sources. Understanding these sources is crucial for effective HCWM strategies, as both major and minor sources reflect the characterisation of waste generated, providing unique challenges for management. The major and minor sources are presented in Table 1 based on the WHO manual by Chartier et al. (2014). The types of waste these sources produce will be further discussed in the HCWM section of generation.

**Table 1**

*Major and Minor sources of Healthcare Waste*

| Major Sources of HCW | Minor Sources of HCW |
|---|---|
| Hospitals | First-aid posts |
| Clinics ex: emergency, maternity, outpatient, transfusion | Physician offices: general practitioners, acupuncturists, chiropractors |

| Major Sources of HCW | Minor Sources of HCW |
|---|---|
| Nursing/ long-term care homes | Dental clinics |
| Military medical services | Psychiatric hospitals |
| Prison hospitals/ clinics | Institutions for disabled persons |
| Laboratories/ research centres | Funeral services |
| Mortuary/ autopsy centres | Ambulance services |
| Animal research and testing | |
| Blood banks | |

**Healthcare Waste Generation**

HCWM is the process of handling waste generated by healthcare activities, ensuring that it is disposed of in a manner that minimises public health and environmental risks. This process includes HCW generation, segregation, collection, storage, transportation, treatment, and disposal to ensure environmental sustainability and decrease health hazards (Blenkharn, 2007).

Furthermore, HCWM has become crucial due to a significant rise in the global generation of HCW. Chartier et al. (2014) link this sharp increase to several factors, including population growth, expanded healthcare services, technological advancements, and the rise in disposable medical products. Moreover, the COVID-19 pandemic has significantly increased HCW generation, with the increased demand for personal protective equipment (PPE) and the increased use of single-use medical supplies (Mondal et al., 2022). This substantial increase highlights the urgency for effective HCWM strategies to handle the additional load of HCW while safeguarding the environment.

In LMIC, poor HCWM practices have aggravated the risk of environmental pollution and the spread of infectious diseases, as waste is often disposed of inappropriately, leading to

contamination of water, air, and soil (Chartier et al., 2014). Thus, understanding HCW is essential for developing effective HCWM strategies, such as through the reduction of waste generation, adoption of sustainable disposal practices, and compliance with legal and regulatory frameworks to prevent the spread of disease and contamination (Chartier et al., 2014).

Understanding the types and amounts of waste produced by HCFs is crucial for its safe disposal. HCW generation involves the types of waste as per the above classification, and its volume and rate produced (Ali et al., 2017). The WHO (2018) found that HIC generate an average of 0.5kg of hazardous HCW per hospital bed per day, while low-income countries generate an average of 0.2kg per bed per day. Chartier et al. (2014) highlight that waste data helps in determining the required capacities for containers, storage, transportation, and treatment technologies. It also aids in inventory procurement, planning, budgeting, assessing environmental effects, and improving current HCWM systems. They add that the most accurate data comes from quantitative waste assessment by collecting data using equipment such as weighing scales. However, when a quantitative assessment is not possible, Chartier et al. (2014) suggest alternative methods which may be applied, such as surveys or interviews with employees, while considering sample size and HCF types. A paper by Janik-Karpinska et al. (2023) collected generation rate data from studies conducted in different countries across the Earth's five main continents. This data is extracted in Table 2, where it is to be noted that even though Chartier et al. (2014) have noted poor HCWM practices from LMIC, it is HIC who have registered a higher HCW generation rate, where the United States of America (USA) generated 8.4-10.7kg/bed/day, in contrast to Morocco who generated 0.4-0.7kg/bed/day.

**Table 2**

*Healthcare Waste Generation Rate Across Continents (Janik-Karpinska et al., 2023)*

| Continent | Country | HCW Generation Rate kg/bed/day |
|---|---|---|
| North America | USA | 8.4 - 10.7 |
| | Canada | 8.2 |
| South America | Argentina | 2.7 - 3 |
| | Brazil | 2.94 - 3.3 |
| | Ecuador | 2.09 - 2.1 |
| Europe | Spain | 3.5 - 4.4 |
| | Norway | 3.9 |
| | Greece | 0.3 - 3.6 |
| | France | 2.7 - 3.3 |
| Africa | Ethiopia | 1.1 - 1.8 |
| | Egypt | 0.7 - 1.7 |
| | Sudan | 0.38 - 0.9 |
| | Morocco | 0.4 - 0.7 |
| Asia | Kazakhstan | 5.34 - 5.4 |
| | China | 0.6 - 4.03 |
| | Jordan | 2.5 - 6.10 |
| | India | 0.8 - 2.31 |

The generation of HCW is influenced by the major and minor sources due to HCFs having varying factors, such as geographical location, size, patient load, and services provided (Chartier et al. 2014). Hospitals are the primary source of HCW which generate all the hazardous and non-hazardous categories mentioned above (WHO, 2018). For example, a

surgical department produces higher volumes of waste compared to at-home insulin administration services, where the former produces a greater volume of sharps and infectious waste (Chartier et al., 2014). Examples of the types of HCW generated by the different HCF sources are presented in Table 3 based on the data collected by Chartier et al. (2014). As previously mentioned, reducing the generation of HCW is an effective HCWM strategy. This involves reusing items where possible, reducing over-packaging, and managing inventory efficiently.

**Table 3**

*Healthcare Waste Types from Major and Minor Sources (Chartier et al., 2014)*

| Source | Sharps | Infectious/ Pathological Waste | Chemical/ Pharmaceutical Waste | Non-hazardous Waste |
|---|---|---|---|---|
| **Major** Hospital medical ward | Syringes/needles<br>Intravenous tubing spikes<br>Broken ampoules | Heavily blood-soiled gauze<br>Body fluid-soiled gloves<br>Empty blood transfusion bag | Empty antibiotic vials<br>Expired disinfectants | Sterile packaging<br>Leftover food<br>Non-bloody diapers<br>Non-bloody intravenous tubing<br>Paper |

| Source | Sharps | Infectious/ Pathological Waste | Chemical/ Pharmaceutical Waste | Non-hazardous Waste |
|---|---|---|---|---|
| **Major** Laboratory | Petri dish<br>Needles<br>Broken pipette | Microbiological cultures<br>Blood tubes<br>Body fluid sample | Fixatives and solvents | Packaging<br>Non-bloody/body fluid containers |
| **Minor** General practitioner's office | Vaccination needles<br>Broken vials | Blood or body fluid-soiled cotton and gloves | Expired drugs and disinfectants | Packaging, paper, uncontaminated gloves |
| **Minor** Home care | Insulin needles and lancets | Contaminated bandages | Broken mercury thermometers | Leftover food, paper, plastic packaging, domestic waste |

## Healthcare Waste Segregation

HCWS is a critical component of HCWM involving the separation of different types of waste at the point of generation to ensure safe handling, treatment, and disposal (Chartier et al., 2014). There is no one correct method for segregation; however, it is the responsibility of the HCF's management to ensure HCWM systems are set up and ensure their employees are adhering to their protocols (Chartier et al., 2014). The WHO stresses the importance of segregating waste right at the point of generation, thus it is the responsibility of the waste producer to correctly segregate waste (Chartier et al., 2014). They note that the simplest, most common segregation practice while still safe is the "three-bin system", where non-hazardous

waste is separated from sharp waste and potentially hazardous waste. However, Chartier et al. (2014) also recommend the use of further segregation containers to further safeguard the environment, due to the different disposal and treatment requirements of different HCW classifications.

**Segregation Containers and Colours**

Colour-coding containers is an efficient method recommended by the WHO, where it makes segregation easier for the producers and ensures the HCW remains separated throughout the rest of the HCWM process. Additionally, labelling containers and using appropriate symbols are also recommended for safe waste handling. For nationalities that do not have any legislation set, the WHO recommends a scheme for HCWS, as per Table 4 (Chartier et al., 2014). Irrespective of different segregation methods, containers should be lid-covered, durable, leak-proof and lined with the correct coloured impermeable and chlorine-free plastic bags. On the other hand, sharp containers should be puncture-proof and impermeable. This reduces the risks of injury or infection to waste handlers (Chartier et al., 2014).

However, even though there is no one correct segregation method, it would be more beneficial to take segregation a step further by separating waste into as many categories as possible, depending on the treatment and disposal practices a country has available (Chartier et al., 2014). Segregation is so crucial that if an infectious waste is disposed of in a non-hazardous bin it would make the whole batch hazardous waste. This would lead to unnecessary increased treatment costs, contamination risks, and inefficient waste management. Thus, Chartier et al. (2014) suggest that non-hazardous waste can be further segregated into recyclable, compostable, biodegradable and non-recyclable waste. Additionally, hazardous waste such as liquid chemicals should never be disposed of down drains but discarded in leak-proof containers. While expired pharmaceuticals should be kept

in their original packaging and returned to the pharmacy to be sent back to the manufacturer.

**Table 4**

*WHO Colour-Coding Segregation Scheme (Chartier et al., 2014)*

| HCW Type | Container Type | Container Material |
|---|---|---|
| Highly Infectious | Yellow with a biohazard symbol, labelled "Highly Infectious" | Strong, leak-proof, autoclavable container/bag |
| Other Infectious and Pathological | Yellow with biohazard symbol | Leak-proof container/bag |
| Sharps | Yellow with a biohazard symbol, labelled "Sharps" | Puncture-proof container |
| Chemical and Pharmaceutical | Brown with chemical hazard symbol | Plastic bag or rigid container |
| Radioactive | Labelled with a radiation symbol | Lead box |
| General | Black | Plastic bag |

**Waste Handling**

After segregation, HCW is handled according to its specific classification, which includes the next steps of HCWM as noted by Blenkharn (2007), collection, storage, treatment, and final disposal procedures.

Several treatment methods are available for HCWM, where the main aim for hazardous waste is to neutralise its pathogens (Diaz et al., 2005). This process can be done through several methods including autoclaving, chemical disinfection, microwaving and incineration, where incineration should be done carefully to minimise air pollution (Diaz et

al., 2005). Moreover, sharp waste is to be treated and then shredded or melted down to prevent reuse or injury (WHO, 2014). Diaz et al. (2005) explain autoclaving as a sterilisation method using high-pressure saturated steam to kill pathogens without the need to use harmful chemicals. This method would make hazardous waste non-infectious, enabling it to be disposed of as general waste or further managed for recycling. Hence, autoclaving is a preferred HCWM treatment method because it is safe, environmentally friendly, and doesn't produce toxic emissions like incineration. However, chemical and pharmaceutical wastes still require high-temperature incineration or chemical neutralisation to destroy toxic components (Diaz et al., 2005).

Conversely, non-hazardous HCW is treated as municipal waste and disposed of according to the country's available methods such as landfills, however, recycling is also available. For radioactive waste, strict protocols dictate containment until its radioactivity decays to safe levels, after which it can undergo conventional disposal (Chartier et al., 2014). As already mentioned, developing countries have poor HCWM practices, one reason is because they opt for open dumping or incineration, which causes several detriments to public and environmental health (Diaz et al., 2005).

## The Imperatives of Healthcare Waste Segregation

Despite the importance of HCWS and its variation across HCFs, it is a crucial component in HCWM to assist the recommendation of Ossebaard and Lachman (2021) for the HCI to mitigate climate change. This requirement is influenced by various stakeholders and has multiple benefits. However, the detriments of improper HCWS are still present.

### Stakeholders of Healthcare Waste Segregation

Key stakeholders in this HCWM process include healthcare providers, hospital management, waste management personnel, regulatory authorities, non-governmental organizations (NGOs), and the local community (Caniato et al., 2015). Each stakeholder is

crucial in maintaining effective and safe HCW practices, contributing to environmental and public health outcomes.

Caniato et al. (2015) note that healthcare providers, such as doctors, nurses, and technicians, are frontline stakeholders directly responsible for producing and segregating waste at the point of generation. Thus, their adherence to waste protocols is essential to prevent contamination and control the spread of infection within healthcare settings (Ali et al., 2017). However, hospital management has the fundamental responsibility of creating policies, providing training and infrastructure, and ensuring that employees adhere to waste segregation regulations (Caniato et al., 2015). According to the WHO manual, effective HCWM involves setting up waste disposal infrastructure, ensuring the availability of waste bins, and conducting regular audits to monitor compliance (Chartier et al., 2014).

Waste management personnel, such as cleaners, are responsible for transporting and disposing of segregated waste. Hence, they must be provided with proper training about handling infectious or hazardous waste, crucial to protect them from exposure to harmful materials and prevent accidents during waste collection and transport (Caniato et al., 2015). Regional and national regulatory authorities, including the Ministry of Health (MOH) and environmental authorities, were found to be key stakeholders. They are to provide oversight, establish guidelines, and enforce standards on HCWS and disposal practices, essential for the creation of policies that mitigate environmental risks from HCW mismanagement (Caniato et al., 2015). Moreover, Caniato et al. (2015) found that NGOs and advocacy groups are interested stakeholders, depending on the level of involvement required from them. NGOs advocate for sustainable practices, often work alongside regulatory authorities in supporting policy development through research and provide training and awareness to healthcare providers (Caniato et al. 2015; Pereno & Eriksson, 2020).

Healthcare academics also have the responsibility of providing HCWM education and

training to prospective students who will eventually be core stakeholders. While healthcare researchers should have an interest in conducting research and developing new HCWM technologies. However, universities are not always experts or knowledgeable in HCWM as seen in Gaza by Caniato et al. (2015).

Finally, the local community is a vital stakeholder affected by improper segregation practices, where negative health impacts can ultimately increase the burden on the HCI (Caniato et al., 2015). They could either be directly affected by air pollution from HCW incineration, or indirectly affected for example through the illegal sale and reuse of HCW, such as needles (Ali et al., 2017).

Several other stakeholders are involved in HCWM, all with different power-to-interest positions as found along the Gaza Strip by Caniato et al. (2015). However, they emphasise that none alone has significant power, as each stakeholder's involvement in HCW is interdependent. Efficient waste segregation relies on clear communication, adherence to regulations, and continuous education across all groups. Through a collaborative approach, stakeholders contribute to a safer environment, minimise potential health risks, and support sustainability initiatives within healthcare systems.

**Benefits of Healthcare Waste Segregation**

Segregation offers numerous benefits, mostly in safeguarding public health and environmental protection. One crucial advantage is the reduction of infection risk. As already mentioned, one hazardous item disposed of in a non-hazardous waste bin would contaminate the whole batch. Thus, ensuring that hazardous waste is kept separate from non-hazardous waste minimises the spread of pathogens, and safeguards healthcare workers and patients (WHO, 2018).

HCWM efficiency is also improved through segregation. Segregating waste into categories as simple as the “three-bin system” (Chartier et al., 2014) or into as many

categories as possible, allows for more effective disposal and recycling processes. A study by Diaz et al. (2008) in Portugal found that rigorous segregation had a drastic decrease in requiring HCW incineration. Hence, this targeted approach drastically reduces the volume of waste requiring special treatment, while creating a domino effect of lowering disposal costs, without compromising safety (Blenkharn, 2007).

Naturally, HCWS has environmental benefits. It ensures that hazardous waste is treated correctly as suggested by Diaz et al. (2005), preventing the spread and contamination of harmful substances, such as pathogens from infectious waste and harmful chemicals from chemical and pharmaceutical waste, from contaminating the environment. Furthermore, recycling no-hazardous waste like paper, plastics, and metals helps conserve natural resources and reduces the carbon footprint of HCFs (Chartier et al., 2014).

**Detriments of Improper Healthcare Waste Segregation**

HCW classification and segregation is an imperative step for caring for the environment. However, this is clearly not always properly done or even implemented as seen by a United Kingdom study by Blenkharn (2007). This is crucial as poor management of both non-hazardous and hazardous HCW ultimately has adverse effects on multiple stakeholders, including the health of healthcare patients and workers, the community, and the whole environment (Singh et al., 2024).

For instance, improper disposal of used syringe needles can easily lead healthcare practitioners and waste collectors, who are the stakeholders most at risk of injury or infection, to get a needle-stick injury. Thus, highly risking infection from blood-borne diseases such as hepatitis B and C and the Human Immunodeficiency Virus (WHO, 2018). Additionally, in the section on HCW classification, cytotoxic and genotoxic substances could also be found in HCW. These materials can have carcinogenic, mutagenic, and teratogenic consequences on stakeholders, where cancer, mutation, and foetal defects are caused respectively (Chartier et

al., 2014).

Incineration is a common treatment for hazardous waste especially in LMIC (Diaz et al., 2005). As a result, this treatment method contributes to air pollution leading to respiratory diseases (WHO, 2018). This further confirms that the incorrect segregation of non-hazardous HCW from hazardous HCW is as detrimental as the improper segregation of hazardous waste. Hence, disposing of general waste in hazardous waste bins is misguided, contributing to unnecessary incineration and environmental pollution. Additionally, as Chartier et al. (2014) note, disposal methods, such as landfills and incineration, do not only harm humans and the environment but are also costly methods of waste management for upfront and future stakeholder costs.

Moreover, as seen in Frumin (2022) the disposal of pharmaceutical waste ultimately circulates back to drinking water. Thus, improper disposal of hazardous waste can contaminate soil and water sources, snowballing to harm wildlife and ecosystems (Singh et al., 2024). Additionally, Ali et al. (2017) note that liquid and chemical HCW are sometimes disposed into public sewers without treatment, where in natural disasters, overflowing of drains can lead to further imaginable hazards. Furthermore, this snowballing could lead to the infection of stray animals from landfill sites, leading to risks of epidemiological disease spreading (Ali et al., 2017).

## Challenges of Applying Healthcare Waste Segregation

Proper segregation ensures that hazardous waste is handled safely, reduces infectious risks to health and the environment, promotes recycling processes and ensures proper disposal. However, several challenges hinder effective waste segregation within HCFs.

### Training and Awareness Limitations

One significant challenge, noted in a systematic review by Yazie et al. (2019), is the lack of adequate training and awareness among healthcare staff, which often leads to

improper segregation at the source. It was noted that many healthcare providers and waste handlers are unaware of the protocols for handling HCW and the risks associated with improper disposal, leading to increased infection risks and contamination. Operational challenges also include high staff turnover, which leads to frequent training needs as new healthcare employees often enter without sufficient orientation on HCWM protocols. Moreover, most of the HCI has become multicultural, this can also present obstacles to HCWM due to differing cultural perceptions and attitudes, with some workers considering segregation as a lower-priority task, affecting their compliance and commitment (Yazie et al., 2019). An Ethiopian systematic review with meta-analysis by Yibeltal and Kelemu, 2024, found that healthcare workers who received training in HCWM were significantly more likely to demonstrate good HCWM practices. However, a lack of public awareness and community engagement can also lead to improper disposal of HCW by patients and visitors, worsening HCWM issues within HCFs (Yazie et al., 2019).

**Infrastructural Limitations**

Inconsistent enforcement and insufficient oversight from regulatory authorities and hospital management often hinder adherence to established segregation guidelines, leaving gaps in compliance across facilities (Pereno & Eriksson, 2020).

Infrastructure limitations, such as a shortage of colour-coded bins or inadequate waste storage facilities, further complicate HCWS (Chartier et al., 2014). Many healthcare settings, especially in LMIC, lack the necessary resources for segregating and storing HCW properly, resulting in mixed waste that requires more intensive handling and processing such as incineration (Diaz et al., 2005). Thus, financial constraints exacerbate these infrastructure issues, as budget limitations prevent the purchase of essential waste segregation materials and reduce funding for staff training and equipment maintenance (Yazie et al., 2019).

### Financial Limitations

Resource allocation for HCWM often competes with other pressing healthcare needs, particularly in LMIC (Yazie et al., 2019). Additionally, Diaz et al. (2005) note that waste disposal treatments, such as incinerators or autoclaves, are often too expensive for smaller hospitals or clinics, especially when factoring in installation, operational costs, and ongoing maintenance. Instead, they may opt for less costly methods that are not compliant with environmental and health standards, such as landfill dumping, increasing health risks (Diaz et al., 2005.

Cost challenges also extend to HCWM training of healthcare workers, further loaded by the high turnover rates, adding more financial strain on healthcare budgets. Additionally, government funding for waste management is frequently insufficient, as HCWS is often overlooked when allocating resources for public health initiatives (Chartier et al., 2014) Ultimately, the WHO notes that the costs involved in establishing and maintaining an effective HCWS system are substantial, and without adequate funding, facilities may struggle to achieve safe and compliant HCWM practices.

## Local and Global Standards for Healthcare Waste Segregation

### Local Standards

In Malta, commercial entities can dispose of clinical waste at a fee of €500 per tonne (excluding VAT), which is then processed at the Thermal Treatment Facility in Marsa (WasteServ Malta Ltd, 2022). Voudrias (2018) found that the USA produces about 5.9 million tonnes of HCW per year. The last officially documented Maltese statistic is from 2005 where 2 tonnes of HCW were being collected daily (Ministry for Resources and Rural Affairs, 2009). Moreover, Vaccari et al. (2018) found that HCW disposal and treatment in Italy cost around US$5 million. Thus, apart from focusing on providing high-quality care, hospitals must also aim to meticulously minimise and manage waste to conserve the

environment and their finances (Voudrias, 2018).

The effects of climate change, such as global warming, have brought about several other supranational entities apart from the WHO and UN to urgently act on these effects, including the UN Climate Change Conferences and the Intergovernmental Panel on Climate Change (Ossebaard & Lachman, 2021). This is a worldwide issue and thus everyone must give some form of contribution to environmental care.

**European Standards**

In Europe, HCWM is guided by global principles set up by an international NGO, Healthcare Without Harm Europe (HCWHE) (European Union, 2020). It aims to reduce the environmental footprint of Europe's healthcare and create a sustainable sector (HCWHE, 2024). Their guidelines for HCWS emphasise segregation at source to be considered for composting and recycling but most importantly, to be done properly due to the issue of mixing hazardous waste with non-hazardous, ending up treated as hazardous (HCWHE, 2020). However, no colour-coding recommendations are given.

Conversely, the National Health Service (NHS) in the United Kingdom provides more comprehensive HCWS guidelines, while still requiring segregation at source. Such as, the NHS England (2022) guideline directs to perform waste generation audits to determine the amount and type of bins required. Container bins can be made of any colour due to manufacturing constraints for recycled plastic-made bins. However, the bag, bin's lid, and label must match the colour-coding scheme in Figure 2. It is interesting to note that sharps are not all considered hazardous, which is a further sustainable method by the NHS to reduce hazardous waste generation amounts from the HCI.

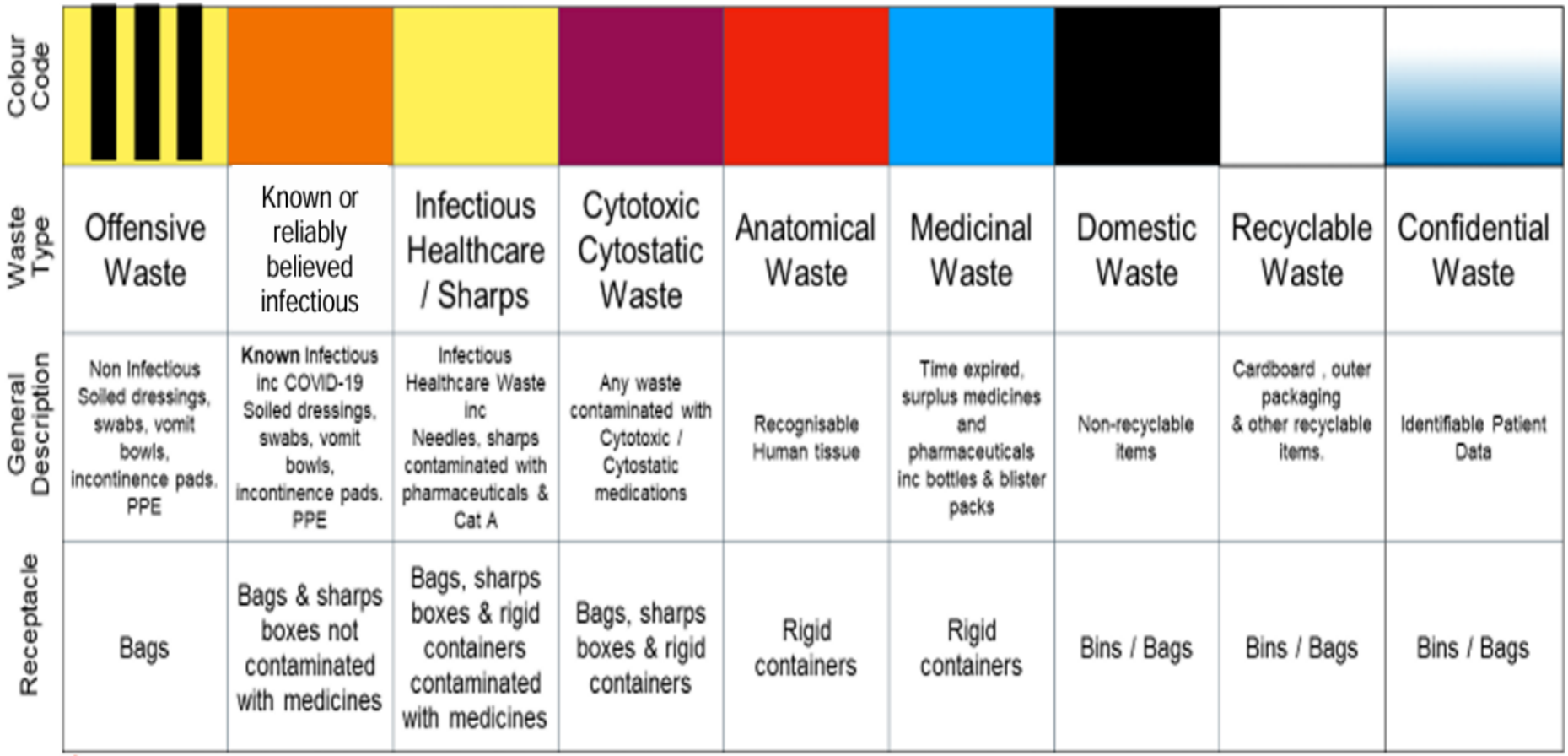
This robust and complex HCWM guideline by the NHS is necessary, due to their target of reaching net zero carbon emissions by 2040, making them the first healthcare provider globally to accomplish this (NHS, 2023).

**International Standards**

Globally, the WHO provides the repeatedly mentioned, comprehensive guideline for HCWM by Chartier et al. (2014). This guidance emphasises a systematic approach to waste segregation, handling, and disposal. As previously presented in Table 4, a standard colour-coding system was also provided by the WHO. These guidelines are widely adopted as a benchmark, particularly in LMIC where HCW infrastructure may be limited.

**Figure 2**

*NHS Waste Colour-coding Segregation (NHS, 2021)*



| Colour Code | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| Waste Type | Offensive Waste | Known or reliably believed infectious | Infectious Healthcare / Sharps | Cytotoxic Cytostatic Waste | Anatomical Waste | Medicinal Waste | Domestic Waste | Recyclable Waste | Confidential Waste |
| General Description | Non Infectious Soiled dressings, swabs, vomit bowls, incontinence pads, PPE | **Known** Infectious inc COVID-19 Soiled dressings, swabs, vomit bowls, incontinence pads, PPE | Infectious Healthcare Waste inc Needles, sharps contaminated with pharmaceuticals & Cat A | Any waste contaminated with Cytotoxic / Cytostatic medications | Recognisable Human tissue | Time expired, surplus medicines and pharmaceuticals inc bottles & blister packs | Non-recyclable items | Cardboard , outer packaging & other recyclable items. | Identifiable Patient Data |
| Receptacle | Bags | Bags & sharps boxes not contaminated with medicines | Bags, sharps boxes & rigid containers contaminated with medicines | Bags, sharps boxes & rigid containers | Rigid containers | Rigid containers | Bins / Bags | Bins / Bags | Bins / Bags |

* All sharps to be placed in tested / approved sharps bins.

** No PPE to be placed in domestic/recycle bins in clinical areas, wards or departments.

In conclusion, HCWS is crucial for ensuring public health, protecting the environment, and maintaining the safety of healthcare workers. Proper HCWS is achieved through the separation of waste at the point of generation into different waste containers, which may be colour-coded. In turn, this reduces the risk of infection, prevents hazardous waste from contaminating general waste, and facilitates cost-effective disposal and recycling processes. Overall, it is essential for sustainable HCWM, to align with global SDGs. Despite its importance, HCWS still faces implementation challenges due to training, infrastructure, and cost limitations. These require targeted investments and enforcement, particularly in LMIC which face more resource constraints, through a coordinated effort from healthcare providers, policymakers, and other stakeholders to implement sustainable, efficient, and safe HCWM practices. Effective HCWS not only mitigates health and environmental risks but also fosters a culture of accountability and safety within HCFs.

# Chapter 3 Methodology

This chapter presented the design and methods employed for this dissertation. The PCC framework was presented as the basis for this scoping review, followed by the established inclusion and exclusion criteria. A detailed search strategy was developed and executed across multiple databases, with all steps of the search process documented to ensure transparency. Followed by the screening process for source selection.

## Research design

HCW being such a broad and emerging subject and to answer the research question "What are the current healthcare waste segregation practices in public hospital settings?", a scoping review was deemed as a suitable research design suitable for this dissertation.

Peters et al. (2020) define scoping reviews as a type of systematic knowledge synthesis aimed at identifying and mapping the key concepts, evidence types, and gaps in knowledge within a particular subject. For the aim of this dissertation, this review will map what research is available and ways in which hospital waste segregation research is being conducted. Additionally, scoping reviews determine whether a full systematic review is feasible, and guide future research by highlighting areas that require further investigation or evidence synthesis through its function of being a hypothesis generator (Munn et al., 2018). This is in line with another aim of this dissertation, to open doors for further HCW research in Malta and a precursor for systematic reviews.

Arksey and O'Malley (2005) introduced the framework for conducting scoping reviews to map the literature on a given topic systematically, without the narrow constraints of traditional systematic reviews. On the one hand, systematic reviews focus on answering specific research questions by analysing a limited set of high-quality studies that are relevant to the topic being researched. On the other hand, scoping reviews are broader in scope and typically utilise a wide range of evidence, varying in study designs and methodologies, to

capture all relevant information on the subject (Arksey & O'Malley, 2005). Overall, scoping reviews are more suitable for exploring and understanding the range of evidence available rather than assessing the quality or answering specific, targeted questions. Thus, a scoping review is suitable for this dissertation's research question, as even though it systematically focuses on hospital waste segregation, this concept is still broad due to different classifications of HCW into general and hazardous along with the vast segregation methods as seen in the literature review.

The methodology has been continuously updated to maintain its relevance and alignment with evolving standards in evidence synthesis, where the original framework by Arksey and O'Malley was later refined by Levac and colleagues in 2010 and with constant updates by the JBI till the present (Peters et al., 2020). Hence, the JBI framework will be followed to perform this scoping review, where the JBI has established rigorous standards to ensure that scoping reviews are systematic, transparent, and trustworthy. In 2018, the Preferred Reporting Items for Systematic Reviews and Meta-Analyses (PRISMA) Statement was extended to scoping reviews (PRISMA-ScR) by several experts, including members of the JBI, to guide reporting (Tricco et al., 2018). Hence, the PRISMA-ScR 2018 checklist will be used to search and document the method, for a more transparent and structured framework.

**PCC framework**

The question for this scoping review is based on the Population, Concept and Context (PCC) framework, suitable for exploring the broad subject. This framework is stipulated by the JBI methodology as the most suitable for a scoping review research question (Peters et al., 2020). The PCC framework applied to this study is explained below.

**P**opulation: Healthcare waste

**C**oncept: Segregation practices

**C**ontext: Public hospitals

## Inclusion and exclusion criteria

As the JBI manual for evidence synthesis explains, inclusion and exclusion criteria are screening guides for which sources will be considered for the scoping review. These guides are dependent on the PCC framed research question and should be as definite and apparent as possible (Peters, et al. 2024). The chosen inclusion and exclusion criteria have been formulated based on the literature review, the research question, the scoping review's objectives, and after a pilot search through Google Scholar using the PCC terms. The pilot search resulted in a broad range of results which were not all relevant to the objectives of this review. This was an antecedent for the established exclusion criteria to ensure that the review directly addressed the intended research question without unnecessary tangents.

The population (P) in the considered sources of evidence is to be aligned with the objectives of the review (Peters et al., 2024). Where for this research question the term 'healthcare waste' is the population keyword. The population keywords, as in Table 5, have been excluded as these hinder the objectives of identifying the current hospital practices of waste segregation. In the found literature, it is seen that hospitals produce several forms of HCW which should be disposed of in different segregation categories. Moreover, sources of evidence focusing on wastewater and pharmaceutical waste will be excluded as highlighted in the literature, these include specialised methods of treatment and disposal distinct from general HCW due to their hazardous nature and potential environmental impact. Additionally, even though food waste is an important matter, it will also be excluded as it is not a healthcare-specific waste stream and does not directly contribute to achieving this review's objectives. Furthermore, these three different wastes involve different stakeholders, regulations, and infrastructures compared to HCW. Hence, the inclusion of these terms would instead broaden the scope excessively while being irrelevant to the primary objectives of this

review. Therefore, their exclusion would allow for more precise and clear identification, categorisation, and synthesis of relevant literature.

In the JBI manual, Peters et al. (2024) point out that concept (C) guides the scope and range of the inquiring questions. Hence, for this review, the concept of 'segregation practices' of hospital employees will be investigated in the sources of evidence chosen. Thus, HCW management practices other than segregation will be excluded as these would not be in the scope of the research question. Moreover, if segregation practices are not explained, such as stating that coloured bins are used but not explaining what segregation or guidelines are assigned, such sources will also be excluded. Outcomes solely discussing health and safety, cost effects, knowledge and awareness studies, and educational intervention studies will be excluded as the objectives of this review are to clarify the current segregation practices being implemented. However, if sources with these outcomes still discuss the hospitals' segregation methods, then these will be included in the review. Waste management practices differ across healthcare settings (Chartier et al., 2014). Therefore, sources focused solely on dental and pharmaceutical professionals will also be excluded, as their waste management protocols differ from those in hospitals and could introduce confounding variables to hospital waste segregation.

Peters et al. (2024) stress that the context (C) also depends on the objectives and questions of the review, however, it encompasses details about the source's specific setting. For this review, 'public hospitals', specifically those providing tertiary care, will guide the screening. Thus, other HCFs will be excluded to adhere to the scope of the research question. Moreover, tertiary public hospitals were included as the only public hospital in Malta delivers tertiary care, thus assisting the objective of this research to prompt HCW research in Malta. Aggregated HCF data will only be included if the segregation practices applied are aligned with both the tertiary public hospital and other HCFs. This is necessary because segregation

practices vary according to guidelines set by different entities, resulting in differences in waste categorization, disposal methods, and treatment management (S Khobragade, 2019).

Other inclusion and exclusion criteria were implemented on the types of sources of evidence to be considered. Due to limited language skills and ease of access, evidence must be published in English and have full text available. To comprehensively answer the research question, it is beneficial to include a broad range of sources in a scoping review, hence grey literature in addition to peer-reviewed studies has been included to gain access to valuable real-world practices and official recommendations (Arksey & O'Malley, 2005). Lastly, the publishing dates of evidence included in this review will be from 2015 onwards. This criterion was based on the literature review findings that the second edition of the previously mentioned WHO global comprehensive guidance was published in 2014 (Chartier et al., 2014). Hence, it was anticipated that from 2015 onwards hospitals might have started to use this global guideline. This manual will also serve as a control when comparing segregation practices between tertiary public hospitals. The search will include evidence published up till the end of June 2024 as it is the period in which the search for sources of evidence was done and cannot be updated due to the limited timeframe and resources to complete the review.

**Table 5**

*Inclusion and Exclusion Criteria*

| Framework | Inclusion | Exclusion |
|---|---|---|
| Population | HCW: Must include both non-hazardous and hazardous waste | Only one form of HCW<br>Not HCW<br>Wastewater/ liquid waste<br>Pharmaceutical waste<br>Food waste |

| Framework | Inclusion | Exclusion |
|---|---|---|
| | | Dental waste |
| Concept | Everyday segregation methods and practices by hospital employees | Waste storage, transportation, and treatment methods |
| | | Unexplained segregation methods |
| | | Effects on health/costs |
| | | Occupational risks |
| | | Levels of knowledge and awareness |
| | | Educational interventions |
| | | Dentist/Pharmacists |
| Context | Tertiary care public hospitals | Private hospitals, clinics, dental clinics, veterinary hospitals, laboratories, health centres, voluntary/charity hospitals, primary/secondary care hospitals |
| Sources of Evidence | Full text available | No access to full-text |
| | Published in English | Published in any language other than English |
| | Published between 2015 and June 2024 | Published before January 2015 and after June 2024 |
| | Grey literature | |

## Search strategy

After setting the eligibility criteria, a structured search follows, identifying and selecting the sources of evidence for this review. As recommended by the JBI methodology, a three-step search approach was implemented to attain adequate and appropriate results for appraisal (Peters et al., 2024). Firstly, two pilot searches were conducted through Google Scholar and MEDLINE Complete, as a pretest to identify which search terms and

combinations are the most sensitive and specific to yield the most relevant results. Additional alternate words and terms relating to the PCC framework were identified through the titles and abstracts from the pilot searches and the literature review. Secondly, a systematic search using all identified terms was carried out through three electronic databases, MEDLINE Complete, Scopus and Web of Science. These databases were chosen based on their use in the systematic review of HCWM audits (Jonathan et al., 2023) due to being a closely related topic to this research question.

The following general search filters, based on the inclusion and exclusion criteria, were applied to all databases:

Published in the period between January 2015 and June 2024

Published in English

Full text available

Finally, reference lists of the chosen sources for appraisal will be analysed for additional studies.

**Search terms**

Applying alternate terms to the search is crucial as different researchers use different terms to describe the same concept in turn broadening the search to ensure that all relevant literature is included (Peters et al., 2024). On the other hand, professional contexts use different terms. Thus, the literature review was crucial to separate linguistic synonyms from those scientific, where the latter is important for the search (Lefebvre, et al., 2023). Overall, using synonyms increases the quality and comprehensiveness of the review. Table 6 below lists the identified alternate terms to the main PCC keywords used for the search.

**Table 6**

*Alternate Terms*

| Framework term | Alternate terms |
|---|---|
| P: Healthcare | Healthcare |
| | "Health care" |
| | Hospital |
| | Medical |
| | Clinical |
| | Biomedical |
| | Hazardous |
| C: Segregation | Segregation |
| | Bins |
| | Classification |
| | Separation |
| | Categorisation |
| | Disposal |
| | Characterisation |
| C: Public hospital | Public |
| | State |
| | Municipal |
| | Government |
| | Hospital |

## Search Tools

The key terms were combined using the Boolean operators as presented in Tables 8 to 10; 'OR' for joining the alternate terms to obtain more sensitive results; and 'AND' to combine all the different PCC elements to ensure they are all included in the search results (Lefebvre, et al., 2023).

Furthermore, Lefebvre et al. (2023) emphasise the importance of including a variety

of free-text terms for each of the chosen search terms to achieve a comprehensive search. Thus, the truncation '*' was applied at the end of a word stem to retrieve as many varied terms to a particular word as possible. This search tool is presented in Table 7 below which identifies the truncations this review is interested in. Parentheses were used to nest terms and specify their search interpretation order, such as '(public OR state OR municipal) hospital', where Booleans within are interpreted first (EBSCO, 2022). Quotation marks were used to search for words which must appear together, such as "health care". However, in Web of Science, quotation marks were used within parentheses for S1 and S3, as in Table 10, to ensure each set of terms was distinct but also appeared together. Without this, trial searches based on S1 from Scopus or MEDLINE retrieved only one term from one set. For instance, using Scopus S1 in Web of Science resulted in studies containing only 'waste' and no 'healthcare' terms.

**Table 7**

*Truncations*

| Truncated word | Words included |
|---|---|
| Segregat* | Segregate, Segregation, Segregations, Segregated, Segregating |
| Bin* | Bin, Bins |
| Classif* | Classify, Classified, Classification, Classifying |
| Separat* | Separate, Separates, Separated, Separation, Separations, Separating |
| Categor* | Categorise, Categorize, Category, Categories, Categorised, Categorized, Categorises, Categorizes, Categorisation, Categorization |
| Dispos* | Disposal, Disposals, Dispose, Disposes, Disposing, Disposed |
| Characteri* | Characterisation, Characterization, Characterise, Characterize, Characterised, Characterized, Characterising, Characterizing |

## Documentation of the Search

Using the above terms and tools, a systematic search was conducted and transparently presented below with the aim of reproducibility following the JBI methodology for scoping reviews. Documented below in chronological order is the search process carried out using the databases, presenting which keywords were used and how they were combined, to yield study results obtained from the search in each electronic database. The search was conducted in July 2024 and presented in Tables 8 to 10 below.

**Table 8**

*MEDLINE Complete Search Documentation*

| **MEDLINE Complete Search** | **Results** |
|---|---|
| **S1**: TI ( (Hospital OR Healthcare OR "health care" OR Medical OR Clinical OR biomedical OR hazardous) AND waste ) OR AB ( (Hospital OR Healthcare OR "health care" OR Medical OR Clinical OR biomedical OR hazardous) AND waste )<br><br>*Limiters applied:* English language, publication date January 2015 till June 2024, full text | 2,601 |
| **S2**: TI ( segregat* OR bin* OR classif* OR separat* OR categor* OR dispos* OR characteri* ) OR AB ( segregat* OR bin* OR classif* OR separat* OR categor* OR dispos* OR characteri* )<br><br>*Limiters applied:* English language, publication date January 2015 till June 2024, full text | 1,045,253 |
| **S3**: TI ( (public OR state OR municipal OR government) (hospital OR hospitals) ) OR AB ( (public OR state OR municipal OR government) (hospital OR hospitals) )<br><br>*Limiters applied:* English language, publication date January 2015 till June 2024, full text | 10,592 |
| **S4:** S1 AND S2 AND S3 | 40 |

**Table 9**

*Scopus Search Documentation*

| **Scopus Search** | **Results** |
|---|---|
| **S1:** TITLE ( ( hospital OR healthcare OR "health care" OR medical OR clinical OR biomedical OR hazardous ) AND waste ) OR ABS ( ( hospital OR healthcare OR "health care" OR medical OR clinical OR biomedical OR hazardous ) AND waste )<br><br>Limiters applied: English language, publication years 2015-2025 | 24,696 |
| **S2:** TITLE ( segregat* OR bin* OR classif* OR separat* OR categor* OR dispos* OR characteri* ) OR ABS ( segregat* OR bin* OR classif* OR separat* OR categor* OR dispos* OR characteri* )<br><br>Limiters applied: English language, publication years 2015-2025 | 7,824,510 |
| **S3:** TITLE ( ( public OR state OR municipal OR government ) ( hospital OR hospitals ) ) OR ABS ( ( public OR state OR municipal OR government ) ( hospital OR hospitals ) )<br><br>Limiters applied: English language, publication years 2015-2025 | 106,987 |
| **S4:** S1 AND S2 AND S3 | 523 |

**Table 10**

*Web of Science Search Documentation*

| **Web of Science Search** | **Results** |
|---|---|
| **S1:** (TI=(("Hospital" OR "Healthcare" OR "health care" OR "Medical" OR "Clinical" OR "biomedical" OR "hazardous") AND "waste")) OR AB=(("Hospital" OR "Healthcare" OR "health care" OR "Medical" OR "Clinical" OR "biomedical" OR "hazardous") AND "waste")<br><br>*Limiters applied:* English Language, Publication date January 2015 till June 2024 | 16,109 |
| **S2:** (TI=(( segregat* OR bin* OR classif* OR separat* OR categor* OR dispos* OR characteri* ))) OR AB=(( segregat* OR bin* OR classif* OR separat* OR categor* OR dispos* OR characteri* ) )<br><br>*Limiters applied:* English Language, Publication date January 2015 till June 2024 | 6,616,965 |
| **S3:** (TI=(("public" OR "state" OR "municipal" OR "government") ("hospital" OR "hospitals"))) OR AB=(("public" OR "state" OR "municipal" OR "government") ("hospital" OR "hospitals"))<br><br>*Limiters applied:* English Language, Publication date January 2015 till June 2024 | 73,472 |
| **S4:** S1 AND S2 AND S3 | 273 |

## Source of Evidence Screening and Selection

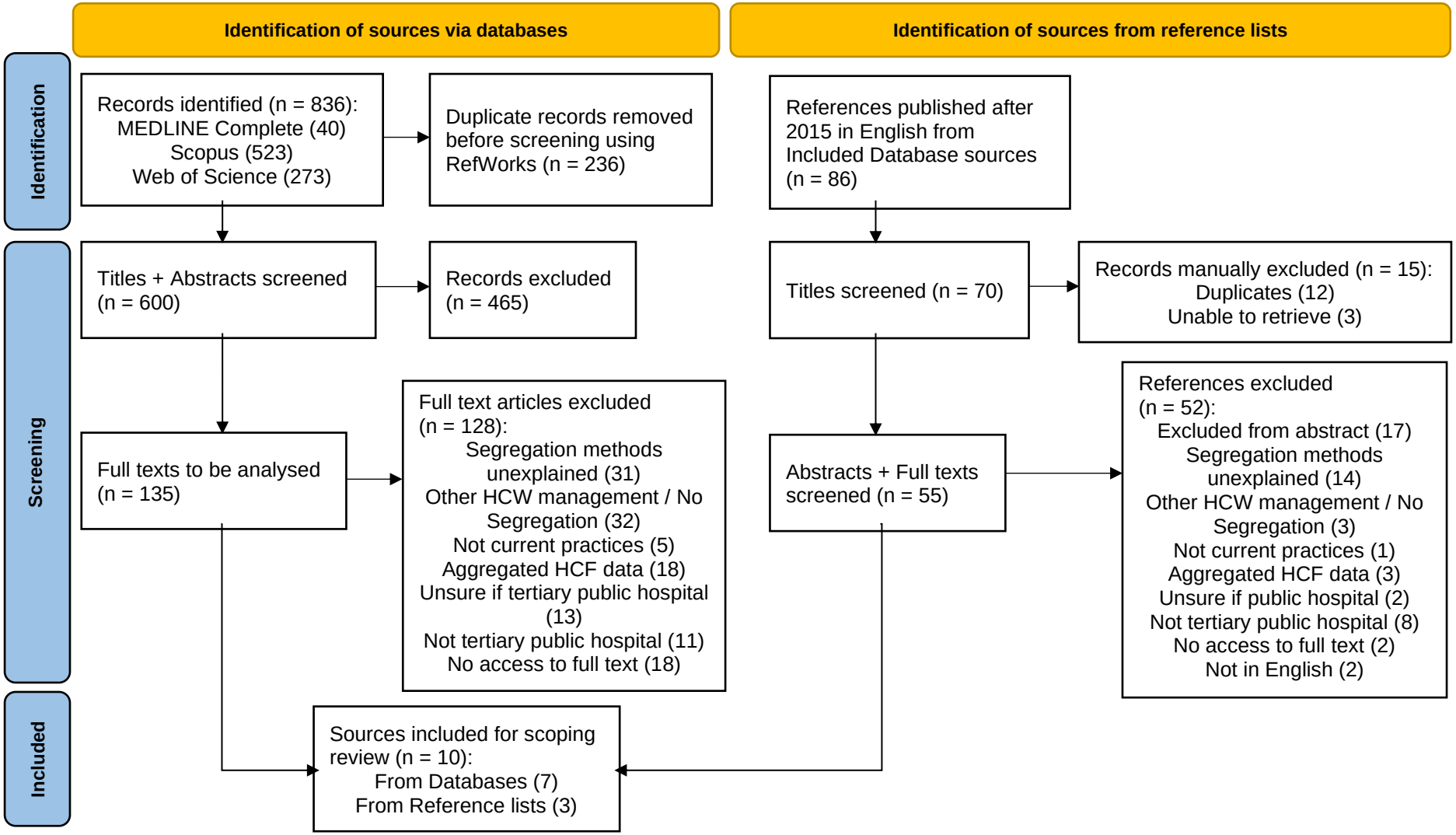
The systematic screening process has been transparently mapped out in Figure 3

below based on the PRISMA flow diagram by Page et al., 2021. From the search using the three databases, a total of 836 sources were attained. Following, the identified sources were collated and uploaded into RefWorks (ProQuest) 2024 reference management software and had 236 duplicates removed. Next, source selection took place in two screening phases by one independent reviewer, myself. First, the titles and abstracts of the 600 sources were screened for relevance to the research question. 465 irrelevant sources were excluded; however, sources with insufficient information were included for further analysis. Thus, the first phase yielded 135 results. Following, the full texts of the remaining sources were analysed against the inclusion and exclusion criteria. If a full text was unavailable from the database source, an additional search for it was done through Google Scholar or Hydi, the University of Malta's electronic library search tool. However, this was not always successful thus such sources had to be excluded. The second phase yielded 7 sources for inclusion (Aung et al., 2019; Dawood et al., 2020; Forumadi et al., 2023; Gaitu et al., 2019; Khan et al., 2023; Leonard et al., 2022; Pindi et al., 2023).

Following, reference lists of the included sources were searched. 86 references published in 2015 or after and titled in English were identified. 70 titles were chosen but 12 duplicates were manually removed this time, and 3 references could not be retrieved. The abstracts and full texts of the 55 remaining titles were screened against the same inclusion and exclusion criteria, yielding an additional 3 sources for inclusion (Farzadkia et al., 2015; Khazaee et al., 2015; Zamparas et al., 2019), totalling to 10 included sources for this scoping review.

**Figure 3**

*Source Selection Process using PRISMA – Flow Diagram*



# Chapter 4 Results and Discussion

In this chapter, the objectives for this scoping review are answered to ultimately answer the main research question of "what are the current healthcare waste segregation practices in public hospital settings?". Firstly, the data of the 10 included studies was extracted and overviewed. Following, the relation of findings to the objectives of the research question, were presented with discussions to investigate the current categories and methods of HCWS in hospitals, their guidelines available to implement segregation, the actual impact of HCWS, and the research methods employed to study hospital waste segregation.

## Data extraction

### Inclusion of Sources of Evidence

Each of the 10 included sources of evidence for this scoping review was deemed suitable for answering the research question as they were aligned with the research framework and its systematic inclusion and exclusion criteria. Each source discussed the population of different HCW types and the concept of segregation practices and methods.

Concerning the study context, Gaitu et al. (2019), Zamparas et al. (2019), Dawood et al. (2020) and Pindi et al. (2023) precisely included public hospitals providing tertiary care. While Khazaee et al. (2015), Aung et al. (2019) and Khan et al. (2023) included tertiary care public hospitals along with other types of hospitals. As mentioned in the third chapter of this study, 'Methodology', studies which included different HCFs along with tertiary care hospitals but had the same segregation practices or were distinguished from the other HCFs, were allowed to be included. To this relation, Khazaee et al. (2015) and Aung et al. (2019) were included as they found that all the hospitals segregated HCW and had the same methods. Whereas Khan et al. (2023) analysed separate hospital data, along with the observation of the same segregation practices.

However, three of the studies' contexts were not explicitly identified as tertiary care

public hospitals. Leonard et al. (2022) included 50 public hospitals from each level of care ranging from health centres to regional referral and district hospitals. However, as per the inclusion criteria, since the same Zambian MOH policies were applied across the facilities, this study was included for review. Conversely, Farzadkia et al. (2015) and Forumadi et al. (2023) did not provide any hospital identification, in fact, the former kept them anonymous. Nonetheless, Farzadkia et al. (2015) mentioned the inclusion of various Karaj hospital categories, specifically noting that among the eight hospitals sampled in 2014, there were four teaching hospitals which are often associated with providing tertiary care (Last, 2007) and one public hospital. Likewise, Khazaee et al. (2015) performed their study in Karaj, Iran, 2013 where all the hospitals of Karaj were included and identified. Amongst these, several public university hospitals and one public hospital providing specialised and sub-specialised care were included, thus providing tertiary care due to their specialisation in care (Last, 2007). Therefore, since the studies were conducted in the same city and around the same time, it is highly likely that the anonymous university and public hospitals included in Farzadkia et al. (2015) were the same as those used in Khazaee et al. (2015). Thus, making them tertiary care-providing public hospitals, which allowed the inclusion of the Farzadkia et al. (2015) study. Similarly, Forumadi et al. (2023) did not name the hospitals investigated. However, it was mentioned that they are affiliated with a public university hospital, which also allowed its inclusion.

**Descriptive Overview**

The descriptive data of the 10 included studies have been extracted in Table 11 below, based on the JBI scoping review guide by Peters et al. (2020), to inform the research question and objectives for this scoping review using the PCC framework. This includes the first author and year of the publication, the study objectives, the HCW types involved as the population, the segregation concept employed, and the context details and geographic

location. The study designs used will be discussed later in the results section, as part of the objectives for this review.

It can be noted that the studies have been published between the years of 2015 to 2023, with the most published years being in 2019 and 2023 having 3 studies each. The studies range from 4 continents, with the most studying the Asian countries of Iran (Farzadkia et al., 2015; Forumadi et al., 2023; Khazaee et al., 2015), Myanmar (Aung et al., 2019), Iraq (Dawood et al., 2020), Pakistan (Khan et al., 2023) and India (Pindi et al., 2023). The Australian country, Papua New Guinea, was studied by Gaitu et al., (2019), Zamparas et al., (2019) investigated the Greek European country and Zambia in Africa was explored by Leonard et al., (2022). For the fiscal year of 2025 the World Bank Group, using the World Bank Atlas calculation method based on the country's gross national income per capita, classified Greece as a HIC, Iraq and Iran as upper-middle income countries, while the remaining countries are all classified as lower-middle income countries (MIC). This classification covers a wide range of income levels and economic contexts. Consequently, even though Greece is classified as a HIC, it has significant variability in this category. It has faced economic challenges such as resource constraints, financial volatility and debt crisis affecting its growth in income levels (European Commission, 2024). The prevalence of studies from MIC may be attributed to observations by Ali et al. (2017) and Ashtari et al. (2020), who noted that HIC have solved their HCWM challenges prior to the year 2000, while LMIC have recently begun to prioritise HCWM regulations. In the case of Greece, its financial challenges may limit its ability to invest in healthcare infrastructure, thus in HCWM, at levels comparable to wealthier HIC. Hence, why Greece might still be studying their HCWM status.

**Table 11**

*Data Extraction Based on the PCC Framework*

| Source | Objectives | HCW Type | Segregation Concept | Context | Country |
|---|---|---|---|---|---|
| Farzadkia (2015) | To test the usability of a national tool for integration data analysis of HCWM status | General<br>Chemical<br>Pharmaceutical<br>Clinical<br>Infectious<br>Pathological<br>Sharps | At generation point<br>Colour-coding | 4 university hospitals<br>3 private hospitals<br>1 public hospital | Iran – Karaj |
| Khazaee (2015) | To investigate the status of HCWM, training and education, and sewage in all hospitals of Karaj city | Hazardous-infectious<br>Municipal and general<br>Sharps | At generation point<br>Colour-coding and labelling | 5 tertiary and 2 secondary care public university hospitals<br>1 tertiary care public hospital<br>3 tertiary care private hospitals | Iran - Karaj |
| Aung (2019) | To provide a standardised HCWM evaluation framework using MCDA to | General<br>Infectious | Colour-coding | 4 tertiary care public hospitals | Myanmar - Yangon |

| Source | Objectives | HCW Type | Segregation Concept | Context | Country |
|---|---|---|---|---|---|
| | assess HCWM practices. | | | 1 secondary and 3 tertiary care private hospitals | |
| Gaitu (2019) | To study the hospital's HCWM situation and suggest recommendations and policy implications. | Medical<br>General non-hazardous<br>Cytotoxic<br>Sharps | 2-stage segregation: at generation and treatment points<br>Colour-coding | 1 tertiary care public hospital | Papua New Guinea - Lae |
| Zamparas (2019) | To examine the current legislation and directives issued for HCWM in Greece and the other EU members.<br>To explore the HCW generation rate on social and economic parameters in selected European countries.<br>To investigate the Greek hospital's management of the disposal of infectious wastes and propose integrated management of such hazardous wastes. | Municipal<br>Infectious<br>Toxic (chemical and pharmaceutical)<br>Others | At generation point<br>Colour-coding and labelling | 1 tertiary care public university hospital | Greece - Rio |
| Dawood | To examine the HCWM practices of | Hazardous | At generation point | 2 tertiary care public | Iraq - |

| Source | Objectives | HCW Type | Segregation Concept | Context | Country |
|---|---|---|---|---|---|
| (2020) | two governmental hospitals, which disposed of their HCW by incineration. | Sharps<br>Non-hazardous | Colour-coding | hospitals | Baghdad |
| Leonard (2022) | To identify the knowledge, attitudes, and practices of healthcare workers on HCWM.<br>To explore the individual and institutional factors associated with proper HCWM practices. | Hazardous<br>Domestic<br>Sharps | At generation point<br>Colour-coding<br>Labelling if coloured bags are stocked out | 50 public HCFs of each care level | Zambia – Luapula, Muchinga, Northern, North-Western and Western Provinces |
| Forumadi (2023) | To investigate HCWM practices and waste generation with an emphasis on genotoxic waste.<br>To assess the kind of training provided for the hospital personnel.<br>To suggest improvements to the existing conditions. | General<br>Hazardous-infectious<br>Genotoxic<br>Cytotoxic<br>Sharps | At generation point<br>Colour-coding | 6 university-affiliated public hospitals | Iran - Seman |
| Khan (2023) | To examine the process of HCWM.<br>To investigate HCW handling and disposal safety and difficulties, the set | Infectious<br>Sharps<br>Non-infectious | Infectious waste segregated at generation point | 1 secondary and 1 tertiary care public hospitals | Pakistan - Swabi |

| Source | Objectives | HCW Type | Segregation Concept | Context | Country |
|---|---|---|---|---|---|
| | organisational rules and procedures, and the extent of directive-adherence. | Recyclable | Other waste segregated at treatment point<br>Colour-coding and labelling | 2 secondary care private hospitals | |
| Pindi (2023) | To assess the HCW segregation compliance in patient care areas using a checklist-based scoring system and establish feedback-based training programs. | Hazardous<br>Contaminated recyclables<br>Sharps<br>Glassware | At generation point | 1 tertiary care public hospital | India - Hyderabad |

## Relating Findings to the Research Question

### Presentation of Results

The results for this review are mapped based on the research question objectives. A presentation of results is given in tabular format followed by discussions using thematic and comparative analysis between studies and the literature review findings from the second chapter. Ultimately, to answer the main research question of what segregation practices and guidelines are implemented by public hospitals.

### Current Categories and Methods of Hospital Waste Segregation

The first objective for this scoping review…

*"R1: What are the current categories and methods of hospital waste segregation?"*

…was to investigate the current categories and methods of hospital waste segregation. The 10 studies reveal diverse categorisations and colour-coding of HCW types as tabulated in Table 12 below. This reflects the various classification systems for categorising HCW depending on regional guidelines and hospital practices.

**Table 12**

*Hospital Waste Categories and Colour-Coding*

| Source | HCW Type | Container |
|---|---|---|
| Farzadkia (2015) | General | Black bag in blue bin |
| | Chemical and Pharmaceutical | Yellow bag in yellow/ blue bin |
| | Clinical, Infectious and Pathological | Yellow bag in yellow/ blue bin |
| | Sharps | Yellow bin |
| Khazaee (2015) | Municipal and General | Black bag |
| | Hazardous-Infectious | Yellow bag |

| Source | HCW Type | Container |
|---|---|---|
| Aung (2019) | Sharps | Yellow boxes |
| | General | Black bin |
| | Infectious | Yellow bin |
| | Highly infectious | Red bin |
| Gaitu (2019) | (At hospital) All Medical | Black bag |
| | Cytotoxic | Yellow bag |
| | Sharps | Brown carton box |
| | (At treatment facility) General | Green bin |
| | (At treatment facility) Medical | Yellow bin |
| | (At treatment facility) Cytotoxic | Orange bin |
| Zamparas (2019) | Urban solid | Black polyethylene bag |
| | Hazardous- contagious | Yellow leak-proof bag/bin with biohazard symbol |
| | Contagious sharps | Yellow puncture-proof bin labelled "Sharps" with biohazard symbol |
| | Mixed Hazardous | Red leak-proof bag/bin labelled with an appropriate hazardous symbol |
| Dawood (2020) | Hazardous | Yellow bag |
| | Sharps | Labelled "Sharps" container |
| | Non-hazardous/Household | Black bag |
| Leonard (2022) | Hazardous | Yellow/ Red/ Orange bag |
| | Domestic | Black bag |
| | Sharps | Sharps container |
| Forumadi | General | Not disclosed |

| Source | HCW Type | Container |
|---|---|---|
| (2023) | Hazardous-Infectious | Red bag |
| | Sharps | Yellow |
| | Cytotoxic drugs | Original package |
| | Genotoxic | Brown/White bag with genotoxic symbol |
| Khan (2023) | Infectious and Sharps | Red bin |
| | Non-infectious | Green bin |
| | Recyclable | Yellow bin |
| Pindi (2023) | General | Not disclosed |
| | Anatomical, Infectious, Pharmaceutical and Chemical | Yellow non-chlorinated bag |
| | Cytotoxic | Yellow non-chlorinated bag with cytotoxic/biohazard symbol |
| | Contaminated recyclables | Red non-chlorinated bag |
| | Sharps | White puncture, leak and tamper-proof bin |
| | Metallic implants and Glassware (including drug-contaminated, excluding cytotoxic) | Blue puncture and leak-proof bin |

***Most Common Categories***

"Infectious" and "sharp" waste, previously defined as heavily soiled waste with blood, bodily fluids and pathogens, and waste-inducing punctures or cuts respectively (Chartier et al., 2014), were consistently identified across studies. They have been segregated in hospitals from seven studies each, where Farzadkia et al. (2015), Khazaee et al. (2015), Zamparas et al. (2019), Forumadi et al. (2023), Khan et al. (2023) and Pindi et al. (2023)

commonly discussed both categories, Aung et al. (2019) only mentioned “infectious” waste, and Gaitu et al. (2019), Dawood et al. (2020) and Leonard et al. (2022) only mentioned “sharp” waste. It can be agreed that “infectious” and “sharp” HCW categories are universal terms reflecting their high-risk nature as hazardous wastes and the necessity for strict waste segregation.

The segregation of sharp waste was consistently disposed of in containers and none in bags, adhering to the WHO guidelines of puncture-proof disposal (Chartier et al., 2014). Moreover, yellow was the most common colour allocated to “sharps”, likewise to the WHO guidelines. However, in Gaitu et al. (2019) the colour brown is noted due to the disposal in cardboard boxes, while Pindi et al. (2023) note the practice of white. Unfortunately, Dawood et al. (2020) and Leonard et al. (2022) did not identify which colour the sharps container had.

Similarly, “infectious” waste has been commonly segregated as per WHO guidelines into yellow bags. However, the regulations of the university-affiliated hospitals in Forumadi et al. (2023) utilise the red colour. Likewise, Khan et al. (2023) use red for “infectious” waste but also “sharps”, while Aung et al. (2019) further segregated “highly infectious” waste into red bins from yellow bins segregating “infectious” waste. As per the WHO guidelines, infectious waste was disposed of in leak-proof and chlorine-free containers by Zamparas et al. (2019) and Pindi et al. (2023) respectively. However, these were the only studies to disclose this observation, therefore it is not known if this practice was followed by the other hospitals.

***Category Overlaps and Inconsistencies***

In relation to the literature review findings, MIC had more prominent discrepancies in HCW nomenclature (Hangulu, 2018). Dawood et al. (2020) and Leonard et al. (2022) noted broad categorisation of “hazardous” waste, while other hospitals distinguished different segregation between sub-hazardous categories like "infectious", “chemical”, "genotoxic," or

"cytotoxic" waste (Forumadi et al., 2023; Pindi et al., 2023). However, it can also be noted that the Indian hospital in Pindi et al. (2023) categorised sub-hazardous waste classifications such as “anatomical”, “infectious”, “chemical” and “pharmaceutical” into one segregation bin. This can be related that these sub-categories were in fact only being segregated into a collective hazardous waste category. Nonetheless, it can be appreciated that the Indian hospital still specifically segregated the hazardous categories of “cytotoxic” and “sharp” waste.

Inconsistencies between terminologies of the same categories have also been noted. Non-hazardous waste terms have the most variations ranging from “general”, “municipal”, “urban”, “domestic”, “non-hazardous”, “non-infectious” and “household”. Yet, it was the category with the most standardised colour to category, black, which is also in adherence to the WHO guidelines (Aung et al., 2019; Dawood et al., 2020; Farzadkia et al., 2015; Khazaee et al., 2015; Leonard et al., 2020; Zamparas et al., 2019). Though, Gaitu et al. (2019) and Khan et al. (2023) noted that hospitals used green as the segregating colour for non-hazardous waste, while Forumadi et al. (2023) and Pindi et al. (2023) did not disclose which colour was used for general waste. This interchangeability of terms could potentially lead to HCWS confusion as noted by Hangulu (2018) in the HCW nomenclature scoping review.

Conversely, the yellow container is the most used for waste disposal, encompassing a wide range of waste categories. These categories span from the broadly defined “hazardous”, to “infectious”, to more specific classifications such as “sharps,” “chemical and pharmaceutical,” “cytotoxic,” and “anatomical,” as well as even the non-hazardous category of “recyclables” (Khan et al., 2023). Moreover, Leonard et al. (2022) noted the use of different coloured containers for “hazardous” waste across HCFs. As a result, most healthcare workers did not adhere to the set segregation scheme.

These significant variations in segregation practices can create confusion, thereby

exacerbating the challenges identified in the literature review regarding the implementation of HCWS. This issue is particularly pronounced in settings with high staff turnover and multicultural hospital employees, where varying perceptions and practices of HCWM can lead to inconsistencies across hospital systems (Ali et al., 2017; Yazie et al., 2019). Consequently, the likelihood of improper HCWS increases, where hazardous waste is incorrectly disposed of with non-hazardous waste. Inevitably, such mismanagement has adverse implications for costs, public health, and the environment.

### *Recycling*

The implementation of segregation methods for recycling remains inadequate. Contrary to the findings in the literature review, which indicate that LMIC typically lack segregation resources and have poor HCWM (Chartier et al., 2014; Diaz et al., 2005), two MIC, Pakistan and India, were notable exceptions in this review, with some of their hospitals segregating recyclable waste (Khan et al., 2023; Pindi et al., 2023). Yet, the more infrastructurally advantaged study by Zamparas et al. (2019) did not note any segregation of recyclables in the Greek hospital. This deviation may reflect isolated MIC improvements or emerging efforts to enhance HCWM practices in resource-limited settings. Thus, further research is required to determine if such improvements or efforts can be adapted to other LMIC facing this challenge.

### *Regional Features*

In this review, HCWS practices did not significantly vary between the highest-income country, Greece, and the remaining MIC. In truth, the MIC of Pakistan had the most thorough HCWS categories, as highly recommended by the WHO guidelines. Where, pharmaceutical waste was further segregated from the hazardous category, with its further segregation of cytotoxic waste. Gaitu et al. (2019) and Forumadi et al. (2023) also observed segregation of “cytotoxic” waste, where the latter additionally had “genotoxic” waste segregation, yet these

hospitals did not segregate other pharmaceutical waste but assumed to be segregated with "medical" and "infectious" waste respectively.

The "three-bin system" by Chartier et al. (2014) is also a prevalent segregation method in this scoping review. "Non-hazardous" waste is separated from "sharps" and "hazardous" waste, using different terminologies as previously noted (Dawood et al., 2020; Farzadkia et al., 2015; Khazaee et al., 2015; Leonard et al., 2022).

A comparative analysis was made between the two Karaj, Iran studies by Farzadkia et al. (2015) and Khazaee et al, (2015), where it is highly likely that they both examined the same hospitals within the city. A distinguished difference in their observations lies in the categorisation of hazardous HCW. Khazaee et al. (2015) broadly categorised it as "hazardous-infectious" (p.1754), whereas Farzadkia et al. (2015) provided more insight into what was disposed of in this category, identifying chemical, pharmaceutical, clinical, infectious and pathological wastes. Another comparison between Iranian studies, this time also includes Forumadi et al. (2023), which revealed further segregation method differences. As already discussed, the Karaj studies observed the "three-bin system" for segregation. However, Forumadi et al. (2023) in Seman, Iran investigated further segregation categorisation performed by its hospitals. This difference is attributed to the different guidelines the hospitals follow across the country, which are analysed later in this review.

***Segregation Practices***

As discussed above, colour coding is a segregation practice commonly applied by all hospitals in the 10 studies reviewed. European and international guidelines recommend that HCW is segregated at the point of generation to ensure effective HCWM (Chartier et al., 2014; HCWHE, 2020; NHS, 2022). While most of the studies observed segregation at the point of generation, some distinctions in practice were identified.

For example, in Lae, the tertiary care public hospital has a two-stage segregation

process: at the point of generation, and after waste collection at the treatment facility (Gaitu et al., 2019). The point of segregation is not the only difference from Gaitu et al. (2019), but there is also variation in colour-coding methods from one stage to another. At the point of generation in the hospital, cytotoxic waste is segregated into yellow bags, sharps in brown carton boxes, and all other waste, categorised as "medical" waste, is segregated into black bags. Upon arrival at the treatment facility, the collected "medical" waste is further segregated into a "general" green bin and a "medical" yellow bin, and the "cytotoxic" waste originally disposed of in yellow bags is transferred into orange bins subjected to different treatment and disposal methods. As Chartier et al. (2014) emphasise, mixing hazardous waste with non-hazardous waste results in the entire batch being hazardous. Thus, if "medical" waste at the point of generation in this Lae hospital includes both hazardous and general waste, the following segregation point at the treatment facility is ineffective. This contamination renders the segregation in Gaitu et al. (2019) redundant, as the "general" waste would still pose a risk due to prior hazardous contamination.

Khan et al. (2023) describe a similar two-stage segregation process, however, segregation practices in these hospitals remain effective as no cross-contamination occurs. In these public hospitals, infectious waste is segregated from non-hazardous waste at the point of generation. Next, non-hazardous waste is further segregated at the treatment facility into "non-infectious" and "recyclable" categories. In contrast, Aung et al. (2019) did not specify the exact stage at which segregation occurs. Nonetheless, the study implied that segregation likely occurred at the point of generation, as suggested by the challenges identified in implementing segregation.

A common missing practice in the studies was the segregation of radioactive waste as recommended by developed HCI guidelines. This raises questions about whether radioactive waste was segregated, particularly since tertiary public hospitals often specialise in oncology

and are likely to provide radioactive therapy. For example, the public Alborz hospital in Karaj, from the Khazaee et al. (2015) study, publicises radiotherapy services on their website (Alborz Hospital, n.d.). While Zamparas et al. (2019) calculated the generation rate of the oncology department of the Rio University Hospital in Greece.

Overall, the 10 studies revealed varying levels of segregation practices among tertiary public hospitals. High levels of segregation practices were observed by Khazaee et al. (2015), Zamparas et al. (2019) and Pindi et al. (2023), while moderate levels were reported by Farzadkia et al. (2015). Unfortunately, poor segregation practices were the most frequently recorded, by Aung et al. (2019), Gaitu et al. (2019), Dawood et al. (2020), Leonard et al. (2022), Forumadi et al. (2023), and Khan et al. (2023).

### *Challenges in Hospital Segregation Practices*

The implementation of hospital waste segregation has been challenged by several factors across the studies. These challenges were similar to those identified in the literature review, revealing training, infrastructural, financial and compliance barriers to effective HCWS.

Training Barriers. Orientation programs and frequent training are crucial for ensuring the continuity of HCWS practice, especially in resource-limited settings. Khazaee et al. (2015) found that all hospitals' healthcare workers were trained in HCW collection, segregation and transport. However, the other Karaj study by Farzadkia et al. (2015) and Pindi et al. (2023) still noted that even with higher segregation practices, frequent staff turnover and lack of new employee training hindered consistent practice. In fact, Pindi et al. (2023) observed a consistent drop in segregation rates in the same months new recruits were employed over the two years studied. Additionally, Gaitu et al. (2019), Leonard et al. (2022) and Forumadi et al. (2023) reported that many hospital employees lack adequate or frequent training, further compromising segregation quality. Conversely, Aung et al. (2019) and Khan

et al. (2023) emphasised the lack of training programs for HCWM awareness. As discussed in the literature, training limitations directly affect staff compliance with proper HCWS and increase health and safety risks, especially with high employee turnover rates or when new employees join. Thus, continuous and reinforced training programs are necessary to ensure long-term behavioural change.

Infrastructural Barriers. The importance of hospital management as a stakeholder of HCWS has already been reviewed. Its organisational administration steers to either poor or effective HCWM. Unfortunately, Gaitu et al. (2019) and Leonard et al. (2022), reported insufficient infrastructure, including colour-coded bins, and waste bin liners and lids respectively. However, Leonard et al. (2022) noted the practice of bin labelling when coloured bags were stocked out. This practice is a good compensation suggestion for this infrastructural limitation, as HCWM supplies are commonly stocked out due to the increasing rates of HCW generation, especially in resource-limited settings (Chartier et al., 2014).
In contrast, Gaitu et al. (2019), Dawood et al. (2020) and Forumadi et al. (2023) observed poor or absent labelling of containers, which the WHO manual finds critical for clear segregation and following HCWM (Chartier et al., 2014).

**Financial Deficiencies.** LMIC face economic challenges in HCWM practices (Diaz et al. 2005). This is reflected in Aung et al. (2019), and Khan et al. (2023) who highlighted that inadequate monitoring, insufficient infrastructure, and budgetary constraints, hindered segregation compliance in Myanmar and Pakistan. Financial constraints in implementing HCWS were noted in the literature review. However, if HCWM budgets are not prioritised, essential implementation aspects such as training programs, infrastructure improvements, and policy enforcement remain underfunded. Leading to the inevitable adverse consequences for public health, environmental safety, and HCWM efficiency.

**Compliance Deficiencies.** Segregation practice compliance was observed in Khazaee

et al. (2015) and Zamparas et al. (2019), though these studies either lacked reporting challenges or the involved hospitals have established efficient HCWS frameworks. Despite its high compliance, Zamparas et al. (2019) still recommended infrastructural improvements in staff awareness, and increasing green suppliers. However, the moderate compliance in Farzadkia et al. (2015), suggests that Khazaee et al. (2015) might have lacked reporting challenges. An interesting challenge found by Farzadkia et al. (2015) was that if healthcare providers had critically ill patients, segregation practices decreased due to their shift in focus and work-task importance.

HCWS compliance was also deficient in Leonard et al. (2022) and Khan et al. (2023) due to poor enforcement of existing policies. As the studies have identified, this leads to inconsistency and confusion among healthcare workers, further exacerbating segregation inefficiencies. A case in point, Farzadkia et al. (2015) and Dawood et al. (2020) observed mismanagement of waste, such as mixing hazardous waste with general waste. Additionally, lack of guidelines, inadequate practices, and deficiencies in knowledge of and adherence to regulations were notable barriers to segregation compliance. However, the influence of guidelines is examined in the next section.

**Guidelines for Hospital Waste Segregation**

In the literature review, developed HCI guidelines and regulations were explored. The next objective for this scoping review…

*"R2: What guidelines are in place for appropriate hospital waste segregation?"*

…was to map the guidelines in place for implementing HCWS in tertiary public hospitals. The studies from this review assisted this objective and provided insight into different international rules and policies on HCWM, presented in Table 13 below.

**Table 13**

*Hospital Guidelines and Compliance Available for Healthcare Waste Segregation*

| Source | Guidelines | Compliance |
|---|---|---|
| Farzadkia (2015) | Karaj Department of Health guidelines | Almost |
| Khazaee (2015) | No guidelines reported | Unavailable |
| Aung (2019) | Hospital management manual 2011 | Yes |
| | No national guidelines | Unavailable |
| Gaitu (2019) | No national guidelines | Unavailable |
| | Own hospital system | Poor |
| Zamparas (2019) | European directives-based Greek legislation | Yes |
| Dawood (2020) | Own hospital policies | Poor |
| | Baghdad national recommendations | Not followed |
| Leonard (2022) | Zambian MOH HCWM guidelines and policies | Not always |
| Forumadi (2023) | Infrastructure, Industry, and Environment Commission of Iran HCWM criteria and procedures 2007 | No |
| | Semnan Medical Waste Control Regulation | Not all hospitals |
| Khan (2023) | HCWM Pakistan rules 2005 | No |
| Pindi (2023) | Indian Biomedical Waste Management Rules 2016 and 2018 | Yes |

The results of the public hospital segregation categories indicate that standard guidelines, such as those recommended by the WHO, were not consistently implemented. Nonetheless, most of the studies reviewed found that national or regional guidelines were

available to hospitals. Two exceptions were Papua New Guinea and Myanmar where national guidelines were lacking (Aung et al., 2019; Gaitu et al., 2019). Whereas Khazaee et al. (2015) did not address the presence of guidelines in their study. Nevertheless, the absence of data in Khazaee et al. (2015) can again be supplemented by the study conducted in the same city and year by Farzadkia et al. (2015), which identified the availability of regional guidelines in Karaj. Furthermore, the hospitals in Karaj were found to comply with these regional guidelines, where segregation categories were consistent, except for the disposal of chemical and pharmaceutical waste which was guided to be segregated in brown containers rather than yellow. It can be observed that the Karaj national HCWS guidelines match the WHO segregation colour-scheme (Chartier et al., 2014). In contrast, not all the HCFs in Zambia complied with national guidelines (Leonard et al., 2022).

Although national and regional guidelines were available, the hospitals in Dawood et al. (2020) and Forumadi et al. (2023) opted to implement their own segregation policies. Conversely, the hospitals in Aung et al. (2019) and Gaitu et al. (2019) compensated for the absence of national guidelines by developing their own hospital waste segregation systems. Myanmar hospitals did follow the standard segregation scheme as suggested by Chartier et al. (2014) when nationalities do not have legislations set (Aung et al. 2019). However, Gaitu et al. (2019) did not. On the contrary, irrespective of having national Pakistani rules, Khan et al. (2023) noted that not only healthcare workers but even HCWM supervisors were unaware of them.

Even though these four studies demonstrated poor to no compliance with guidelines or policies, the availability of guidelines significantly drives good HCWM practice, as seen in the Ethiopian meta-analysis by Yibeltal and Kelemu, 2024. Thus, hospitals adhering to HCWM guidelines (Aung et al., 2019; Farzadkia et al., 2015; Pindi et al., 2023; Zamparas et al., 2019) were more likely to achieve higher HCWS practices, as seen in Hyderabad, India

(Pindi et al., 2023) and Karaj, Iran, (Farzadkia et al., 2015; Khazaee et al., 2015), compared to those without access to or adherence to segregation protocols.

**Impact of Segregation Practices**

The literature review highlighted the implications and importance of HCWM, along with the several benefits and detriments of HCWS. However, another objective to be addressed in this scoping review…

*"R3: To what extent and with what effects does the proper or improper segregation of hospital waste impact the environment?"*

…was explored to the true impact of HCWS. Notably, most studies emphasised the adverse consequences of inadequate HCWS, while some also acknowledged the benefits of applying segregation.

***Detriments***

The criticised practice of mixing hazardous waste with non-hazardous waste was noted more than wished in this review. Farzadkia et al. (2015) acknowledged that this malpractice led to useless segregation practices. Although segregation is in place, the two-stage segregation practice in Gaitu et al. (2019) was discussed to not be a proper HCWS practice in view of the above-criticised practice and the increased risk for employee infection, especially to direct waste handlers.

Moreover, Dawood et al. (2020) observed that segregating all hazardous waste into a yellow category is a poor HCWS practice since it is all incinerated with disregard to the classification that prevents burning of plastic which would release toxic air polluting emissions.

In relation to financial impacts, Zamparas et al. (2019) and Forumadi et al. (2023) highlighted that the increasing production of hazardous waste, paired with inefficient segregation, results in larger volumes of waste requiring treatment, significantly increasing

HCWM expenditure. Moreover, Forumadi et al. (2023) added that a lack of segregation schemes would result in all HCW being categorised as 100% hazardous waste, accumulating into the known detriments on the environment, affecting climate change.

***Benefits***

The importance of proper segregation is crucial to HCWM as emphasised across the studies reviewed. Aung et al. (2019) analysed segregation as the most important criterion for HCWM. This is aligned with what Chartier et al. (2014) reported, that any problems at the stage of segregation can affect other HCWM stages. This projects the importance of segregation to enable effective HCWM, ultimately caring for the environment and improving climate change.

Khazaee et al. (2015) recognised that segregation prevents the mixing of various HCW types by enabling healthcare workers and the public to distinguish between them. Furthermore, they observed that HCWS at the point of generation facilitates proper disposal and treatment, mitigating pollution and infection risks in nearby environments.

An interesting improvement to segregation practices was suggested by Gaitu et al. (2019) to expand the current segregation colour-scheme at the Angau Memorial General Hospital in Lae, likewise to the WHO recommendations (Chartier et al., 2014). They, along with Zamparas et al. (2019) and Forumadi et al. (2023), emphasised that systematic segregation methods not only accelerate the segregation process but also simplify further segregation at treatment facilities and reduce waste expenditure. Additionally, it reduces the storage time of HCW, minimising exposure to the environment, humans and animals, until treatment and disposal. This significantly lowers the risk of infectious disease transmission.

The different categorisation of HCW allows for specific waste treatment methods tailored to waste categories, thus reducing the need for special or costly treatment and disposal methods (Aung et al., 2019; Zamparas et al., 2019). Voudrias (2018) supports this

view, as it facilitates a circular economy, for example, the recycling of plastic (Khan et al., 2023) and the reuse of equipment. This benefits hospital management by lowering procurement demands, reducing manufacturing rates, and cutting waste treatment costs. However, Voudrias (2018) also acknowledged that some traditional waste streams, such as the disposal of heavily blood-soiled items or body tissue, cannot be avoided. Hence, for such HCW, special treatment, such as autoclaving, can be applied before disposal to eliminate its infectious properties. This emphasises the importance of thorough segregation to facilitate efficient treatment and minimise the volume of waste requiring special methods (Aung et al., 2019).

Despite these benefits, treatment methods, such as the incineration of all hazardous waste, are not always environmentally sustainable. As noted by Dawood et al. (2020), incineration is not a solution for HCW, but simply transforms it into air and soil pollution instead. Thus, Dawood et al. (2020) highlight the same point as Aung et al. (2019) and Zamparas et al. (2019) that effective segregation practices are critical for separating the larger volumes of non-hazardous waste from the hazardous. Thus, reducing unnecessary hazardous waste volumes requiring energy-intensive and costly special treatment.

Another benefit observed by Pindi et al. (2023), was the decrease in needle-stick injuries, from four cases in 2017 to one case in 2020 when segregation compliance started to increase, to no recorded injuries in 2021.

**Research Methods Employed in Hospital Waste Segregation Studies**

The last objective of this scoping review…

*"R4: Which research methods are commonly employed in the study of hospital waste segregation?"*

…was to evaluate the research methods employed across the reviewed studies investigating HCWS practices. A pragmatic research philosophy was employed by all the

studies, driven by a shared concern for environmental and public health, and a desire to address HCWM practice. Moreover, methodological approaches varied from quantitative, to qualitative to mixed-method studies. Nonetheless, it is important to note that while the studies investigated HCWS practices, they also explored other aspects of HCWM, as per their objectives outlined in Table 11. Thus, explain why they required mixed methods to study HCW from generation to disposal.

However, to adhere to the objective of this scoping review, only the data collection and analysis methods investigating hospital waste segregation were reviewed and summarised in Table 14 below. Nevertheless, Pindi et al. (2023) was the only study to exclusively focus on HCWS practices. The table additionally includes the study designs used and the total number of hospitals with the average number of beds included in each study, except for the study by Leonard et al. (2022) which included 50 HCFs but did not discuss the availability of beds.

**Table 14**

*Data Collection Tools to Research HCWS*

| Source | Number of hospitals (N) and bed-average (n) | Study Type | Data Collection | Data Analysis |
|---|---|---|---|---|
| Farzadkia (2015) | N = 8<br>n = 217.5 | Pilot cross-sectional study | Direct field-observation Yes/No questionnaire | Descriptive statistics<br>Critical analysis |
| Khazaee (2015) | N = 11<br>n = 175 | Cross-sectional survey | Quantitative questionnaire | Descriptive statistics |
| Aung (2019) | N = 8<br>n = 628 | Comparative cross-sectional study | Structured questionnaire<br>Indirect field-observation checklist<br>Interviews | Analytic Hierarchy Process (AHP) and Analytic Network Process (ANP) |
| Gaitu (2019) | N = 1<br>n = 128 | Cross-sectional case study | Quantitative questionnaire<br>Direct field-observation descriptive checklist | Descriptive statistics<br>Thematic analysis |
| Zamparas (2019) | N = 1<br>n = 800 | Cross-sectional case study | Indirect field-observation value scale-factor questionnaire | AHP |
| Dawood (2020) | N = 2<br>n = 1000 | Observational case study | Direct field-observation descriptive checklist | Descriptive analysis |
| Leonard | N = 50 HCFs | Mixed-methods cross- | Multiple-choice questionnaire | Descriptive statistics |

| Source | Number of hospitals (N) and bed-average (n) | Study Type | Data Collection | Data Analysis |
|---|---|---|---|---|
| (2022) | | sectional study | Interviews | Thematic analysis |
| | | | Direct field-observation | |
| | | | Availability/Functionality checklist | |
| Forumadi (2023) | N = 6<br>n = 104 | Cross-sectional survey | Direct field-observation compliance/non-compliance questionnaire | Statistical analysis |
| | | | Interviews | |
| Khan (2023) | N = 4<br>n = 131 | Comparative cross-sectional study | Mixed-method questionnaire | Descriptive statistics |
| | | | Direct field-observations | |
| | | | Interviews | |
| Pindi (2023) | N = 1<br>n = 200 | Longitudinal case study | Indirect field-observation Yes/No checklist | Statistical analysis |

### *Study Designs*

The reviewed studies collectively employed diverse research designs and methods, primarily using a cross-sectional framework. This framework supports the analysis of hospital waste segregation practices at a specific point in time. However, Pindi et al. (2023) was the only study to employ a longitudinal framework, using an observational study design. They were able to note trends and variations in segregation compliance over two years.

Additionally, case studies were the most frequently used designs, with Gaitu et al. (2019), Zamparas et al. (2019) and Pindi et al. (2023) each investigating one public hospital providing tertiary care, while Dawood et al. (2020) compared two tertiary care public hospitals. Surveys were also a common method of investigating segregation practices in Iran, where Khazaee et al. (2015) used a quantitative approach, while Forumadi et al. (2023) used a mixed-method approach. However, the other study from Karaj applied a quantitative pilot study design to test a national tool to analyse hospital waste management status (Farzadkia et al., 2015). Furthermore, Aung et al. (2019) and Khan et al. (2023) both employed a comparative study design to compare eight and four hospitals respectively.

### *Data Collection Tools*

Data Collection methods varied significantly in approaches, but ultimately all methods were aimed to investigate hospital waste segregation practices. Hence, due to this objective, the Hawthorne effect was unavoidable. Like how the systematic review by Purssell et al. (2020) found that hand-hygiene adherence of healthcare workers increased during observations of their practices due to this effect. Similarly, the participants from these 10 studies could have modified their waste segregation practice behaviours or responses, during observations or answering questions. This effect, where their awareness of having their practices assessed, could have led to the performance and adherence to best segregation practices while the studies occurred. However, Purssell et al. (2020) add that methodological

qualities vary this effect as seen in the discussion of these results.

**Field-Observation.** The most common method to investigate hospital waste segregation was direct field observation. Nevertheless, these observations varied from using quantitative structured ‘yes or no’ surveys (Farzadkia et al., 2015; Pindi et al., 2023), to an ‘availability and/or functionality’ (Leonard et al., 2020) or a ‘compliance or non-compliance’ (Forumadi et al., 2023) checklist. The pilot study by Farzadkia et al. (2015) concluded that the national tool, the questionnaire prepared by the Iranian MOH and Medical Education, is effective in assessing the status of HCWM in hospitals and facilitates comparative analyses. However, limitations can still arise from quantitatively structured field-observation surveys. Like with any quantitative questionnaire, doubt and inconsistencies in questions or respondents can lead to subjective bias, making the analysis of HCWS results inconsistent (Choi & Pak, 2005). Conversely, Gaitu et al. (2019), Dawood et al. (2020) and Khan et al. (2023) qualitatively surveyed field-visits to describe segregation practices, where the former followed a WHO assessment tool

On the other hand, indirect field observations were also implemented by Pindi et al. (2023), where infection control nurses and supervisors, and nursing managers observed patient care areas daily, also using a ‘yes or no’ checklist, based on the previously identified Indian HCWM guidelines with 2018 updates. Additionally, from each of the eight hospitals included, Aung et al. (2019) employed a manager with medical expertise and familiar with HCWM, to indirectly assess HCWS practices using an evaluation framework. Similarly, Zamparas et al. (2019) administered a questionnaire to healthcare management experts and specialists to observe and assess the scale factors, protocol performance, indicators of fulfilling environmental objectives, and evaluation of hospital segregation.

In mixed-method research, Anguera et al. (2017) found that observational data collection tools enable the objective study of natural and spontaneous behaviour, supporting

rigorous and flexible studies. In fact, Gaitu et al. (2019) acknowledged the cruciality of their direct observations in documenting real segregation practices. However, as Leonard et al. (2022) acknowledged, indirect observations or reliance on 'availability and/or functionality' spot checks may lack validity in reflecting actual individual segregation behaviours and practices, potentially introducing bias. Instead, Leonard et al. (2022) relied on self-reports from their questionnaire. In addition, the Hawthorne effect in Leonard et al. (2022) might have been reduced by observing fields with a spot check, but this was still present in their other data collection methods.

On the contrary, Zamparas et al. (2019) found this method to be particularly beneficial in environments where multiple factors influence waste management decisions, enabling hospitals to align their operations with best practices and protocol requirements. This might be possible due to the AHP methodology applied by Zamparas et al. (2019). This is suitable for single-hospital studies like theirs, where expert-determined pairwise comparisons provide a structured approach to evaluate the multiple factors influencing HCWS. However, it is feasibly challenging to apply to larger sample populations, such as Leonard et al. (2022) with 50 HCFs, as it can lead to data collection inconsistencies and poor observational focus (Jalao et al., 2014). Proving this, Aung et al. (2019) similarly implemented a multi-criteria decision-analysis (MCDA) framework, including the ANP to the AHP, which posed challenges across eight hospitals in achieving consensus and consistency among respondents. Thus, to address this limitation Aung et al. (2019) recommend integrating direct field-observations with their evaluation framework to enhance the objectivity and reliability of their approach.

Despite focusing on only one hospital with fewer beds than Zamparas et al. (2019) and using indirect observations, Pindi et al. (2023) mitigated their risks for limitations and bias. They achieved this by monitoring two years of compliance rates using photographic

evidence taken by the appointed data collectors, needle-stick injury reports and daily waste weighing validation measures. Thus, while AHP provides a strong framework for evaluating multiple factors influencing HCWS, its applicability depends on the objective and design of the study and considerations for scale and methodological integrations.

**Questionnaires.** The next most popular data collection tool was a questionnaire. This method also differed between the five studies that distributed it. Adding to the AHP approach, Aung et al. (2019) developed a structured questionnaire based on the evaluation framework they created in collaboration with the medical experts who provided the indirect observations. Thus, the first part of their study focused on the development process of this evaluation framework, implementing MCDA. Additionally, the criteria identified were based on the WHO guidelines on safe HCWM by Chartier et al. (2014) and related to the Myanmar context by triangulation of literature review and the opinions of the medical experts. Aung et al. (2019) found that the MCDA approach has been used in several studies to assist in selecting appropriate waste treatment methods and management companies. Thus, this mixed-method approach enabled the development of a partially objective and partially subjective questionnaire for evaluating HCWM, including segregation, across the hospitals from Myanmar. The objective aspect of the questionnaire arose from the formulaic ranking of HCWM criteria and sub-criteria, providing a standardised comparison for the framework. On the other hand, the subjective aspect arose from the reliance on personal expertise and judgment to assign weights to these criteria.

On the other hand, Khazaee et al. (2015) and Gaitu et al. (2019) distributed a quantitatively structured questionnaire. Where, the former used WHO recommendations from the first edition of the guideline repeatedly referred to in this review, to develop 44 questions and distributed the tool to hospital workers and environmental healthcare managers. While Gaitu et al. (2019) developed 113 ‘yes or no’ and close-ended questions and administered

them to workers from all the wards of the public hospital. The questionnaire assessed knowledge, attitudes, practices, awareness, and factors influencing HCWM practices. Similarly, Leonard et al. (2022) investigated the knowledge, attitudes and practices of healthcare workers through 20 multiple-choice questions. These structured questionnaires allowed for standardised data collection, however, the reliance on self-reported data introduced potential bias in responses, as participants might overstate their adherence to proper practices (Bowling, 2005).

However, Khan et al. (2023) used "both structured and unstructured questions" (p.47) to survey waste and hospital management teams across the four hospitals. Vitale et al. (2008) diagnosed an organisation using a mixed-method questionnaire, which was found to have a significant difference in the perceptions of responses. Hence, mixed-method questionnaires would not just be able to provide standardised HCWS results but would also be able to provide a comprehensive understanding of hospital waste segregation behaviours and challenges. Nonetheless, there is still the limitation of relying on the willingness of participants to provide in-depth answers to unstructured questions, hence lower response rates and shorter comments were attained by Vitale et al. (2008). This would make data analysis more complex and may introduce reliability bias if responses are insufficiently representative of the broader hospital segregation practices. Furthermore, Khan et al. (2023) might have increased their Hawthorne effect, as they supervised their questionnaire sessions.

Additionally, the reliance on managers or team leaders to answer questionnaires, like Aung et al. (2019) and Khan et al. (2023), might implement representational bias on the HCWS practices of the whole hospital. While, the inclusion of various levels and roles of hospital workers directly involved with HCWS, like in Khazaee et al. (2015), Gaitu et al. (2019) and Leonard et al. (2022), reduces this bias.

**Interviews.** The last and least data collection method was the exploration of HCWS

practices through qualitative interviews. Manzi et al. (2016) found that qualitative data collection tools were equally as effective as those quantitative in studying waste management behaviours, providing insights into understanding waste management behaviours, factors influencing workers and their opinions about HCWM. In these reviewed studies, qualitative findings from interviews were complemented with quantitative data to explore deeper insights into the practices and challenges of HCWS in hospitals. Once again, objectives and participant selection varied between studies.

Aung et al. (2019) interviewed the same managerial medical experts who conducted the field observation and answered the survey questionnaire. Using the same participants enabled deeper insights and better understanding about their decision-making processes in answers and findings from the previous data collection tools on HCWS practices in their hospital. However, their sole reliance on these participants did not mitigate representational bias. Conversely, this approach provided insights into policy and multi-criteria decision-making.

Similarly, Leonard et al. (2022) focused on administrative perspectives and interviewed facility managers and environmental health specialists. However, they included this method not just to supplement quantitative findings from healthcare workers and field observations, but also to investigate the attitudes to HCWM. Similarly, Forumadi et al. (2023) interviewed hospital directors and waste management employees, along with other unidentified personnel to specify the current state of HCWM, including segregation. While Khan et al. (2023) also unidentified the managers interviewed from the hospitals. Therefore, a mixed-method approach enables a more comprehensive understanding of not only what HCWS practices are in place but also the underlying reasons for their occurrence.

***Data Analysis Methods***

The data analysis methods employed by the 10 studies were based on the differing

nature of their data collection and objectives. These encompassed both quantitative and qualitative approaches, with some studies utilising mixed methods to provide a more comprehensive analysis.

**Quantitative Analysis.** Studies that collected quantitative data primarily used statistical methods for analysis. For instance, Farzadkia et al. (2015) and Pindi et al. (2023) employed descriptive statistical methods to analyse their structured field observations. Similarly, Khazaee et al. (2015) used this method to analyse their survey questionnaires. Their analysis was effective for summarising HCWS practices and hospital issues, but they had limited capacity to explain the reasons behind observed segregation practices and complexities.

To mitigate this limitation, Forumadi et al. (2023) and Khan et al. (2023) also attained qualitative HCWS data as discussed above, which was also analysed statistically. While the mixed methods approach of data collection allowed for a broader understanding of HCWS practices and insights behind them, the quantitative analysis approach provided a limited understanding of compliance or non-compliance to HCWS. Conversely, Pindi et al. (2023) moderated this limitation with longitudinal data and validation methods, which enabled better analysis of variations in data over time (Montgomery, 2005), thus variation in HCWS practices, providing a more detailed understanding of segregation compliance rates and trends.

This method can answer the five basic questions from “who” to “why”, but its primary strength is its ability to clearly summarise general trends or compliance rates (Vetter, 2017) of hospital segregation practices. However, this analysis risks overlooking crucial insights into the reasons behind behavioural persistence, being unable to form conclusions (Harris, 2016).

On the other hand, Zamparas et al. (2019) were more able to analyse the complexity

of multiple factors influencing hospital waste segregation practices, using the AHP to analyse data. This advanced quantitative analysis used pairwise comparison matrices in its framework to systematically weigh and prioritise collected data in a hierarchical ranking, enabling a structured evaluation of HCWS. Then, from indirect field-observations, two pairs of HCWS factors with indicators and criteria with sub-criteria were compared using an intensive scale of one to nine. While the case study was effective in analysing multiple-factor issues, this method still relies on numerical values and calculated results attained from qualitative judgements for weight assignment, which is a common limitation of AHP (Zamparas et al., 2019).

**Qualitative Analysis.** The only study solely applying qualitative analysis was that of Dawood et al. (2020). Where a descriptive analysis of their direct observations of hospital segregation practices from the two hospitals was given. Additionally, they verified their observed results through direct communication with the environmental managers of the hospitals. However, a systematic review by Mwita (2022) found that qualitative data analysis is often more prone to researcher bias due to its subjective nature, where the subjectivity of the researcher, the complexity of data and the time-intensive process, can limit its feasibility and efficiency. Moreover, it is difficult to generalise and replicate such methods, especially in larger scales of studies, such as Leonard et al (2022) who also directly observed HCWS. Nevertheless, the systematic review acknowledged its ability to understand complex realities and actions, such as the multiple factors affecting hospital waste segregation, and is a strength over quantitative analysis.

**Mixed Methods Analysis.** The remaining three studies employed a mixed-method approach and applied both quantitative and qualitative data analyses. Due to their mixed methods of data collection and their respective objectives, Gaitu et al. (2019) and Leonard et al. (2022) found descriptive statistics and thematic analysis appropriate to analyse their

quantitative and qualitative data. This combination was able to decrease limitations from single method approaches in analysing HCWS data, allowing comprehensiveness and complexity in their conclusions. While statistical analysis was already discussed, thematic analysis also has its own strengths and limitations. Clarke and Braun (2017) find this data analysis to provide flexibility in the identification, analyses, and interpretation of results. However, this flexibility in theme identification from open-ended responses may also introduce inconsistencies in findings due to its subjectivity.

However, Aung et al. (2019) assessed the status of HCWS using their developed MCDA framework. The inclusion of AHP and ANP to analyse the data collected through their mixed methods offered balanced perspectives on HCWS practices (Aung et al., 2019). However, Aung et al. (2019) still acknowledged that the consistency in analysing results across the hospitals required significant effort.

Overall, applying both approaches in data analysis provides a more holistic view of HCWS practices. However, the limitations from the individual approaches are still to be considered in this analysis approach.

This chapter answered the research question by individually answering the supplementary questions. In the following chapter conclusions to this dissertation will be given, including a summary of these results, with recommendations for future research using these findings.

# Chapter 5 Conclusions and Recommendations

This final chapter concludes this dissertation by summarising the findings of this dissertation, including a summarised answer to the research question. Moreover, limitations of this scoping review have also been given. Finally, recommendations for future research were given.

## Dissertation Summary

### Introduction and Literature Review

The first aim of this dissertation was to be the first scoping review to map hospital waste segregation practices. This was attained through the research question of…

*"What are the current healthcare waste segregation practices in public hospital settings?".*

…based on the PCC framework as stipulated by the JBI. After a literature review on HCWS and brief insights into other HCWM practices. The pillar of international standardisation of healthcare, the WHO, was found to have developed a guideline on the safe management of HCW from healthcare-related activities. This guideline has been updated and a second edition was published in 2014 (Charter et al., 2014). Thus, insights into and suggestions on practising HCWS were reviewed, where different implications and challenges were noted. However, implementations of segregation practices were noted to be inconsistent across the world (Chartier et al., 2014).

### Methodology

As a major source of HCW generation, public hospitals were the context of this review to investigate their segregation criteria for different types of HCW populations. Hence, in continuation of the use of the JBI framework for scoping reviews, the methodology was presented. This included the rigorous inclusion and exclusion criteria, following the PCC framework, to search through three databases deemed suitable for this review. Sources,

including grey literature, were searched for using different search tools, published within the last decade, to attain results specifically on public hospitals providing tertiary care and discussed segregation practices about different types of HCW. This search was systematically performed and presented following the PRISMA-ScR checklist. As a result, 10 sources were attained and included in this scoping review.

**Findings and Discussions**

These 10 sources ranged from cross-sectional surveys to mixed-method studies, up to a longitudinal observational study. Additionally, they were predominantly conducted in MIC, due to the discovery that HIC had resolved most of their HCWM issues over two decades ago (Ali et al., 2017; Ashtari et al., 2020).

An analysis in relation to the supplementary questions was done and results with discussions were presented. Ultimately, managing to attain an answer to the main research question, where a summary of findings follows.

**Summary Answer to the Research Question**

This scoping review found significant variability in HCWS practices among public hospital settings. While some hospitals adhered to the WHO guidelines manual of safe HCWM by Chartier et al. (2014), from simple “three-bin system” segregation practices to more advanced recycling practices, others faced challenges due to inadequate training, limited infrastructure, and inconsistent guidelines.

The best practices in hospital waste segregation involve systematic approaches to ensure compliance, optimise processes, and align with international standards to safeguard public and environmental health. These practices represent significant advancements in HCWM, but their effectiveness relies upon consistent implementation and adaptation to context, such as in resource-limited settings of LMIC.

The importance of implementing a colour-coding system in HCWS was highlighted.

For instance, yellow bins were commonly used for hazardous waste, while black bins were for non-hazardous waste, aligning with the above WHO manual. This system simplifies waste segregation for hospital workers, reduces cross-contamination and improves waste stream management efficiency. In turn, several benefits are attained while reducing detriments from the best practices of HCWS.

However, compliance with colour coding was inconsistent across studies, emphasising the need for standardisation of guidelines, and universally implementing and enhancing rigorous training. This also highlighted the need for investing in infrastructure and enforcing policy to improve HCWS and attain its true beneficial impacts.

## Limitations

The limitations of a scoping review are not generally evaluated (Peters et al., 2020). However, ultimately being a postgraduate dissertation, I have chosen to analyse and present the limitations of this dissertation as a whole.

### Study Design

As a scoping review, the exclusive reliance on secondary data was unavoidable. Hence, the mapping of findings was dependent on the methodologies and reporting accuracy of the reviewed studies. Additionally, most of the studies focused on multiple or all the management practices of HCW, except for one study (Pindi et al., 2023). Thus, insights into HCWS practices were not always comprehensively investigated. Moreover, this required a more rigorous and time-consuming analysis of studies on HCWM practices other than segregation.

### Language Bias

The inclusion criteria restricted the review to sources published in English and excluded other languages. Thus, this limits the findings in this review as possibly relevant data, not published in English, might have been missed (Neimann Rasmussen &

Montgomery, 2018).

**Temporal Bias**

The exclusion of sources published prior to the year 2015 would have limited the findings of hospital waste segregation. However, this scoping review aimed to look for the "current practices" and compare them to the most recent international WHO guidelines on HCWS.

**Contextual Limitations**

The review focused specifically on public hospitals providing tertiary care, excluding private hospitals or other HCFs. In fact, many sources were excluded in the search for sources, due to focusing only on other HCFs types or if included tertiary care public hospitals had segregation results integrated with excluded HCFs. This limits the generalisability of findings across the broad HCI, where waste segregation practices differ significantly. However, implications for practice were not in the aim of this scoping review. Hence, methodological quality assessments and synthesis were not required (Peter et al., 2024).

**Researcher Bias and Time Constraints**

The last and major limitation of this dissertation is the availability of only one researcher, myself, to conduct a scoping review as this dissertation is an examinable requirement towards a post-graduate master's degree. Typically, two or more researchers are required to select studies and interpret data (Peters et al., 2024). Hence, this review was at high risk of researcher bias. Firstly, the time restrictions along with being the only researcher, had to limit public hospital contexts to those providing tertiary care. Following, this bias was due to the subjectivity of my preferences or interpretations in including or excluding studies without a second or third reviewer of studies. This also limited data interpretation, where findings might have been aligned with my expectations, rather than objective evidence.

However, this bias was mitigated by providing a transparent, rigorous and systematic

methodology through the PRISMA-ScR checklist and the implementation of the JBI scoping review framework to present this scoping review.

## Recommendations for Future Research

As a last aim for this dissertation to be a precursor to HCW studies in Malta and HCWS systematic reviews, recommendations are given for future research on the waste segregation practices of tertiary care-providing public hospitals. These recommendations are based on the methodological findings of the reviewed studies as the objective of investigating what research methods were applied in hospital HCWS studies was reached.

### Standardisation of Healthcare Waste Segregation Guidelines

A critical gap identified in this review is the inconsistency in the application of HCWS guidelines across different regions. Future research could focus on the development and evaluation of standardised guidelines for HCWS that can be adopted universally, with adaptability to different contexts. This would assist in attaining continuously effective HCWS practices, without being limited to segregation knowledge and awareness. Furthermore, this could mitigate improper HCWS practices in multicultural settings, where different hospital guidelines can confuse hospital workers when they are employed in a new hospital using different policies.

Additionally, no radioactive waste segregation was identified in the studies, even though this is included in the WHO guideline (Chartier et al., 2014). Hence, I further recommend the standardisation of guidelines to ensure that the hazardous waste of radioactivity is safely disposed of.

### Longitudinal Studies

All the studies in this review, except for Pindi et al. (2023), used a cross-sectional design. This framework provided a glimpse of HCWS at a given time. Hence, future research could focus on longitudinal designs to track HCWS over time, to track the evolution of

segregation with training, infrastructural improvement and policy changes. Such as Pindi et al. (2023) were able to assess two years of HCWS compliance.

**Mixed-Method Approach**

Although many studies used mixed methods approaches to investigate HCWS, more research is needed to provide a comprehensive understanding of this practice. Since, as already mentioned, most studies investigated all HCWM practices combined. However, from the evaluation of the data collection tools and analysis methods, studies using a mixed-method approach, like Aung et al. (2019) and Leonard et al. (2022), had an advantage in understanding not only what HCWS practices exist but also why behaviours and barriers occur. Furthermore, Newenhouse and Schmit (2000) highlighted that the combination of quantitative and qualitative methods in waste research can develop effective waste management plans, reduce research bias, and increase waste management awareness in the community. As per Aung et al. (2019) and Zamparas et al. (2019), segregation practices are influenced by multiple factors. Thus, future research could also integrate the more advanced analytical tools of AHP and ANP, to ensure greater objectivity and consistency in complex analysis.

**Exploring Challenges to Effective Segregation**

Many studies, such as Forumadi et al. (2023) and Khan et al. (2023), highlighted that lack of training, poor infrastructure, and insufficient resources were significant barriers to effective HCWS. Future studies should investigate further into these limitations, to identify specific challenges in various hospital contexts and provide targeted solutions, especially in resource-limited settings.

**Impact of Segregation on Environmental and Occupational Health**

Although the third objective of this review, regarding the true impact of HCWS on the environment, was answered. Direct environmental effects of HCWS, such as carbon

footprints, were not identified. Thus, future studies should explore the long-term impact of proper segregation on environmental sustainability. Occupational health could also be explored such as how Pindi et al. (2023) noticed a substantial decrease in needle-stick injury reports in relation to better segregation compliance.

### Development of Training

Since several studies, including Farzadkia et al. (2015) and Gaitu et al. (2019), identified gaps in staff knowledge and training on HCWS, further research is needed on the effectiveness and rigour of training programs. Studies should investigate training methodologies and their effectiveness in enhancing staff knowledge and compliance with HCWS protocols. Additionally, future research could compare different training approaches and assess their impact across different hospitals.

### Hospital Waste Segregation Monitoring

Monitoring of segregation compliance was poor in certain hospitals, such as the observed low enforcement in Khan et al. (2023) or even no national guidelines in Gaitu et al. (2019). Thus, future research could explore the implementation of increasing compliance monitoring

## Concluding remarks

This review highlights not only the diversity of approaches in studying HCWS in public hospitals but also the cruciality of standardisation of guidelines to mitigate the detriments of improper hospital waste segregation. Furthermore, importance is to be given to providing effective training to increase awareness of proper HCWS and its detriments if unachieved. Lastly, infrastructure improvements in assisting HCWS, such as ensuring the availability of coloured bins, are to be developed. However, without compliance monitoring, these factors might not be adhered to and would only increase detriments. Hence, these approaches to HCWS from public hospitals can assist the HCI in improving HCWS globally,

thus reducing the detriments of climate change as required by Ossebaard and Lachman (2021). Overall, achieving alignment with the UN SDGs to ultimately contribute to a healthier environment for both healthcare workers and the community they serve.

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