Master's thesis

NTNU
Norwegian University of Science and Technology
Faculty of Medicine and Health Sciences
Department of Public Health and Nursing

Shishir Pokhrel

Healthcare Waste Management At St. Olav University Hopsital

Recommendations to promote Circular Economy

Master's thesis in Master of Science in Global Health
Supervisor: Vikram Singh Parmar
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Abstract

Background: Healthcare waste management is a pressing global issue, impacting both the environment and public health. A substantial portion of healthcare waste is hazardous, necessitating specialized handling and treatment. Circular economy practices have gained prominence worldwide, aiming to transform linear waste management systems into sustainable, circular ones. While many European countries are embracing these principles, challenges persist. This study examines the adoption of circular economy principles and identifies potential challenges in healthcare waste management, focusing on St. Olav University Hospital as a case study.

Methodology: This study conducted an extensive investigation into St. Olav University Hospital's waste management system, assessing its alignment with circular economy principles, waste handling techniques, and areas for improvement. The research employed field observations, interviews, and surveys involving key personnel responsible for waste management at the hospital. Data analysis utilized coding and memoing techniques, emphasizing challenges faced in healthcare waste management.

Results: The study revealed that St. Olav University Hospital is making strides in aligning its waste management practices with circular economy principles while adhering to regulatory and best practice guidelines. Nonetheless, several areas for improvement were identified, with a particular focus on waste management training, education, and communication.

Conclusion and Recommendations: The findings emphasize the critical need for enhanced training and communication regarding waste management practices among St. Olav University Hospital's staff and students. The hospital possesses cutting-edge technology, but the effectiveness of waste management largely hinges on the education and responsibility of its personnel. To address these challenges, we propose the establishment of a Healthcare Waste Management Committee and the integration of waste management curriculum within relevant courses and training programs. These solutions hold the potential to enhance training, education and communication among the hospital staff and eventually waste management practices, fostering a safer and healthier environment for all.

Keywords: Healthcare waste management; Circular Economy; Training and education; Communication; waste management committee; Sustainability; Environmental health; Waste segregation; curriculum.

List of Figures

Note: All the pictures were taken during the field visit.

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Abbreviations and Acronyms

HCWM: Healthcare Waste management

HCWMC: Healthcare waste management committee

WHO: World health organization

HCW: Healthcare waste

EU: European Union

GGHH: The global green and healthy hospitals

BWM: Biomedical waste management

HCF: Healthcare facility

ICRC: International committee of the red cross

MW: Medical waste

CEAP: circular economy action plan

UNCTAD: United Nations Conference on Trade and Development

HCWH: Healthcare without harm

EPRS: European parliamentary research service

UNIDO: United Nations Industrial Development Organization

NEA: National environmental agency

WtE: Waste to Energy

MSW: Municipal solid waste

CCS: Carbon capture and storage

RDF: Refuse derived fuel.

CEWEP: The Confederation of European Waste-to-Energy Plants

DME: Durable Medical Equipment

TOV: Trøndelag Ortopediske Verksted

IFAT: International federation for alternative trade

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1 Introduction

Waste generated by healthcare facilities can often be managed as municipal solid waste. However, some of this waste, including sharps, pathological, infectious, pharmaceutical, biological, and hazardous chemicals, requires special handling. This type of waste is commonly called "hazardous HCW" or "special healthcare waste"(Hasan & Rahman, 2018). In 1983, the World Health Organization's European office discussed biomedical waste management for the first time in Bergen, Norway. The beach wash-ups in 1988 brought this issue to light, and now it is a globally recognized humanitarian concern(Paul et al., 2018).

Healthcare waste (HCW) and its improper management pose a significant threat to the environment and human health. According to the World Health Organization (2022), 33% of healthcare facilities worldwide do not properly manage medical waste(World Health Organization, 2022). This highlights the need for additional attention to this issue,as improper HCW management poses a risk to hospital staff, patients and their attendants, municipal workers,the general public, and the environment(Kuchibanda & Mayo, 2015). To reduce HCW's potential negative consequences, it is crucial to reduce waste generation and properly manage it from start to finish. Correct waste segregation at the origin point is a crucial measure in managing healthcare waste(Prüss et al., 1999). This involves separating different types of waste, such as sharps, pathological, infectious, pharmaceutical, biological, and hazardous chemicals so that they can be handled appropriately. Proper storage on-site, disinfection and transport to a final disposal location are also key components of proper HCW management. Healthcare workers also need the necessary knowledge and attitudes to manage HCW effectively(Janik-Karpinska et al., 2023). This includes understanding HCW risks, proper handling, and storage procedures, and reducing waste generation. A substantial amount of greenhouse gas emissions come from the healthcare sector, accounting for approximately 4-5% ofglobal emissions(Pichler et al., 2019). Healthcare facilities must implement measures to reduce waste generation and properly manage it.

1.1 Background

In recent years, numerous countries have been actively promoting the adoption of circular economy practices, especially within manufacturing and services. This shift is particularly pertinent in the context of medical waste management, an area that has long operated within a linear economic framework(Kandasamy et al., 2022). The impetus for this change stems from the recognition of the multifaceted adverse ecological and economic consequences associated with the linear economy approach. This conventional model has led to excessive generation and thoughtless disposal of waste, resulting in environmental pollution and degradation. Furthermore, the linear economy's heavy reliance on continuous resource extraction has led to scarcities in raw materials, driving up their prices and subsequently affecting global markets and economic stability(European parliament, 2023a). As a response, the circular economy concept, emphasizing sustainable production, minimal waste generation, and resource efficiency, has gained prominence as a solution to mitigate environmental impact, alleviate resource shortages, and foster a more resilient economic system(Kandasamy et al., 2022).

The circular economy is an economic framework that prioritizes waste reduction and resource efficiency by emphasizing the ongoing reuse, refurbishment, and recycling of products and materials. Implementing circular economy principles in the healthcare waste sector faces significant challenges due to stringent regulations prioritizing infection control and safety, complex and single-use materials, lack of infrastructure, limited awareness, high costs, and the need to adapt established waste streams(Mahjoob et al., 2023). However, through the promotion of innovative waste treatment technologies, the implementation of strategies to minimize waste, and the exploration of circular product design, the healthcare industry can make significant progress in adhering to the principles of a circular economy, all while upholding the utmost standards of patient care and safety(Mahjoob et al., 2023).

In Europe, many countries are steadfastly embracing the circular economy, yet challenges persist. Sustainable healthcare waste management is being advanced through EU policies linked to environmental protection, climate action, renewable energy, and greening the healthcare sector—aligned with the Sustainable Development Goals and the European Green Deal (Healthcare without Harm,2020a). The Global Green and Healthy Hospitals (GGHH) Waste Guidance Document offers strategies for healthcare facilities to achieve sustainable waste management goals, spanning

transportation, storage, treatment, recycling, and disposal (Healthcare without Harm, 2020a). Additionally, Health Care Without Harm has introduced global principles for sustainable healthcare waste management (Healthcare without Harm, 2013). These collective efforts reflect Europe's commitment to merging circular principles with healthcare practices, while innovation remains essential in addressing persisting threats.

In a recent investigation conducted by Healthcare without Harm Europe, during the summer of 2020, an effort was made to gain deeper insights into waste management practices and difficulties faced by European hospitals. Among the 25 responses received from 9 different countries, including Norway, it was evident that over 50% of participants noted that their national regulations mandated the incineration of medical waste (Healthcare without Harm,2020b). Notably, the primary hurdles reported in shifting towards non-incineration alternatives were financial constraints and a lack of supportive regulations. Despite the well-documented adverse effects of incineration on health and the environment, a substantial number of European public health authorities and national governments continue to endorse incineration as the sole secure approach to hospital waste management (Chartier et al., 2014). This underscores the intricate interplay between the challenges associated with medical waste, the principles of a circular economy, and the pursuit of sustainability.

The idea of promoting a circular economy through the use of single-use products and direct waste incineration presents an interesting paradox. While this seems to go against the core concept of circular economy, it's crucial to explore this idea in depth. The focus of this thesis is to provide recommendations that foster the principles of a circular economy. Despite the apparent contradiction, it's important to acknowledge that Norway stands apart from other global regions in terms of waste management. This distinction arises from various factors like climate conditions, regulatory frameworks, culture, and available infrastructure. In light of these considerations, our study's focus can be narrowed down. We can delve into the waste management practices within a Norwegian hospital. By understanding how waste is managed in this context and identifying potential changes, we can better align the hospital's operations with circular economy principles.

In essence, while the proposed approach might seem contradictory to circular economy ideals, the unique conditions of Norway warrant a closer look. The study's scope can then center on a real-world

application within a hospital setting, aiming to bridge the gap between established practices and the circular economy's aspirations. In the realm of safe and sustainable healthcare waste management in Europe, there stand five guiding principles that serve as beacons. These principles encompass the journey towards zero waste, the gradual reduction of incineration, the aspiration for a toxic-free future, the safeguarding of worker well-being, and the path ahead to collective progress (Healthcare without Harm,2020b).

However, amidst these overarching pillars lies a modest yet profoundly significant factor: effective communication, education, and training. While these guiding principles provide the structural foundation, the people who operate within this system bear a pivotal role in their successful realization. This role is often underestimated but paramount, and hinges upon the imparting of knowledge, fostering understanding, and honing skills. Ultimately, Better Communication can have a beneficial effect on the self-efficacy of professionals(Deveugele, 2015), on improving services, and on the possibility of minimizing errors, which should be a priority, considering that these skills cannot be improved with just Theoretical knowledge(Pilnick et al., 2018). On the other hand, a study that looked into how well nurses and healthcare staff learned about managing healthcare waste found that at first, they didn't know much about Biomedical Waste Management (BWM). But, with focused training, their understanding improved a lot. Knowing BWM is really important for healthcare workers (HCWs) to stay safe from infections. To make sure everyone follows the right rules for managing waste properly, it's a good idea to have regular training sessions as part of their education (Shaheen et al., 2020).

1.1.1 Definition and Classification of Healthcare Waste

Hospital waste, generally described as the leftover or discarded solid stuff that comes from treating humans or animals, conducting research, or working with biological materials (Lee, 1989), can carry diseases and pose health threats. This waste mix, which comes as a result of healthcare activities, includes things like needles, body parts, chemicals, medicines, and even radioactive materials (WHO, 2002). Interestingly, healthcare facilities (HCFs) play a big role in creating hazardous waste. However, if we don't manage this clinical waste properly, it can lead to infections, harmful effects, and injuries that affect healthcare workers, those handling the waste, and the community(Muduli & Barve, 2012).

The problems associated with healthcare waste don't stop at the doors of medical institutions – they also touch on the environmental risks tied to how we process and get rid of our trash. Notably, the increasing danger of HIV/AIDS makes it incredibly important for us to dispose of things like needles and syringes safely(Kuchibanda & Mayo, 2015). A comprehensive study by the World Health Organization (WHO) found that quite a significant 15 to 20% of healthcare waste from medical facilities could potentially harm public health due to the risk of spreading infections, toxicity, or even radioactivity (Janik-Karpinska et al., 2023). Yet, even with these concerns, there's still a lack of consistent rules for how we classify and manage medical waste, leading to different practices across countries. Dealing with this inconsistency is really important to make sure we protect both public health and our environment consistently.

Type of Waste	Description	Sources and examples
Infectious Waste	Waste suspected to contain pathogens	Laboratory cultures, waste from isolation wards, tissues (swabs), materials, or equipment that have been in contact with tubing, catheters, IGS toxins, live or attenuated vaccines, soiled plaster costs, and other materials contaminated with blood, infected Patient's excreta.
Pathological waste	Human and animal tissues or fluids	Body parts, blood, and other body fluids, fetuses, animal carcasses.
Sharps	Sharp waste	Needles, infusion sets, scalpels, knives, blades, and broken glass may cause punctures and cuts. This includes both used and unused sharps.
Pharmaceutical waste	Waste containing pharmaceuticals	Pharmaceuticals that are expired or no longer needed; items contaminated by or containing pharmaceuticals (bottles, boxes).
Genotoxic Waste	Waste-containing substances with genotoxic properties	Waste containing cytostatic drug (often used in cancer therapy) genotoxic chemicals.
Chemical waste	Waste containing chemical substances	laboratory reagents; film developer, disinfectants, (disinfectants) that are expired or no longer needed solvents
Heavy metal waste	Waste with high content of heavy metals	Batteries, broken thermometers, blood-pressures gauges
Pressurized wastes	Wastes of Pressurized containers	Gas cylinders, gas cartridges, aerosol cans

Radioactive waste	Waste containing radioactive substances	unused liquids from Radiotherapy or laboratory research, contaminated glassware, packages, or absorbent paper, urine and excreta from patients treated or tested with unsealed radionuclide, sealed sources.
General solid waste	Waste generated from offices, kitchens, packaging material from stores	Paper, food, boxes, bottles
Microorganisms	Any biological entity, cellular or non-cellular capable of replication or of transferring genetic material	

Table 1: Categories of Medical waste, source: (Admin, 2020);(Mato & Kaseva, 1999)

1.1.2 Healthcare waste Management Process

Several health care facilities produce huge amounts of waste, some of which pose serious healthrisks. In order to mitigate these risks, medical waste management is a crucial aspect (Bansod & Deshmukh, 2023b). The process is a series of steps from generation to final disposal as shown in fig 1. It has the ultimate goal of reducingwaste and promoting a sustainable circular economy (ICRC, 2015).

Effective medical waste management is essential in reducing the risk of spreading infections and diseases and protecting the environment from contamination. The process involves separating waste into hazardous and non-hazardous categories and handling and disposing of hazardous waste properly so that harm is minimized. The success of this process is measured by the reduction of waste sent to disposal, and the utilization of materials within the healthcaresystem (Stericycle, 2022). This is done focusing on nearly zero waste. The steps in the medical waste management process are clearly illustrated, so that it is easier to understand them (Zulfiquer Ahmed Amin, 2018).

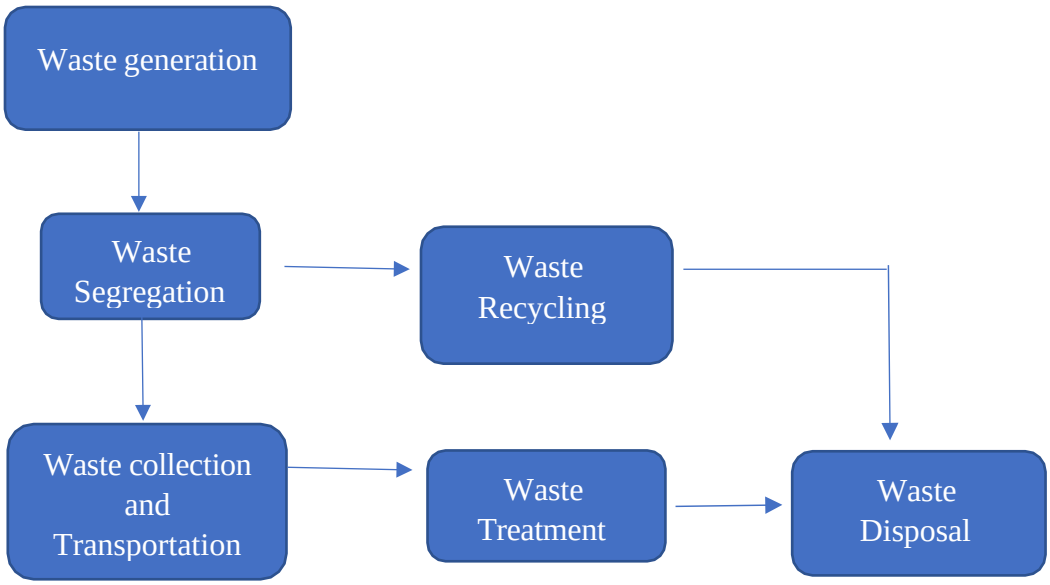

Figure 1: Steps in Waste management

1. Waste Generation

Proper management of medical waste is vital to prevent potential hazards to those who handle it. To minimize the waste generated by healthcare facilities, reducing waste at its source, recycling, and appropriate stock management are effective methods as shown in fig 2. Waste minimization aims to reduce the amount of waste generated in society and eliminate harmful and persistent waste. Reusing harmless materials during production can reduce waste at the source. (International Committee of the Red Cross, 2011).

Figure 2: Waste minimization techniques, source: Global Environment Facility

2. Waste Segregation

Healthcare facilities segregate waste into different categories. To minimize public health and environmental harm, this method is used (International Committee of the Red Cross, 2011). A small amount of waste must be disposed of rather than a large amount when properly segregated. This reduces associated manpower, costs, and risks. It is unfortunate that segregation is often not performed properly, resulting in hazardous and non-hazardous waste being mixed together. Handling and disposing of non-hazardous waste may increase the risk of harm. Healthcare workers need effective training and awareness programs to address this issue (Windfeld & Brooks, 2015). Infrastructure and equipment are also necessary for waste segregation, storage, and transportation. By enforcing strict regulations and imposing penalties for noncompliance, healthcare facilities can be made to follow proper waste segregation procedures. Additionally, by educating the local community about how to dispose of healthcare waste, the risks associated with this waste can be reduced.

3. Waste collection and Transportation

Handling medical waste (MW) requires proper segregation and management to prevent infection spread. MW collection should take place daily to minimize accumulation, and staff members responsible for collecting waste must be equipped with protective gear (ICRC, 2011). The collected waste is then transported from the healthcare facility to a treatment center for proper disposal, recycling, or further treatment processes. These treatment facilities can be located on-site, within the healthcare entity or externally (Windfeld & Brooks, 2015). It is imperative to follow strict guidelines for MW management to ensure healthcare personnel and environmental safety.

To ensure the safety of all personnel involved in the transport process, containers must be properly sealed. Besides leak-proof containers and protective gear for drivers, transportation vehicles must be equipped with safety features (Jacob et al., 2021). Medical waste transportation must also comply with local, state, and federal regulations. To make sure the process is safe and secure, this is required.

4. Waste Treatment

Healthcare waste treatment is a crucial step in the medical waste management process, as it ensures the safe and secure disposal of hazardous waste generated by healthcare activities. Waste treatment reduces the potential risk posed by medical waste to human health and the environment. Waste treatment methods include physical, chemical, and biological processes that aim to neutralize, destroy, or make waste less harmful.

Physical treatment methods encompass both incineration and non-incineration systems. Non-incineration systems, as illustrated in Figure 3, are further categorized into methods such as autoclaving, microwave disinfection, and other techniques. These approaches are designed to eliminate microorganisms and pathogens present in waste. Chemical treatment involves chemicals to treat waste, such as hypochlorite solutions for sterilization (World health organization, 2014). Biological treatment methods include composting, anaerobic digestion, and landfill bioreactor, which aim to break down organic components of waste into harmless substances through biological processes (Kenny & Priyadarshini, 2021). In conclusion, it is critical to implement proper healthcare waste treatment methods to ensure medical waste does not threaten human health and the environment.

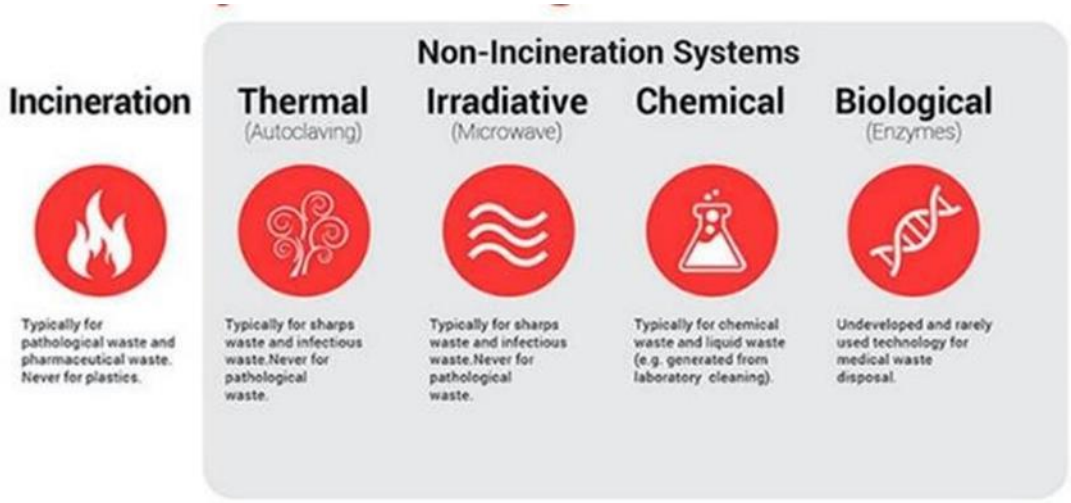

Figure 3: Waste Treatment Methods, source: (Airlina, 2020)

5. Incineration

Healthcare waste is commonly incinerated. By burning the waste at high temperatures (800- 1200 degrees), pathogens are eliminated by 90%, and hazardous chemicals are neutralized (Giakoumakis et al., 2021). Typically, incineration occurs at specialized facilities, where the waste is heated to extreme temperatures. This process takes waste and turns it into ashes and gases, a method often used for handling various types of medical waste. While it gets the job done well, it's pricier than something like burying the waste in a landfill – roughly three to five times more expensive per amount of space used (Estates Return Information Collection, 2018).

Aside from air pollution and greenhouse gas emissions, incineration of healthcare waste can also negatively impact the environment. It is possible to reduce the emission of harmful chemicals such as dioxins by burning waste efficiently (Ababneh et al., 2019). Medical waste incineration can also emit mercury, which can be harmful to the environment and human health. Fly ash generated by incineration contains heavy metals and is polluting. In addition, burnt clinical waste releases large amounts of greenhouse gases that contribute to climate change. For each kilogram of clinical waste burned, approximately 3 kilograms of carbon dioxide and other greenhouse gases are released (Tait et al., 2020).

6. Autoclave Disinfection

Autoclaving is a disinfection process that uses heat and steam to eliminate microbes from healthcare waste. This method operates at lower temperatures than incineration and relies on pressure and steam to achieve its disinfection effects (ICRC, 2011). The standard operating conditions include a 60-minute cycle at 121°C and 1 bar, followed by a 60-minute cycle at 134°C to ensure complete disinfection (Windfeld & Brooks, 2015). Autoclaving success depends on several factors such as temperature, steam penetration, waste load, length of the treatment cycle, and air removal from the chamber (Attrah et al., 2022). However, autoclaving alone is not enough to treat all types of waste. In some cases, pre-treatment with incineration is necessary before waste can be disposed of in a landfill.

7. Microwave Disinfection

Microwave disinfection is a method of treating medical waste using high-frequency electromagnetic waves to kill pathogens. The process involves placing the waste in a microwave chamber, where the energy generated by the microwaves heats the waste, killing the microorganisms. This method is highly efficient and can sterilize waste in a matter of minutes, compared to traditional methods such as autoclaving, which can take hours (Clark, 2022). The disinfection is operated at temperatures ranging between 177 and 540 ◦C electromagnetic waves of wavelength ranging between 1 mm and 1 m and frequency ranges between 300 and 3000 MHz (Giakoumakis et al., 2021).

One of the major advantages of microwave disinfection is its speed and efficiency. The high-frequency waves penetrate the waste, heating it evenly and thoroughly, resulting in a more thorough and efficient disinfection process. Additionally, the method consumes less energy compared to other disinfection methods, making it more environmentally friendly. It also generates less waste, as there is no need for the pre-treatment required by methods such as autoclaving. The compact size of microwave disinfection units makes them ideal for use in smaller medical facilities, where space may be limited. Overall, microwave disinfection is a highly effective and efficient method of treating medical waste, offering numerous benefits over traditional methods.

8. Chemical Disinfection

Chemical disinfection kills pathogens and microorganisms in urine, feces, blood, and hospital sewage. This process is often disinfected with bleach (1%) and diluted active chlorine (0.5%). Nevertheless, chemical disinfection can cause skin and eye irritation or inhalation of volatile chemicals (Windfeld & Brooks, 2015). Ozone, lime, ammonium salts, and peracetic acid can also be used.

It depends on a lot of factors, like pH, contact time, how waste and chemicals mix, and recirculation vs. flow (Attrah et al., 2022). It's important to evaluate the characteristics and desired outcome of the waste and weigh the advantages and disadvantages of each treatment method. Liquid residues go into sewage systems, and solid residues go into landfills.

9. Waste Recycling

Waste recycling involves utilizing the waste produced or by-products for new purposes, potentially reducing the need for landfills or waste dumps. The medical sector often generates a significant amount of non-hazardous waste, but much of it can be recycled. Items like plastics, batteries, paper, glass, metals, and silver used in photography processing can all be reused (Windfeld & Brooks, 2015).

Organic waste, such as food waste, can be utilized for composting, while fly ash from incineration can be treated and used in building materials like concrete blocks or used as an energy source to heat water for central heating systems (Windfeld & Brooks, 2015). By using these methods, recycling helps to minimize the waste that is disposed of in landfills and reduce the negative impact on the environment (Ababneh et al., 2019).

10. Waste disposal

As a result of healthcare waste disposal, hospitals manage and dispose of waste in a safe and efficient manner. In order to minimize infection and environmental pollution risks, healthcare facilities should handle potentially hazardous waste carefully and follow proper disposal procedures (Giakoumakis et al., 2021). Incineration, autoclave disinfection, microwave disinfection, chemical disinfection, and recycling are all methods for disposing of waste.

Healthcare waste should be separated into hazardous and non-hazardous categories, labeled appropriately, and disposed of in compliance with local and international regulations. Using incineration and autoclave disinfection, healthcare waste can be safely disposed of. Table 2 shows how different categories of waste are handled and disposed. Chemical disinfection or microwave disinfection can be used to safely disinfect liquid infectious waste. Besides minimizing the environmental impact and reducing the volume of waste, recycling is also a safe way to dispose of waste. To protect public health and the environment, healthcare waste must be disposed of in a safe, secure, and environmentally friendly way (Giakoumakis et al., 2021).

General nonhazardous waste	Secured landfills
Liquid wastes	Chemical disinfectant. neutralization with reagent and discharged into the sewerage system.
Human anatomical wastes	Incinerated and sent to landfill sites.
Sharps	Needles can be cut by needle cutter and contained in 1% bleach solution and sent to landfill for disposal.
Microbiology waste	Autoclave/Microwave/Incineration F/b landfill disposal.
Infectious solid waste	Autoclave/Microwave/Incineration F/b landfill disposal.
Radioactive waste	The solid wastes are disposed by concentration and storage.
Pressurized containers	Disposed of with general waste in secured landfills.

Table 2: Waste disposal methods, source: (Zulfiquer Ahmed Amin, 2018).

2 Literature review

2.1 Healthcare Waste Management in Europe

Every year, an astonishing amount of waste – approximately 2.2 billion tons – is generated within the European Union. It's quite surprising that more than a quarter of this waste (27%) belongs to the category of "municipal waste," which encompasses the everyday waste managed by local municipalities, primarily originating from households (European Parliament, 2018). Interestingly, waste generation and its management practices exhibit significant disparities among EU member states, although a discernible trend leans towards heightened recycling efforts and a reduced reliance on landfills.

To address the environmental implications of waste, the European Union has embraced ambitious targets encompassing recycling, landfill practices, and packaging waste. The overarching vision here is the establishment of a more sustainable framework known as the "circular economy," aiming to optimize resource utilization and curtail waste generation (European Parliament, 2018).

In line with this vision, the EU introduced the Waste Directive 2018/851/EU, which places a pronounced emphasis on waste prevention and underscores recycling as a pivotal instrument in transitioning to a circular economy (EUR-Lex, 2018). This directive effectively integrates waste management into strategic processes, a concept akin to prevalent practices in industrial sectors (Mokra & Loosova, 2021).

Interestingly, strategic waste management procedures often align with the standards of environmental management systems, commonly employed in industrial contexts. An intriguing strategy involves reevaluating waste management approaches in sectors such as medical facilities, integrating waste prevention principles into the decision-making framework for procuring goods and services (Mokra & Loosova, 2021). A pivotal factor ensuring the successful integration of a circular economy is the mitigation of adverse health and environmental impacts, all while ensuring economic viability (European Union, 2021).

Hence, the EU's waste management policies encompass not only the reduction of environmental and health repercussions but also the enhancement of resource efficiency. The overarching objective is the minimization of overall waste generation. In scenarios where waste generation remains inevitable, the focal point shifts to converting waste into a resource, accompanied by elevated recycling rates and secure waste disposal practices (Healthcare without Harm, 2020a). An illustrative case is the EU's waste generation of 2,135 million tons in 2020, with hazardous waste constituting 4.4% (95.5 million tons) of the total (Eurostat, 2023). Importantly, hazardous waste production in the EU increased by 5.1% in 2020 when compared to the figures from 2010.

Furthermore, the proportion of hazardous waste within the total waste generated varies markedly across EU member states. For instance, Romania records the lowest proportion at a mere 0.5%, while Bulgaria reports the highest at 12% (Eurostat, 2023). Among non-EU member countries, Turkey exhibits the highest proportion of hazardous waste at 28.5%, followed closely by Norway at 13.3% (Eurostat, 2023).

The European Green Deal, which aims to encourage sustainable growth throughout the continent includes the new Circular Economy Action Plan (CEAP) from the European Commission as a fundamental element. The CEAP, which was approved in March 2020, is intended to establish a circular economy by minimizing waste and fostering material reuse within the EU economy (European Commission, 2020). The strategy covers every phase of the life cycle of a product and emphasizes waste reduction, circular economy principles, sustainable consumption, and product design (European Commission, 2020). Last but not least, the CEAP will assist the EU in realizing its 2050 climate neutrality target, ease the strain on natural resources, foster long-term economic growth, and safeguard biodiversity (UNCTAD, 2021).

Many European nations are actively progressing towards the realization of circular economy objectives. A central tenet of the circular economy involves safeguarding the environment, a key facet of which is the gradual reduction of incineration. However, a study conducted by HCWH Europe in 2020 on healthcare waste management revealed that a substantial portion of waste in numerous countries continues to be incinerated, predominantly due to its perceived safety and lack of risks (Healthcare without Harm, 2020b). This same study indicated that 24% of respondents identified cost as a significant hurdle impeding the transition to non-incineration technologies, while another 20% attributed the challenge to inadequate regulations (Healthcare without Harm, 2020b).

The journey towards widespread adoption of groundbreaking innovations in the market comes with substantial transitional expenses, such as research and development costs, asset investments, and the need for subsidies to promote novel business models. Unfortunately, suitable financial instruments to address these costs are currently lacking (EPRS, 2018b).

In spite of the array of challenges, the European Parliament has devised a series of strategic plans and regulations to pave the way for a comprehensive transition to a circular economy. These encompass the Circular Economy Action Plan (CEAP), the promotion of sustainable products, the transformation of critical sectors into circular paradigms, and the focus on plastics and packaging. These initiatives are instrumental in advancing the overarching goal of achieving a fully operational circular economy across Europe by the year 2050 (European Parliament, 2021).

2.2 Circular economy Model

The circular economy is a strategic framework centered on the creation and utilization of products in a sustainable manner, with the primary objectives of reducing waste generation and maximizing the efficient utilization of resources (European Parliament, 2018). In stark contrast to the linear economic model that involves the extraction of raw materials, their conversion into products, and eventual disposal, the circular economy seeks to establish a continuous cycle of materials usage. This approach aims to curtail waste production and elevate the effectiveness of resource management by prolonging the lifespan of materials through reuse, refurbishment, and recycling (PaulaNadaj, 2023).

The rationale for embracing the circular economy is multi-faceted and compelling. At the forefront is the imperative to minimize waste, a goal achieved by optimizing resource utilization and facilitating effective recycling practices (Hart & Pomponi, 2021). This proactive approach not only mitigates greenhouse gas emissions but also curbs the accumulation of waste in landfills and the contamination of precious air and water resources (Hart & Pomponi, 2021). Startlingly, the World Health Organization underscores an annual global waste production of approximately 2.01 billion tons, a staggering quantity that is worrisomely on the rise (Filipenco, 2023). In 2016, 2.5 billion tonnes of waste (or about 5 tonnes per capita) were generated in the European Union (EPRS, 2018b).

The circular economy not only embodies an ethical imperative but also serves as an avenue for enhancing resource efficiency. This, in turn, translates into diminished expenditures linked to the acquisition of raw materials, waste management, and the logistical challenges of storage and transportation (PaulaNadaj, 2023). Furthermore, the circular economy propels innovation, ushering in transformative technologies and novel products. The advocacy of post-use repair, product reusability, and designs geared towards recyclability necessitates the integration of contemporary solutions and advanced technological processes. This dynamic not only fosters heightened competitiveness within industries but also generates substantial employment opportunities (International Labor Organization, 2023). In essence, the circular economy's virtuous cycle extends beyond waste reduction, resonating with economic, environmental, and societal progress.

Figure 4: Circular Economy Model, source: (UNIDO, 2017)

2.3 Circular Economy vs Safety

This research delves into the intricate relationship between the circular economy and safety concerns within the healthcare realm. The central thesis consistently underscores the importance of marrying environmental sustainability with the well-being of individuals and the broader public. However, it is evident that these two aspects often have conflicting priorities. While safety measures like favoring single-use products to curb infection risks are crucial, they can inadvertently lead to increased waste generation and hinder efficient resource utilization – a contradiction to circular economy ideals.

In the healthcare sector, the prime focus is on safeguarding both patients and staff (Lee et al., 2021). This imperative necessitates stringent infection control protocols and the use of disposables to minimize cross-contamination. While these practices are vital for public health, they generate substantial medical waste, posing challenges for sustainable disposal. Single-use medical items, disposable supplies, and personal protective gear contribute significantly to healthcare waste, obstructing circularity efforts in this domain (Jain, 2022).

The healthcare industry grapples with the challenge of harmonizing safety goals with circular economy principles. This conundrum stems from the need to balance human health protection with minimizing the industry's environmental impact. Achieving this balance demands innovative waste management strategies, sustainable sourcing of medical resources, and integrating circular design principles in healthcare product development. Potential avenues for promoting circularity while upholding safety include introducing durable and reusable medical equipment, implementing waste reduction techniques, and exploring waste-to-energy technologies (Tola et al., 2023).

Effectively addressing the confluence of the circular economy and safety concerns in healthcare necessitates a comprehensive, interdisciplinary approach. Collaborative endeavors among stakeholders – policymakers, healthcare professionals, waste management experts, and industry representatives – are essential for devising tailored solutions (Pereno & Eriksson, 2020). These solutions should tackle the unique challenges faced by the healthcare sector, promoting sustainable waste management practices, and optimizing resource utilization concurrently. Through this collaborative approach, the healthcare industry can strive for equilibrium between safety imperatives and circular economy ideals, significantly contributing to a future marked by improved health outcomes and heightened sustainability.

2.4 Waste Management In Norway

In Norway, there's a clear connection between how much the economy grows, how much people buy and use, and how much waste is created. This pattern of waste increasing along with economic and consumption growth has been going on since 1990. However, an interesting twist happened in 2020 when there was a decrease of 5 percent in waste. This drop was mainly because the economy shrank, and people consumed less due to the COVID-19 pandemic(*Waste - Environment Norway*, 2022). Despite this unusual year, both in 2020 and 2021, the country still ended up generating the same amount of waste: a total of 11.6 million tons each year (statistics Norway, 2022). This consistent waste generation emphasizes the ongoing challenge of managing waste while also aiming to improve recycling efforts in Norway. It's a reminder that finding ways to reduce waste remains crucial, even in the face of changing economic circumstances.

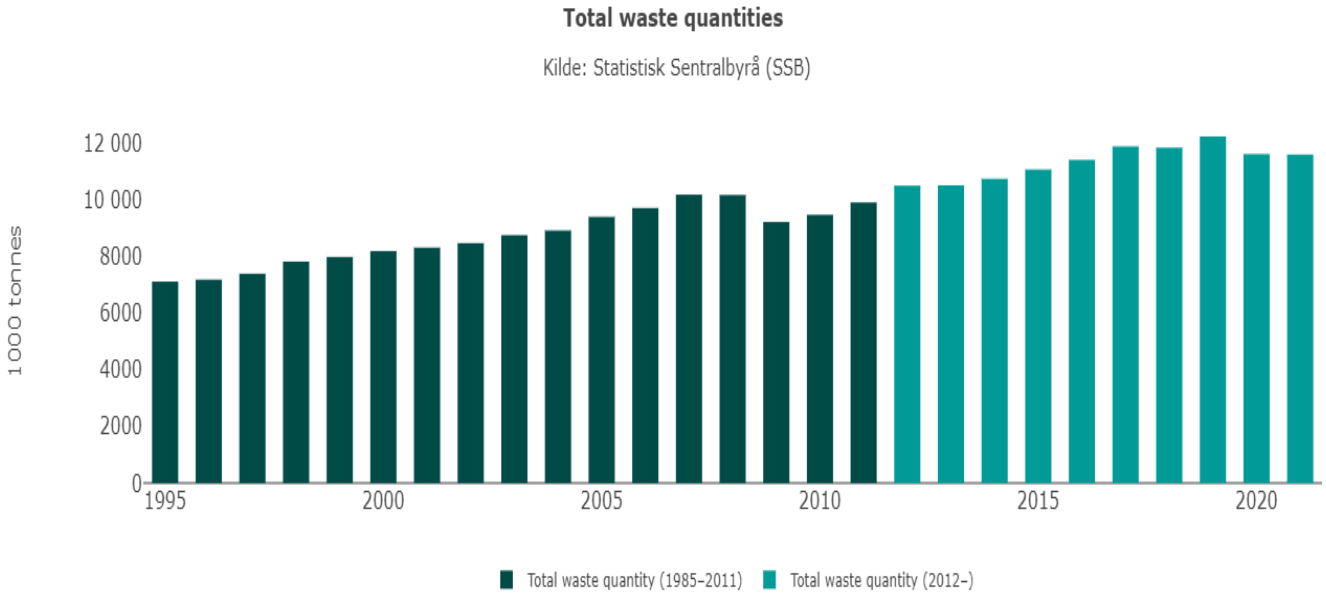

Figure 5: Total Waste Quantities, source: Statistics Norway

The increased production of waste has led to a greater demand for effective waste management services. To address this, the NEA (National Environmental Agency) has implemented strict regulations governing how waste should be treated. Starting in 2016, the Waste Regulations of 2015 require organizations handling hazardous waste to provide financial security measures (Riis et al., 2021b). This requirement acts as a safety net, ensuring that responsible waste management

practices are maintained, even in cases of business closure, financial challenges, or unexpected operational disruptions. While the combination of industry growth and regulatory frameworks seems to set the stage for the waste management sector's expansion, it remains unclear to what extent market growth and the simultaneous increase in industry participants can be attributed to these factors.

Waste management in Norway is a dynamic field influenced by several factors. Landfilling, historically the primary waste management method, poses significant environmental concerns due to leachate contamination and the squandered potential of untapped resources within waste. Over the past two to three decades, the country has transitioned from relying heavily on landfilling, especially for biodegradable waste, to a more diversified approach(*Waste - Environment Norway*, 2022). Notably, in 2021, an impressive 73 percent of regular waste underwent recycling, encompassing both material recovery and energy-recovery through incineration. This recycling initiative involves utilizing waste-derived resources in new product production. However, around 44 percent of these recovered materials are repurposed in this manner (statistics Norway, 2022).

These efforts are partially driven by EU regulations, as higher material recovery rates are essential to align with these mandates concerning municipal and construction waste. Economic growth has historically spurred greater waste generation due to larger homes and increased replacements of furniture and electronic items, necessitating responsible waste management practices. However, an important environmental target for Norway is to ensure that waste growth lags significantly behind economic expansion, thus generating more value from each ton of waste produced (NEA, 2023). Nevertheless, the financial crisis and the COVID-19 pandemic have had their impacts, with a decrease in industrial waste attributed to these events.

Improvements in waste management have yielded positive environmental outcomes by curbing hazardous substance releases and greenhouse gas emissions. Stricter landfill regulations have led to better leachate control and reduced methane emissions. Recycling, a pivotal component of addressing environmental concerns, extends the lifespan of resources and mitigates the necessity for fresh resource extraction. Nevertheless, improper waste management, particularly the release of hazardous substances into the environment, poses risks to ecosystems, and marine litter, notably

plastic and persistent materials, remains an ecological challenge. Norway has responded by focusing on waste recovery to avoid environmental degradation, with particular emphasis on reuse, material recovery, and controlled pollutant diffusion (Healthcare without Harm, 2022).

As Norway moves toward a circular economy, the design, production, and consumption patterns of products are evolving. Product longevity, ease of repair, minimal pollutants, and resource retrievability are key considerations (European Union, 2021). The country employs deposit and return systems for various waste types and mandates proper waste collection and disposal by municipalities. Moreover, businesses hold responsibility for their waste management, with producer responsibility schemes in place for specific end-of-life products (TOMRA, 2022). This holistic approach aims to promote efficient waste management and recycling while safeguarding the environment and ensuring compliance with export regulations.

2.5 Waste Treatment in Norway

In the year 2020, a substantial amount of waste, approximately 1.971 billion tonnes, underwent treatment within the European Union (EU) (Eurostat, 2023b). This encompasses waste management conducted both within the geographical boundaries of the EU and includes waste imported into the EU, while excluding exported waste.

The trend in total waste treatment across the EU from 2004 to 2020 sheds light on two principal treatment categories: recovery and disposal. During this timeline, the volume of waste subjected to recovery processes—namely recycling, backfilling, or incineration with energy recovery—surged by 33.9%, escalating from 870 million tonnes in 2004 to a notable 1.165 billion tonnes in 2020. Consequently, the proportion of waste subjected to recovery methods within the overall treatment paradigm expanded from 45.9% in 2004 to a notable 59.1% in 2020 (Eurostat, 2023b).

Recent developments in Norway's waste management sector, as highlighted by Becidan et al. (2015), have brought about significant changes. These include: (1) A noticeable increase in adopting waste-to-energy (WtE) practices to convert waste into usable energy; (2) Implementation of a ban on depositing organic waste in landfills since 2009, leading to a decrease in active landfill sites; (3) The substantial export of municipal solid waste (MSW) to Sweden, primarily directed to WtE facilities that contribute to district heating systems. This export, averaging around 1.6 million tonnes annually over the past five years, is primarily driven by the economic advantages of Sweden's gate fee structure, driven by surplus WtE capacity; (4) Occurrences of excess energy generation, particularly heat, during certain periods, prompting discussions on efficient energy utilization; (5) Within the capital city of Oslo, a commendable initiative focuses on segregating food waste from other waste streams like paper, plastic, glass, and metal. Additionally, Oslo is exploring the implementation of carbon capture and storage (CCS) technology to enhance waste management practices.

Notably, Norway exports a substantial volume of MSW and general waste to Sweden, where a majority undergoes treatment in WtE facilities that produce district heating. Although precise export data remains challenging to ascertain, an estimated yearly export of approximately 1.6 million tonnes of MSW over the past five years underscores the role of Sweden's cost-effective

gate fees driven by an excess of WtE capacity. Conversely, Norway also imports around 400,000 tonnes of waste annually, mainly sourced from the UK. An interesting aspect is the strategic use of refuse-derived fuel (RDF) from the UK as a key fuel source for Norwegian WtE plants, a practice identified by the Norwegian Environment Agency in 2017.

Regarding the management of bottom and fly ash, an area where there is currently no EU-wide regulatory consensus on final treatment or disposal, Norway has adopted two separate approaches. Fly ash is directed to specialized landfills designated for hazardous wastes, with two such facilities in operation. The primary site is situated on Langøya island in the Oslo fjord. On the other hand, bottom ash is either disposed of in landfills or utilized in regular landfills. Despite various industrial and research initiatives, no additional disposal or utilization methods have been officially sanctioned at present (Becidan et al., 2015).

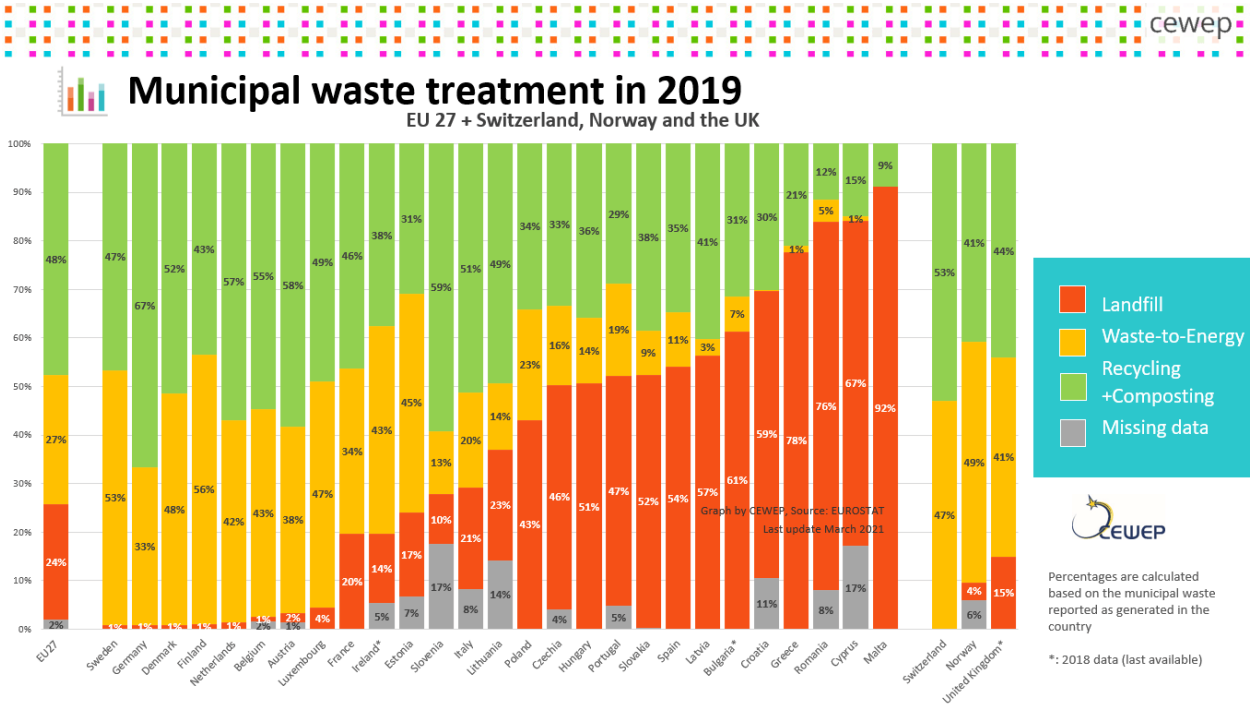

Figure 6: Waste Handling in EU, Source: (CEWEP, 2021a)

The presented graph visually portrays the waste management strategies of various countries, including EU Member States, Norway, Switzerland, and the United Kingdom, with data categorized by the proportion of waste sent to landfills. The graph delineates the distribution of recycling (inclusive of composting), Waste-to-Energy utilization, and landfilling within each

nation, while also highlighting data gaps representing disparities between generated and treated waste. Notably, Germany emerges as a recycling leader in 2019, with an impressive 67% of municipal waste being recycled or composted. Eight Member States have effectively reduced landfilling to below 10%, aligning with the new Landfill Directive's 2035 target, while ten others still landfill more than half of their municipal waste, signaling the necessity for enhanced waste management strategies in those regions (CEWEP, 2021a).

Harnessing energy from Waste-to-Energy (WtE) facilities brings forth a range of advantages that extend beyond waste reduction and environmental alleviation. These facilities offer communities a dual advantage: not only do they provide a greener waste disposal method, but they also offer a clean energy source, thereby enhancing energy efficiency. However, it's crucial to note that the WtE sector grapples with navigating stringent emissions regulations and aligning with renewable energy standards. Addressing waste management challenges necessitates an integrated approach, wherein WtE is coupled with the principles of a circular economy. This synergy not only curbs the environmental impact of economic activities but also establishes a symbiotic relationship between waste reduction, energy generation, and sustainable resource utilization.

3 Rationale of the study

The main goal of this study is to explore how St. Olav University Hospital is putting circular economy principles into practice for managing healthcare waste. Additionally, it aims to identify any possible ways to improve the hospital's waste management system for better efficiency. The study takes a qualitative approach, focusing on the methods and strategies the hospital uses for effective waste management. It also examines how well the hospital follows waste management standards set by the EU and the Norwegian government. The study looks closely at the hospital's waste management practices within its premises. It highlights the hospital's efforts to be environmentally responsible and sustainable.

The significance of this study lies in understanding how St. Olav University Hospital is committed to sustainable development, particularly in healthcare waste management. It also showcases a model for creating waste management systems that prioritize sustainability. This model can be beneficial for other developing nations seeking guidance on managing healthcare waste effectively while also safeguarding the environment and public health. Importantly, this study doesn’t focus on categorizing or measuring the amount of waste. Instead, it emphasizes providing insights into how the hospital's waste management system works and how it aligns with circular economy principles.

3.1 Research Question

The study aims to address the following research inquiries:

1. In what ways is St. Olav Hospital implementing principles of the circular economy?
2. What are the methods employed by the hospital for the treatment and management of healthcare waste?
3. What potential enhancements can be made to the existing healthcare waste management system at St. Olav's Hospital?

3.2 Objectives

The primary goal of this study is to investigate the present healthcare waste management procedures employed by St. Olav's Hospital. Additionally, the study seeks to assess the hospital's approach in developing strategies and utilizing methods to promote environmental sustainability and enhance public health outcomes.

3.3 Limitations of the study

Despite the fact that the study attempted to gather and interpret data to the greatest extent possible, the following limitations were found:

i. **Lack of accurate Durable Medical Equipment (DME) Management Data**: Complex processes and inadequate data prevented the research from providing accurate DME waste management statistics.

ii. **Communication and simplicity**: Meetings and contacts with departmental staff may have improved the research. A more open and transparent data gathering environment might have yielded better participant insights and improved waste management knowledge.

iii. **Time constraints and delayed responses**: Participant delays extended the study's duration. Time restrictions prevented participation from becoming more varied, which may have affected the dataset and opinions.

4 Methodology

The objective of this study was to investigate the healthcare waste management practices implemented at St. Olav University Hospital in Trondheim, Norway. The data collection procedure encompassed a triangulation approach, incorporating in-depth interviews with the personnel, field visit and an online survey, to procure a comprehensive understanding of the subject matter.

4.1 Study Area: St. Olav University Hospital, Trondheim

St. Olav's Hospital, located in Trondheim, Norway, is named after Saint Olaf and serves the Sør-Trøndelag region. With a long history of providing medical care to Trondheim, it was founded in 1628. The hospital is situated on the island of Øya and has undergone several renovations, including an expansion from 2005-2013, and currently has a capacity for 1000 beds and employs around 10-11 thousand people. In addition to medical treatment, St. Olav's Hospital offers clinical training for medical students and other healthcare professionals affiliated with the Norwegian University of Science and Technology (NTNU).

Figure 7: St. Olav University Hospital, Source: Geir otto johansen

4.2 Flowchart

The fieldwork for the research was conducted in December 2022. The detailed studyframework during the research is shown in Figure 8.

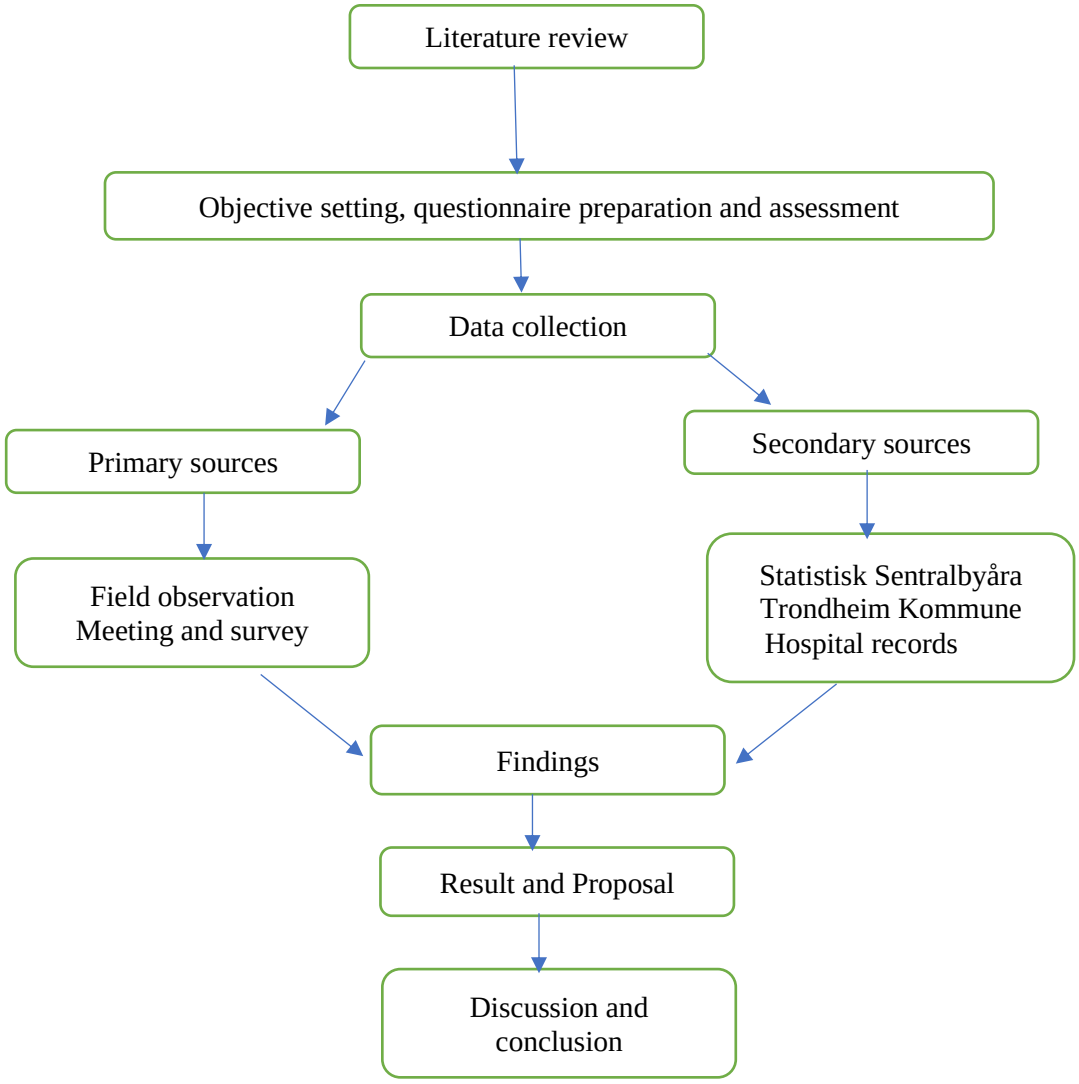

Figure 8: Research Process

4.3 Field observation of Waste Management system at the facility

The Forsyningssenteret, also known as the Supply Center, is a centralized collection and treatment facility. It forms a key component of St. Olav's Hospital's healthcare waste management strategy. The hospital, which is part of Trondheim University Hospital in Norway, comprises 20 clinics and divisions. Each clinic and division have its own staff responsible for managing waste generated in their respective departments. The Forsyningssenteret serves as the central hub for the collection, sorting, treatment, and transportation of all healthcare waste produced by the hospital. Having these processes centralized ensures consistent and effective waste management, reducing contamination risks and promoting the health and safety of patients, staff, and the community. The supply center is a testament to St. Olav's Hospital's commitment to responsible and efficient healthcare waste management. The facility serves as a model for best practices in waste management and represents the hospital's dedication to maintaining a clean and healthy environment for all.

Figure 9: The supply center

4.3.1 Types/Number of wastes and Handling Techniques at St. Olavs University Hospital

The careful rules and procedures that hospitals follow for managing and getting rid of different types of waste are really important. They're crucial for keeping patients, healthcare workers, and the environment safe. Taking care of healthcare waste is a vital part of making sure everyone's health and safety are protected. This involves separating waste, labeling it carefully, storing it properly, transporting it safely, treating it correctly, and getting rid of it in the right way within the hospital. It's really important to follow the local rules and guidelines to make sure both people's health and the environment are taken care of (Bansod & Deshmukh, 2023). After looking closely at the area and using the available information, the table below shows the specific techniques that St. Olav University Hospital uses to manage different types of wastes.

Waste type	**Residual waste**	**Flasks, Bottles, Plastics**	**Paper, cardboards,**	**Glass**	**Metal**
Description	Household waste, gloves, syringe without needles, infusions bags and sets, pads, bandages	Hard plastics, any kind of plastic bottles	Papers, newspapers, confidential papers, cardboards	Vials, ampoules, jam jars, canned goods,	All kinds of metal
Collection unit and handling technique	Should be thrown in the waste suction after putting in a bag.	Should be thrown in the waste suction after putting in a bag.	Put in environmental boxes and disposed of in collection unit, while confidential papers should be kept in a macular bag. Cardboards are folded and put in waste room in a big container.	Placed in waste room in a container and they are rinsed before they are delivered.	Place in waste room in separate container
What happens	Energy recovered at Heimdal Heating center	Used as fuel in incinerators. Energy used for District heating and Steam production.	Recycled into new papers/cardboards or goes to energy recovery.	Material recycling, production of new glass, insulation, foam ice cream, ice concrete	recycled

Waste type	**EE waste and batteries**	**Fluorescent Bulb**	**Dangerous or chemical waste, spray cans**	**Risk waste/Infectious**
Description	Computers, ovens, radio, tv, lamps, others.	Lamps and energy saving bulbs	Acids, waste oil, lye, cans	Drug Residues, bloody waste, pathological waste, infectious wastes, syringes, organs etc.
Collection unit and handling technique	Places in waste rooms, collected in cages. Standard batteries (AA, AAA OSV) and poles lost.	Put in the marked red row box in the waste room. Electronic Declaration must be sent	Follow procedure EQS/ICQS ID 3852. Electronic declaration must be sent	Kept in yellow container marked with department signature and crossed as infectious and labelled.
What happens	Environmentally harmful substances are destroyed, and others recycled.	Recycled and used in production of new glass and metal products.	Environmentally harmful substances are destroyed, and others recycled.	Can be energy recovered and used as district heating.

Table 3:types of waste and handling techniques

Waste fraction year	2021	2022	Change	Change % Note
Total amount of tons	2842	3223	+399	+13%
- Residual waste tons	1582	1750	+168	+9% Including wet organics
- Tons of plastic	29.3	37.3	+8	+27%
Risk-pathological ton	444	454	+10	+2.5% Share Pathological 10%

Table 4: Amount of waste generated.

As per table 4, The transition from 2,842 tons of waste in 2021 to 3,223 tons in 2022, marking a 399-ton increase (13%), holds an intriguing tale of growth and challenges faced by St. Olav's Hospital. This surge, while reflective of a vibrant hospital environment, stems largely from high activity in 2022, accompanied by ambitious conversions and developmental measures. These transformations, crucial for progress, inevitably result in an uptick in waste generation due to construction, renovations, and operational transitions.

However, St. Olav's Hospital remains resolute in its commitment to waste reduction and sustainability. The 168-ton increase (9%) in residual waste from 2021 to 2022, reaching 1,750 tons, underscores the urgency to address waste management. A pioneering step in this direction is the upcoming separation of wet organic waste, encompassing food waste, as a distinct fraction, effective January 1, 2023. This strategic shift acknowledges that treating wet organics as residual waste is counterproductive and necessitates specialized treatment.

The amplification of plastic waste by 8 tons (27%) from 29.3 tons in 2021 to 37.3 tons in 2022 is emblematic of a global concern. This underscores the importance of proactive measures to limit plastic waste generation and elevate recycling efforts. The marginal rise in risk-pathological waste by 10 tons (2.5%) from 444 tons in 2021 to 454 tons in 2022 reinforces the hospital's commitment to mitigating health hazards associated with waste.

In addressing this complex waste landscape, a multi-faceted approach is imperative. Education,

training, and improved communication within the hospital stand out as crucial factors. Comprehensive training programs can empower staff to make informed decisions on waste generation and segregation. By understanding the repercussions of improper waste management, employees are better poised to contribute to waste reduction. Moreover, this shift can cascade to the wider patient and visitor community, instilling a culture of environmental consciousness.

Effective communication channels hold the potential to be game changers. Clear signage, digital platforms, and engaging materials can propagate waste management practices seamlessly. Regular updates, interactive sessions, and transparent guidelines can make responsible waste disposal an integral aspect of hospital culture. To illustrate, waste management training sessions could convey the significance of reducing plastic waste, aligning with the stark 27% increase in plastic waste. Such sessions could also highlight the 9% surge in residual waste, compelling participants to adopt strategies for waste reduction.

By fostering an environment of understanding, St. Olav's Hospital can make substantial strides in waste management. The surge in waste, a reflection of progress, need not be detrimental to the environment. It can serve as a catalyst for change – a catalyst that, when coupled with education, training, and effective communication, can steer the hospital towards a sustainable waste management paradigm. In the end, the hospital's journey towards responsible waste management is a testament to its commitment to both the community it serves and the environment it thrives in.

4.3.2 Waste Network at St. Olav University Hospital

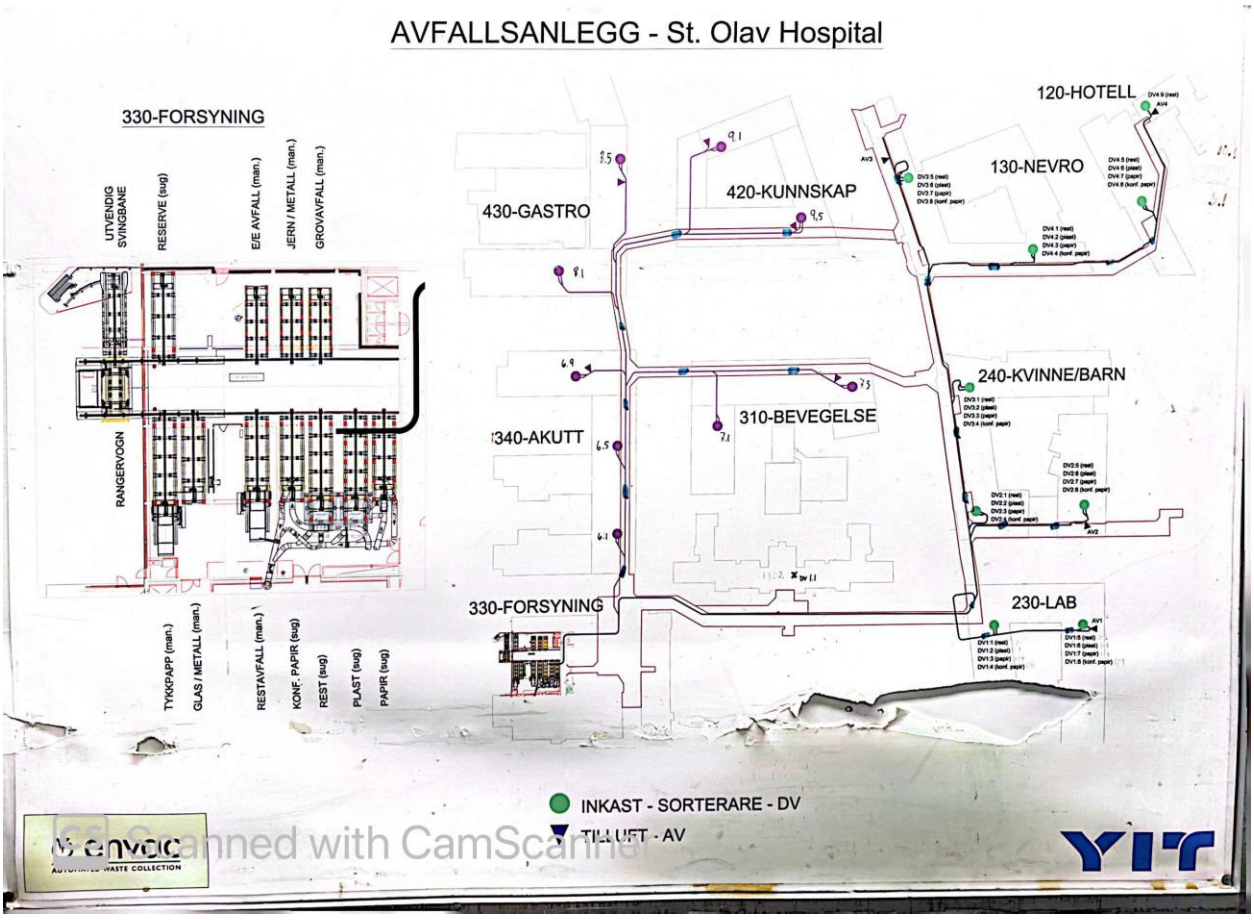

Figure 10: waste network at St. Olav hospital

Proper waste management holds immense importance within hospital premises, placing significant emphasis on maintaining hygiene and cleanliness. Its significance lies not only in minimizing the risk of contamination but also in establishing a safer environment for both patients and staff members. This is achieved by establishing a comprehensive interconnected system where waste is systematically collected and efficiently transported to a central processing facility.

The waste management network at St. Olav University Hospital is depicted in Figure 10 which shows how the waste transmission system is connected to every department. This network involves the deployment of designated collection units, represented by green symbols, across various departments of the hospital. These collection units serve as points where waste is sorted and appropriately disposed of. Additionally, the waste network incorporates a mechanism for clean air

supply, depicted by black triangle symbols. This element is responsible for maintaining a fresh air supply and creating a vacuum-like suction effect, which ultimately directs waste towards the central processing center for effective treatment and disposal.

A network of pipes is used to transport four main categories of waste: **general waste, plastic, confidential documents, and paper**. Each type of waste undergoes a distinct treatment process upon reaching the waste treatment facility (see figure 11). As a result of these processes, energy is generated in the form of either electricity or heat. It is essential for those managing the waste to have a comprehensive understanding of the system to prevent the mixing of different waste types within the collection unit.

Moreover, it's crucial to highlight the pivotal role played by the waste treatment plant in promoting sustainability and minimizing its impact on the environment. The plant achieves this by converting waste into usable energy, thereby conserving resources, and decreasing dependence on non-renewable energy sources. Furthermore, the plant's operations contribute to reducing the volume of waste in landfills. This has the positive effect of lowering the potential for environmental pollution and associated adverse consequences. Ultimately, the responsible management and disposal of waste contributes significantly to upholding public health and safety, ensuring that the local community remains safeguarded from potential health risks.

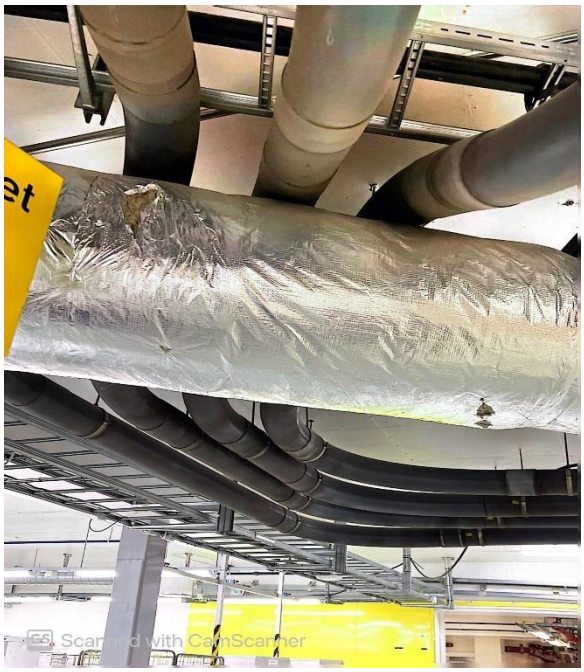

Figure 11: waste transmission pipes

Implementing a waste sorting and disposal system has revolutionized waste management. This innovative system uses a motor and pipes to transport waste to its designated disposal area, making waste management efficient and environmentally conscious. An operator can select the type of waste to be disposed of from a list displayed on the unit. Once the selection has been made, the motor kicks into action and moves the pipes to connect the waste to the appropriate disposal location.

Figure 12: Waste collection unit and Movable parts for Segregation

The waste sorting and disposal system plays a crucial role in mitigating pollution and safeguarding natural resources. Its efficiency leads to a reduction in landfill waste, subsequently decreasing the pollution of soil and water. Furthermore, effective waste disposal serves to conserve valuable resources that would otherwise be depleted if proper management practices were not in place. It cannot be overstated how vital it is to adhere to local waste disposal guidelines and regulations.

Governments and organizations across the globe have established these regulations and guidelines to ensure the proper handling of waste, aiming to protect both the environment and public health. By following these guidelines, the safe disposal of waste is ensured, benefiting both the environment and the general public. This approach significantly reduces the potential for environmental harm and contributes to the preservation of the health and well-being of future generations. These efforts align closely with the fundamental principles of the circular economy, underlining the importance of resource conservation and sustainability.

4.3.3 Waste Treatment at St. Olav university Hospital

Waste treatment involves a systematic approach to responsibly handling waste materials. Through deliberate processes, waste is treated to mitigate its impact on the environment and, in some instances, to recover valuable resources. This method is a key contributor to reducing the adverse effects of waste disposal on the environment and promoting sustainability.

In line with this philosophy, the concept of waste-to-energy conversion stands out as an environmentally conscious and sustainable waste management solution. By diverting a significant proportion of waste away from landfills, this approach effectively reduces the strain on these sites and decreases reliance on non-renewable energy sources. The process unfolds within specialized facilities, where meticulously sorted waste undergoes a transformation into usable energy using techniques like anaerobic digestion and thermal conversion. The energy harnessed through this process can be harnessed to generate electricity or power buildings, offering a dual advantage of waste management and energy production.

St. Olav University Hospital has taken charge of its waste management by setting up its own treatment facility to handle various types of waste. It's worth noting that waste requiring special care, like infectious waste, is responsibly managed by external organizations. Figure 13 gives us a glimpse of the waste treatment facility at Forsyningssenteret, where most waste gets treated.

Figure 13: Waste treatment facility

As depicted in Figure 14, when waste arrives through the pipelines, it enters the treatment chamber. What's impressive is that each type of waste has its own special chamber and storage space, all clearly color-coded for easy organization. This thoughtful arrangement not only simplifies the waste management process but also reflects a commitment to doing things right.

Figure 14: Treatment chambers

What's truly remarkable is that this waste treatment doesn't just stop at cleanliness – it generates something valuable. St. Olav University Hospital taps into this process to produce electricity and heating. In a way, waste becomes a unique source of sustainable energy, showcasing the hospital's dedication to both practicality and the environment.

4.3.4 Hazardous Waste at St. Olav university Hospital

In the intricate landscape of healthcare, an often overlooked yet critical aspect is waste management. St. Olav's Hospital has risen to the occasion, exemplifying an all-encompassing approach that prioritizes safety, environmental stewardship, and cutting-edge practices. This commitment is embodied in a meticulously designed set of protocols and practices that guide the hospital's waste disposal journey.

Each day, the hospital orchestrates a seamless process for waste collection and its subsequent transport to a central treatment hub. This meticulous choreography is not only driven by efficiency but also by a keen focus on minimizing the risk of work-related injuries. To this end, the responsibility of waste handling is predominantly entrusted to skilled waste handling staff and, in some instances, aided by the prowess of robotic systems (see figure 15). This harmonious fusion of human expertise and technology ensures both efficient waste management and the well-being of the hospital's dedicated workforce.

Figure 15: Pathological waste and robots

At the heart of St. Olav's waste management strategy lies an on-site treatment approach. The hospital deftly employs techniques like incineration and specialized treatment facilities to process a substantial proportion of its waste. However, the treatment of hazardous waste, notably the likes of pathological and infectious waste, necessitates a tailored strategy due to their heightened risk

profile. In response, St. Olav's Hospital collaborates with esteemed partners like Retura and Norsk Gjenvinning. These partnerships, while promising in their potential, bring forth unique challenges, as unattended hazardous waste could escalate infection risks, demanding a meticulous and swift management approach. To confront these challenges, St. Olav's Hospital has taken innovative strides. A standout example is the transportation of infectious waste. Recognizable yellow containers serve as a visual cue, while robotic systems primarily manage this crucial task. This proactive measure significantly curtails infection risks and underlines the hospital's unwavering commitment to the secure handling of perilous waste. Specialized treatment hubs, such as the Oslo treatment center and Senja, play a pivotal role in managing these unique waste streams. Simultaneously, a substantial portion of the hospital's waste finds a second life at the Heimdal treatment plant, cleverly transformed into energy for district heating.

In anticipation of safe and efficient hazardous waste disposal, St. Olav's Hospital has put in place a daily transportation mechanism to treatment sites. However, certain situations may warrant temporary on-site storage. Recognizing this, the hospital has ingeniously introduced dedicated storage compartments, meticulously maintained at a chilling -18 degrees Celsius. This cool environment effectively thwarts the growth of harmful microorganisms, significantly reducing the probability of infections and cross-contamination. This meticulous approach mirrors St. Olav's Hospital's resolute commitment to creating a safe and health-focused environment.

Figure 16: Storage and transport of hazardous waste

Zooming out to a broader context, the management of hazardous waste resonates with heightened significance. Laden with harmful substances, such waste poses a lingering threat to both the environment and human well-being. Inadequate handling can trigger the release of toxic substances, polluting soil, water, and jeopardizing both wildlife and humanity.

A conscientious approach to managing hazardous waste becomes essential, serving as a protector not only of our environment but also of our collective well-being. This interconnected narrative is closely intertwined with Waste-to-Energy (WtE) facilities, representing Norway's commitment to sustainable waste management principles. St. Olav's Hospital plays a significant role in the Heimdal incineration plant, contributing to Trondheim's district heating network. This innovative process harnesses the heat generated from waste incineration, not just for effective waste management, but also for generating sustainable energy. However, the WtE sector grapples with challenges related to renewable energy and strict emissions standards. The solution might lie in aligning WtE practices with a circular economy model, mitigating the environmental impact of economic activities (HCWH Europe, 2020).

An instructional video of how waste management works at St. Olav can be accessed with the link attached on the page. The video of the waste management system provides an educationalresource for those working within St. Olav’s hospital premises, demonstrating the appropriate methods for handling waste and raising awareness about the importance of responsible waste management. The automatic waste system helps to ensure that hospital waste management practices are environmentally responsible, reducing waste impact on the environment and promoting sustainability.

/www.youtube.com/watch?v=3yiSgROR0Ls

4.3.5 DME waste at St. Olav hospital

While investigating waste treatment at the hospital, a pertinent issue emerged regarding durable medical equipment (DME) waste. Durable Medical Equipment, or DME for short, refers to equipment that's built to last through multiple uses and is mainly intended for medical purposes. These items typically aren't something people would use unless they're dealing with an illness or injury. They're also designed to be suitable for home use. artificial limbs, leg support, wheelchairs, hospital beds, canes, crutches, walkers, oxygen therapy gear, and even the supply of oxygen gas itself – all of these falls under the category of DME (Janssen & Saffran, 1981).

Notably, there's a lack of data and clarity within the waste management department at St. Olav about such waste, which is projected to rise significantly in the coming years. The World Health Organization (WHO) anticipates DME waste to be among the world's fastest-growing waste streams, with a projected annual increase of 6%, driven by an aging population's escalating demand for medical equipment due to chronic diseases (World Health Organization, 2011). In Norway, DME waste presents a mounting challenge due to the country's rapidly aging populace. The Norwegian Directorate of Health reported that DME costs reached around 6.9 billion Norwegian Kroner (NOK) in 2018, constituting 1.4% of total healthcare expenditure. The majority of DME users are elderly individuals. Although Norway has initiated recycling and reuse efforts, more comprehensive strategies are required to ensure the safe and sustainable disposal of medical equipment. To address this, the Norwegian government introduced a take-back scheme obligating manufacturers to recycle their products post-use. However, this scheme's progress has been slow, emphasizing the need for robust policies to manage DME waste effectively.

At St. Olav Hospital, durable medical equipment (DME) is a cornerstone of patient care, sourced both internally and externally. The hospital acquires non-customized orthopedic aids from external vendors, while a subsidiary, "Trøndelag Ortopediske Verksted" (TOV), specializes in crafting personalized orthopedic equipment. TOV's expertise lies in designing, producing, and adapting orthopedic aids tailored to individual patient needs, with an emphasis on their specialized purpose and non-reusability (Phillips & Zuckerman, 2001). See figure 17 for DME handling at St. Olav hospital. In addition to orthopedic aids, St. Olav Hospital provides a diverse range of DME, encompassing home medical equipment, mobility aids, and assistive devices. These items are

typically procured from external suppliers or rented, with the hospital overseeing the delivery and installation process. Upon conclusion of their usage period, patients assume the responsibility of returning or appropriately disposing of the equipment.

However, the disposition of DME poses a considerable challenge both locally and globally. The burgeoning volume of DME waste raises environmental concerns as a substantial proportion finds its way into landfills or incineration. Beyond environmental impact, the improper disposal of DME could potentially engender public health hazards, given the potential presence of infectious materials or hazardous substances. The mitigation of these challenges requires concerted efforts to establish sustainable and responsible DME disposal practices.

Considering the multifaceted nature of DME use, its disposal predicaments, and the crucial intersection of environmental and public health considerations, this aspect of healthcare waste management presents a fertile ground for future research endeavors. Potential research avenues could delve into innovative disposal techniques that prioritize both environmental conservation and public health. Furthermore, investigations into policy frameworks, regulatory mechanisms, and collaborations between healthcare institutions and waste management entities could pave the way for more effective and holistic solutions in managing the evolving landscape of DME waste.

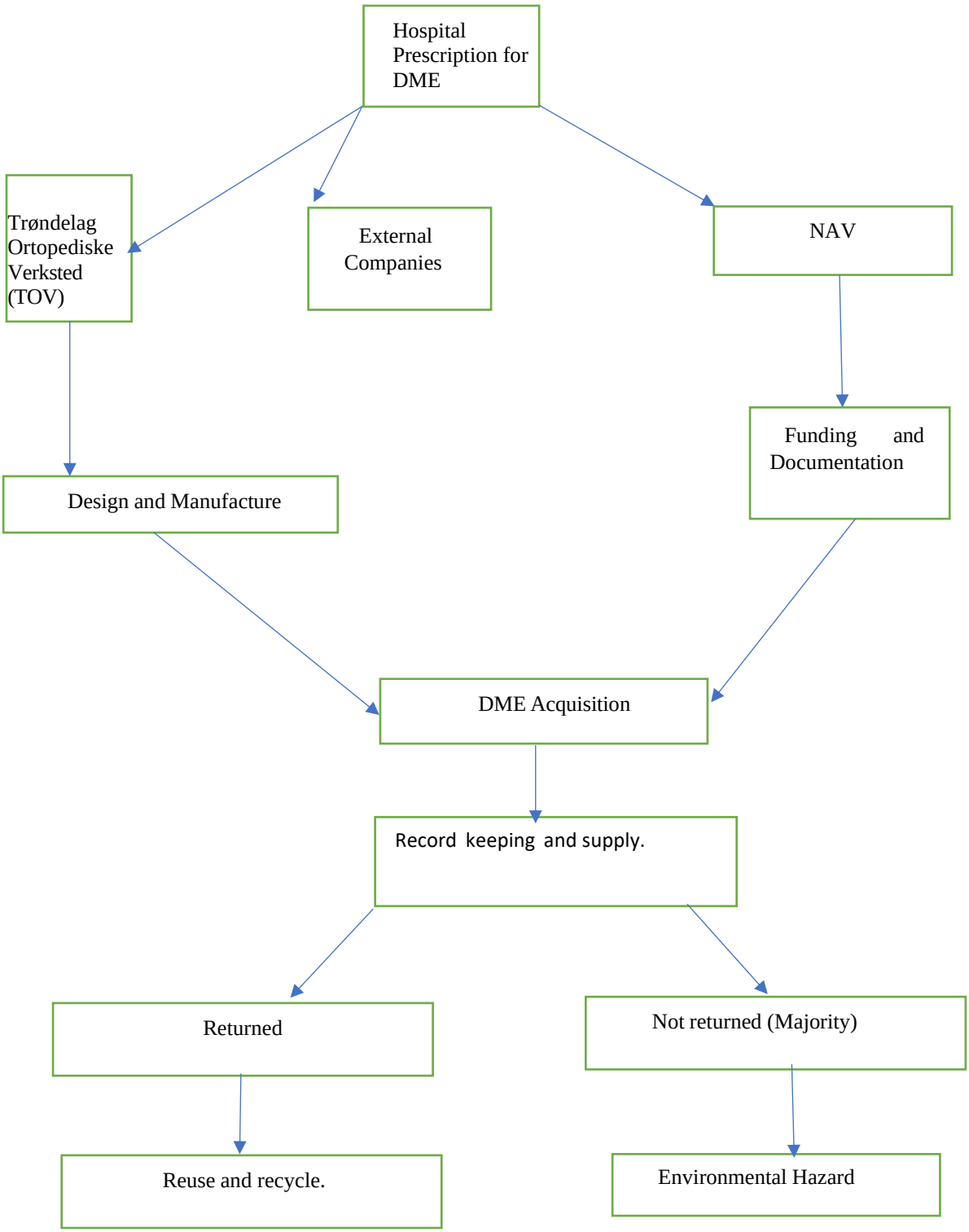

Figure 17: DME workflow at St. Olav hospital

4.3.6 Training and communication at St. Olav hospital

Following the revealing survey outcomes that highlighted the prominent challenges and areas requiring enhancement within the waste management facility at St. Olav University Hospital, our attention was drawn towards three crucial aspects: communication, education and training, and a sense of carelessness. Concurrently, this study strives not only to identify these challenges but also to propose pragmatic solutions in anticipation of their potential occurrence during our investigative journey.

In light of the aforementioned concerns, we have meticulously crafted two potential solutions to effectively tackle these hurdles. Firstly, we propose the establishment of a Healthcare Waste Management (HCWM) committee, vested with the responsibility of orchestrating comprehensive training and educational initiatives. Extensive prior research has consistently underscored the paramount significance of continuous training and knowledge augmentation among healthcare and sanitation personnel as pivotal instruments for the amelioration of HCWM practices (Tudor et al., 2005).

Furthermore, our proposed approach involves the incorporation of a waste management curriculum into relevant undergraduate programs. This curriculum will be specifically tailored for students pursuing related majors, while fundamental Health, Safety, and Environment (HSE) courses with a focus on waste management will be offered to all individuals within the hospital and university community. The primary objective of this curriculum integration is to cultivate a proactive comprehension of waste management practices. By instilling such knowledge early on in their academic journeys, our aim is to shape a future workforce that inherently prioritizes effective waste management techniques. It is essential to educate people through various means on how to minimize or reduce waste. Once individuals are informed about the environmental repercussions of waste and have been instructed on strategies to combat and decrease it, they can complement the efforts of municipal authorities (Kumar & Kumar, 2020).

In order to present these solutions effectively, it becomes imperative to gain a comprehensive understanding of the prevailing training protocols and communication hierarchy within the hospital. Additionally, it is vital to grasp the intricate communication hierarchies both within the hospital and the university (NTNU). This grasp of the overall system will enable us to formulate insightful recommendations that align with the organizational structure and effectively address the challenges identified.

4.3.7 Training at St. Olav Hospital

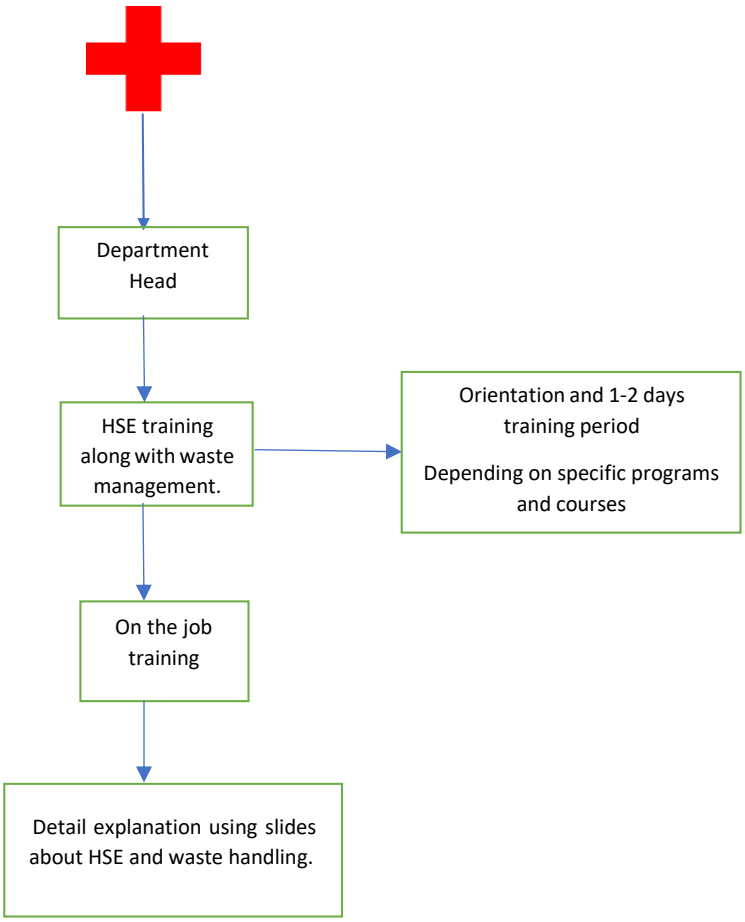

Figure 18: Training flowchart at St. Olav hospital

Figure 18 illustrates the training process conducted at St. Olav Hospital. The initiation of training and the development of effective training methods are the responsibilities of department heads, in collaboration with other supportive team members. The hospital's approach to training is straightforward, providing foundational information. However, it's not guaranteed that everyone within the hospital receives this information, as discussions with the staff have revealed.

Staff members typically receive their training through specific programs and courses, often in a hands-on, physical setting. Upon enrolling in courses at NTNU, they are offered basic Health, Safety, and Environment (HSE) training and other relevant training related to their studies. Surprisingly, waste management training does not currently have a dedicated module. This might

be because there is an assumption that everyone is already acquainted with waste management, including how to handle and segregate waste, given the availability of information in books and papers. However, practical experience is indispensable for comprehending the intricacies of waste management in real-life scenarios.

Despite possessing theoretical knowledge of waste management, staff members could greatly benefit from practical training. At St. Olav Hospital, department heads are responsible for organizing training sessions lasting 1-2 days, which include demonstrations of HSE training related to fire and other occupational hazards. Regrettably, practical training for effective waste management is conspicuously absent, and staff members are not fully cognizant of the gravity of this issue. Furthermore, there is a noticeable deficiency in follow-up training to keep staff members updated on recent changes to waste management policies.

4.3.8 Delegation of authority at the supply center

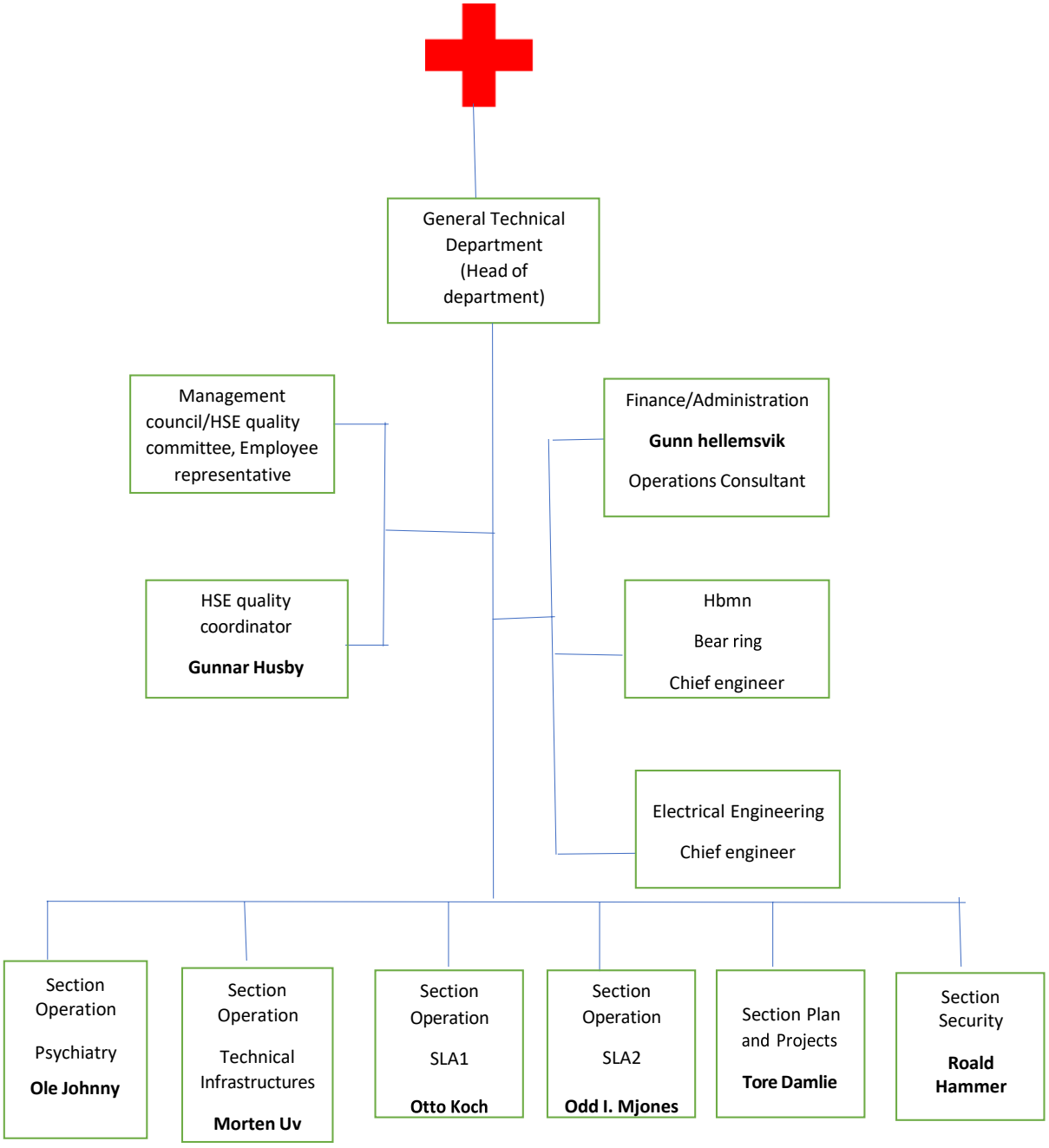

Figure 19: organizational structure at the supply center

Effective waste management at St. Olav Hospital hinges on seamless communication among various involved departments. Within any organization, waste management responsibilities are distributed across multiple departments, including operations, maintenance, safety, environmental health, and safety (EHS), and facilities management. Each department plays a crucial role in ensuring the safe and efficient collection, storage, transportation, and disposal of waste. However, the absence of effective communication among these departments can lead to a disjointed waste management process, resulting in confusion, delays, and potential safety risks, as highlighted by research (Obonadhuze et al., 2021).

Therefore, it is imperative to emphasize the importance of robust communication to ensure that all stakeholders engaged in waste management comprehend their roles and responsibilities fully. Through effective communication, each department can gain a clear understanding of how its functions contribute to the overall waste management process, fostering improved coordination and heightened efficiency. Additionally, effective interdepartmental communication can serve as a proactive means to identify and address potential safety hazards.

Figure 19 offers a depiction of the departmental hierarchy at St. Olav Hospital's Forsyningssenteret, or supply center. In this hierarchy, department heads oversee all activities, while various line managers or section operation heads are responsible for ensuring the smooth functioning of the supply center. They supervise lower-level staff and ensure that waste management adheres to established standards. However, through four significant meetings with one of the section heads responsible for overseeing operations at the waste management facility, concerns about communication within the hospital and with other departments have come to light.

According to this section head, the communication within the hospital is relatively straightforward but sometimes lacks proper follow-up. This issue has left him dissatisfied with the current state of communication. Recognizing and addressing communication challenges within St. Olav Hospital is vital, as it can significantly impact the efficiency and safety of waste management processes, ultimately contributing to a healthier and more sustainable healthcare environment.

4.4 Data Collection

The primary methods employed for data collection in this study encompassed one-to-one interviews and surveys since interviews are one of the most important case study evidence (Yin, 2018) and people's experiences and perceptions are obtained the best way when the interviewees can participate in shaping the interview (Johannessen, Christoffersen and Tufte, 2011). Online surveys were distributed to various individuals responsible for hospital operations. Despite having 42 views on our online survey, only four individuals responded and completed it. Meeting everyone in person proved to be challenging as they seemed busy. Nevertheless, we managed to connect with some of them and gather valuable insights into their waste management practices. Our participants comprised section heads, nurses, and workers at Forsyingsenteret. Participants were identified as A1, A2, A3, and A4 to ensure confidentiality. To gain comprehensive insights into waste management operations at St. Olav University Hospital, we sought out experienced and knowledgeable individuals in areas such as strategy, current operations, and technology.

Our initial contact was established with a section leader at Forsyingsenteret, who became our formal/informal liaison and facilitated connections with other relevant department personnel. Participants in the interviews had varying levels of work experience, ranging from more than 5 years to 1-3 years or less than a year for temporary employees. All interviews were conducted in person during a field visit to St. Olav Hospital. Before each interview, we meticulously prepared an interview guide comprising both open-ended and structured questions. All interviews were recorded using a sound recording app on a mobile phone and subsequently transcribed. During the interviews, detailed notes were also taken. Relevant statements were later translated into English before being incorporated into the thesis. The questionnaire was meticulously designed and tailored to assess the knowledge and practices of healthcare waste management at St. Olav Hospital. It comprised approximately 21 questions, including some informal or friendly inquiries (see Appendix). The questionnaire was initially drafted in a Word document and later transformed into an online survey using a dedicated survey system. The online survey was designed for maximum accessibility and ease of use, requiring an internet connection for initial access but offering the option to save or download the survey for later completion. The questionnaire was first administered to professionals in January 2023. The study duration extended beyond the initial expectations due to challenges in obtaining responses from participants, necessitating multiple

follow-ups. Eventually, we managed to collect valuable information related to our study topic. The time required to collect data from professionals varied, contingent upon the need to verify the validity of survey responses. Response times for completed surveys ranged from approximately 20 days to one month or longer among professionals.

4.5 Data Analysis

The data analysis process in this study was guided by the works of Creswell and Poth (2016), Yin (2018), and Leedy and Ormrod (2015b). Figure 20 illustrates the five major developmental steps involved in this analysis. Notably, the three steps highlighted within circles were carried out iteratively, with a particular focus on the read-through and coding stages. It is important to emphasize that, according to Leedy and Ormrod (2015b) and Creswell and Poth (2016), the process of analysis and interpretation typically commences early in the research process, often occurring concurrently.

In my own research, I observed a similar pattern. Even though I actively engaged in the analysis of interview data at a specific point in time, the process of reasoning from these interviews had its inception during my initial interactions with employees at the hospital in the context of my thesis work. Subsequently, my visit to the waste facility at St. Olav Hospital for waste management marked a pivotal moment in my research journey. From the very first conversation related to my master's thesis, I began comparing and contrasting the impressions and insights that were starting to take shape.

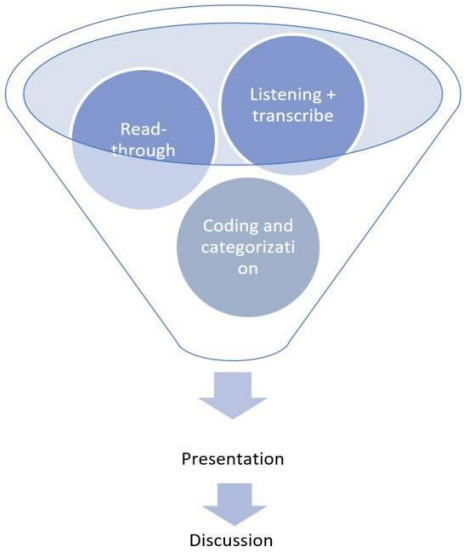

Figure 20: models for data analysis

The initial step in our formal analysis process involved a meticulous review of the recorded interviews, resulting in nearly verbatim transcriptions of the conversations. Following this, I conducted a swift initial read-through of these transcriptions to gain an overview and identify any prominent topics that immediately caught my attention. This initial review led to the creation of a concise list of primary categories, which would serve as the foundation for further coding. This preliminary organization of the data was instrumental in aiding recall and facilitating its use as the analysis progressed, aligning with the guidance of Leedy and Ormrod (2015b).

Subsequently, I established a table with these codes after making notes from descriptions, which would later become a key tool for labeling data pieces conceptually similar to a single main category, a process often referred to as "memoing." With this structure in place, I proceeded to conduct a thorough, in-depth review of each interview individually. During this phase, I carefully filled in the preliminary table with the primary highlights of what each participant had shared, along with the corresponding code generated from their descriptions (see table 3). In parallel, I began the process of memoing, as advocated by Creswell and Poth (2016). This involved capturing statements and ideas from the interviews and placing them into the relevant categories within the table, thereby aiming to extract a deeper level of insight and information from the interview data. Throughout this process, it's worth noting that the interviews adhered closely to the structure outlined in our interview guide, which was designed to focus on identifying specific challenges. As a result, we were able to distill three major themes that participants emphasized as requiring significant attention and consideration.

4.6 Assessment of Research Method

In assessing the quality of our research, it's important to consider the central concepts of reliability and validity, as emphasized by Yin (2018). Reliability, in essence, refers to the ability to obtain consistent results if the study were to be repeated. Our literature guide, as outlined in the appendix, reveals that many of the questions we posed relate to the actions taken by individuals, their procedures, and suggestions for improvement. Consequently, it's reasonable to expect that many of the responses would indeed be similar, given that they represent common practices within the hospital. This is especially true within a limited time frame, as change is a continuous process in any organization.

Validity, particularly in qualitative studies, revolves around the degree to which the researcher's methods and findings accurately align with the study's purpose and effectively depict the reality being investigated, as highlighted by Jacobsen (2005). Internal validity, in the broader context of research, pertains to the extent to which the methods and data employed enable us to draw accurate conclusions about cause-and-effect relationships and other relevant connections, as described by Leedy and Ormrod (2015a). In qualitative research, ensuring that the research closely aligns with its intended purpose is crucial. Throughout our study, we have prioritized transparency, striving to provide a clear and honest account of our methods and findings. This includes collecting data from multiple sources, such as public documents, site visits to a sorting facility, and in-depth interviews with key personnel.

Turning to external validity, it refers to the extent to which research findings can be applied to contexts beyond the specific study, essentially addressing the generalizability of the study's results. It's important to clarify that our research was not conducted with the aim of providing insights into all hospitals or the entire municipality of Trondheim. Rather, our focus was specifically on St. Olav University Hospital. However, it's worth noting that our study does offer valuable information that may be transferable to other hospitals dealing with medical solid waste, shedding light on conditions and practices that could be relevant in a broader context.

4.7 Ethical approval

In this study, there was no requirement for ethical approval since no personal health data or biological material was collected. It does not require formal clearance from the Norwegian Regional Committee for Medical and Health Research Ethics (REC). All Consortium members involved as contributors to the study know most of the information sought is publicly available. Anonymity and confidentiality are ensured by not reporting or publishing personal details of participants.

5 Findings

The findings from the study suggest that although the participants had some prior knowledge of healthcare waste management, they were not fully content with the existing system. We analyzed the data further through focused coding (see appendix), which involves identifying patterns and relationships between the codes. In this study, coding could involve identifying the relationships between the initial codes and grouping them into broader themes as shown in fig 21, such as "Training and Education," "Communication," and "Carelessness."

For instance, participants emphasized the need for more comprehensive and regular training on waste management practices to enhance their understanding and promote proper disposal ofmedical waste. They also highlighted the importance of effective communication between healthcare workers, waste management personnel, and the management team to ensure compliance with waste management policies and regulations. Furthermore, participants raised concerns about carelessness in waste management practices, such as improper segregation and disposal of hazardous waste, which poses a risk to public health and the environment. Addressing these issues is crucial to promote sustainable healthcare waste management practices and ensure the safety and well-being of the community.

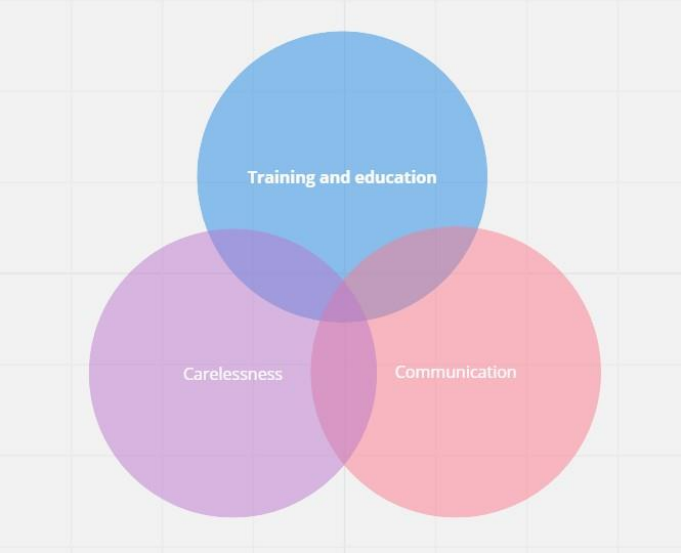

Figure 21: Main categories after analysis

A1	A2	A3	A4
Proper segregation	Timely waste collection	Focus on pharmaceutical waste	Training
Inadequate Leadership	Lack of communication and coordination	Inadequate training	Interdepartmental communication
Practical training	On the job training	Transparency in the workplace	Mixing of organic and inorganic waste
Recent Updates	Supervision team formulation		

Table 5: codes from participants responses

Table 5 illustrates how concepts extracted from the narrative data function as the foundation for constructing theoretical arguments, a process commonly referred to as memoing. Each column in the table corresponds to codes generated through the analysis of themes derived from data provided directly by participants, obtained through interviews or surveys. Upon analyzing the responses gathered from in-depth discussions and specifically designed questions, we identified three main categories that require attention to improve the healthcare waste management system. These categories include Training and education, Communication, and Carelessness, and we have developed a comprehensive plan that addresses each concern raised by the participants.

Training and education: Practical training; on the job training; inadequate training and education

Communication: Inadequate leadership; lack of communication; Transparency; Interdepartmental communication

Carelessness: Segregation; timely waste collection; pharmaceutical waste

5.1 Main category 1: Training and Education

The initial theme that surfaced during our analysis revolved around "Training and Education." It became evident that the proper handling of medical waste, in accordance with established standards, heavily relies on the knowledge and skills of the staff responsible for waste management. As emphasized by Khashaba et al. (2023), a combination of effective training and supervision is pivotal for the success of waste management programs.

At St. Olav's Hospital, a consensus emerged among most participants, highlighting concerns about insufficient training for staff members in proper waste management practices. Additionally, it was noted that temporary workers, especially during the summer months, receive inadequate training. An alarming finding was that 75% of participants reported rarely or never receiving updates regarding healthcare waste management policies. Furthermore, almost all participants expressed the need for waste management to be integrated into the nursing curriculum. This aligns with the growing trend in universities, as discussed by Davis and Read (2006), where courses or modules in waste management are being developed to ensure the delivery of high-quality education with up-to-date information and practical examples.

A4: *"Temporary workers are not given enough attention for the training rather training is kindof formality done for few days with some slideshow which is not so effective."*

Participant A4 raised a pertinent issue regarding the effectiveness of training, highlighting that it often appears to be a mere formality conducted over a few days with slide presentations that are not particularly impactful. This sentiment underscores the importance of ensuring that the purpose of training is fully realized. While some information may be available, it may not reach all staff members, including those responsible for waste handling. Such gaps can lead to errors in waste handling and treatment, with potential adverse consequences for both the environment and public health.

A1: "I *have been working here for more than 5 years now and, I have not experienced getting involved in some kind of practical waste training programs".*

A2*: "I attended on the job training at the beginning of my job, which was focused on HSE and just a bit about waste management."*

Participants A1 and A2 shared their experiences with training at the hospital. A1 mentioned the absence of practical waste management training despite five years of service, while A2 described training primarily focused on Health, Safety, and Environment (HSE), with limited emphasis on waste management. Both participants highlighted the need for more practical and comprehensive training programs. During informal discussions, participants emphasized the importance of mandatory training courses and in-person instruction. These measures could ensure that all staff members and even visitors are well-versed in the proper procedures for handling various types of waste, promoting confidence and safety in their duties.

A relevant quasi-experimental study conducted in a Spanish hospital, as cited by Mosquera et al. (2014), demonstrated that healthcare waste management training can improve biomedical waste segregation, thereby reducing waste volume and associated costs. The participants themselves recognized the lack of sufficient training in healthcare waste management and the absence of regular updates on the matter as a significant challenge they encountered during their work. The table below illustrates the descriptions provided by participants, with initial codes derived from these descriptions. These initial codes were further categorized into three main themes.

Code	**Description**
Lack of training	Participants stated that staff lack proper training on healthcare waste management.
Temporary workers	Temporary workers during summer do not get enough training.
Ineffective training	Training is often not effective and does not fulfill its purpose.

Practical training	Participants emphasize the need for practical training and regular updates on healthcare waste management.
No regular updates	Participants highlighted that there are no regular updates on healthcare waste management.

Table 6: Table showing the origin of category1; Training and Education

5.2 Main category 2: Communication

The second prominent theme that emerged from our analysis is "Communication." Effective waste management within a hospital setting relies heavily on robust communication among various departments. This is not only essential for meeting patient needs and ensuring safe, high-quality, patient-centered care, but it also plays a pivotal role in how healthcare delivery is managed (Merlino, 2017). However, numerous participants expressed concerns regarding communication and coordination at St. Olav's Hospital.

Many participants voiced their argument over the lack of effective communication between different departments, which, in turn, can lead to issues in waste handling and treatment. Even minor aspects like the proper dissemination of information could be significantly improved, considering the hospital's advanced technological capabilities. Remarkably, 75% of the respondents indicated that they were not even aware of, let alone included in, decision-making processes related to Health, Safety, and Environment (HSE). This underscores the need for enhanced communication and staff involvement.

Improving communication and involving staff in decision-making processes can foster better relations among colleagues and enhance the effectiveness of their work. Furthermore, positive communication among employees can positively influence an individual's level of organizational commitment and motivation (Chmielewska et al., 2020). When asked about the improvements they would like to see, some respondents specifically highlighted the importance of clear and concise communication.

A2: "I don't know about people's nature but communication between departments and within can

be made more better…umm transparency within what is going on and what changes have been made."

A3: "the main thing is training and communication for me. proper coordination among staff members and…good leadership is also important."

A1: "I have never involved in decision making process related to waste management practices at the hospital…and my problem is not even that but how common mistakes keeps happening because of minor causes"

Participant A2 emphasized the significance of communication both between and within departments. They noted that in Norway, it's a common tendency for people to keep to themselves and only communicate when absolutely necessary. However, they highlighted the potential benefits of being more open and communicative, particularly in achieving organizational goals. Prioritizing effective communication can have a substantial impact on enhancing the speed and accuracy of employee tasks, especially when combined with improvements in communication structures (Musheke & Phiri, 2021).

A2 also stressed the need for transparency when it comes to changes made by higher authorities or senior staff, particularly regarding major policy updates, such as those related to healthcare waste management. According to Kahn (1990), engagement in the workplace means being not only physically but also psychologically present while fulfilling an organizational role. Engaged employees are passionate about their work and feel a deep connection to their company, which, in turn, fosters innovation and propels the organization forward (Gallup, 2004).

Participant A3 highlighted the importance of training, communication, and effective leadership. Although they didn't delve into the specific reasons behind these points, their emphasis suggests that these elements are vital. Effective leadership practices rooted in values like respect, trust, and open communication are crucial not only for delivering high-quality care but also for creating a positive work environment where staffs feel respected and valued. This, in turn, helps maintain their motivation, job satisfaction, and commitment to the organization (Field & Brown, 2019).

Participant A1 made an insightful observation about how employee involvement in organizational decision-making can serve as a motivating factor and foster healthy relationships. A1 also pointed out that common and simple mistakes continue to occur due to ineffective communication among staff members. The codes from the participants' descriptions are summarized in Table 7 for reference.

Code	Description
Lack of communication	Participants stated that there is a lack of communication and coordination between departments that can lead to problems with waste handling and treatment.
Transparency	Participants emphasized the need for transparency and effective communication channels between departments.
Proper labeling	Participants highlighted that administrative staff may not be aware of the procedures for properly labeling and segregating waste.

Table 7:Table showing the origin of category 2: Communication.

5.3 Main Category 3: Carelessness

The third prominent theme that emerged during our analysis of waste management practices at St. Olav's Hospital is the issue of carelessness among employees. This theme highlights a significant concern where the lack of attention to detail by staff members can potentially lead to occupational hazards. While employees are generally aware of their responsibilities in waste disposal, instances of human error and carelessness can result in serious consequences.

A critical incident was brought to our attention by Participant A4, highlighting a grave concern within St. Olav's Hospital's waste management practices. A4 revealed an alarming situation where the contents of a waste bin were required to be clearly indicated on a sticker affixed to the outside of the bin. However, a significant problem arose due to the uneven placement of these stickers in relation to the bin's actual contents. This seemingly minor oversight had the potential to lead to a serious issue – the misclassification of waste categories. This act of carelessness had far-reaching implications, primarily increasing the risk of mixing different types of waste. Such mixing poses a substantial threat, particularly in a hospital setting, as it heightens the likelihood of hospital-acquired infections and other related problems. It's worth noting that approximately 25% of hospital waste is estimated to have the potential to cause life-threatening infections, as reported by Khan et al. in 2017. These infections primarily pose risks to individuals within the hospital environment.

A4: "There have been instances where waste containers have been improperly labeled, because of stickers placement, causing different types of waste to be mixed together."

Figure 23 illustrates the vertical placement of the sticker contents, which had been a contributing factor to this issue. In the rush of daily tasks, staff members may inadvertently mark the wrong category when disposing of pathological waste. This oversight significantly heightens the chances of infections spreading within the hospital environment. In response to this critical concern, Figure 22 demonstrates a proactive solution implemented to mitigate these incidents. The tick box for pathological waste disposal has been strategically relocated to reduce the likelihood of such errors. This measure has been taken to enhance precision in waste disposal and minimize the risks associated with carelessness among staff members.

Figure 23: sticker before

Figure 22: sticker after

A2:" due to improper segregation of waste, the hospital is charged over 25000nok after it is inspected by the waste handling companies. This can be minimized if we be careful and separate the waste."

A1: "Organic waste is stored in plastic bags, which causes leaks and emits bad odors and that feels unpleasant in a hospital because it sits there for long period sometimes".

Participant A2 made a significant revelation concerning the financial implications of improper waste segregation at St. Olav's Hospital. A2 pointed out that the hospital incurs substantial costs, amounting to over 25,000 NOK, every time waste handling companies come to collect waste if proper waste segregation has not been carried out initially. This assertion underscores the critical importance of attention and sincerity during the initial waste segregation process. By ensuring that waste is correctly categorized at the source, incidents of improper disposal can be greatly reduced, thereby preventing unnecessary costs. Achieving this objective necessitates a comprehensive approach involving training, education, and effective communication among staff. These elements are intrinsically linked and, when executed cohesively, have the potential to yield significantly improved results.

Moreover, implementing a robust waste segregation program offers additional benefits, as highlighted in a case study article from 2016 (Choi & Jung, 2016). Such a program not only promotes environmental responsibility but also mitigates the expense associated with waste disposal in landfills. Participant A1, on the other hand, emphasized a specific issue related to organic waste within the hospital environment. A1 drew attention to the problem of foul odors

resulting from untimely waste collection. To address this concern, it is imperative to establish a well-structured routine for the timely collection of organic waste. This routine can be effectively managed and overseen by a dedicated waste management committee. Table 8 serves as a valuable resource, illustrating how we generated codes from participant descriptions and subsequently grouped them into relevant categories, facilitating a more systematic analysis of the issues at hand.

Code	Description
Improper labeling	Participants stated that there have been instances where waste containers have been improperly labeled, causing different types of waste to be mixed.together.
Segregation	Participants emphasized the need for proper segregation of waste toavoid contamination and increased costs.
Storage of organic waste	Participants stated that the storage of organic waste is a challenge in the waste management system at St. Olav's Hospital and highlighted issues suchas leaks and bad odors.

Table 8: Table showing the origin of category 3: Carelessness.

5.4 Barriers in Healthcare Waste Management at St. Olav Hospital: A European Perspective

St. Olav Hospital, like many European healthcare institutions, faces specific challenges related to healthcare waste management. These Barriers, if left unaddressed, can have serious repercussions not only for the hospital's operational efficiency but also for environmental sustainability and public health. Here, we explore how these issues manifest at St. Olav Hospital and the potential impact on healthcare waste management:

1. **Social norms**: Social norms play a crucial role in shaping human behavior, operating through two primary mechanisms: conformity and compliance. Conformity occurs when individuals align their actions with perceived socially acceptable behavior, while compliance involves modifying behavior to elicit a positive response or avoid punishment. The "social context," representing the observable behavior of others, significantly influences behavior change, as exemplified in the realm of recycling attitudes (McKenzie-Mohr & Smith, 1999; Derksen & Gartrell, 1993).

   In our specific case, highlighted by participant responses and interviews, instances of improper waste segregation were noted. Notably, pharmaceutical waste being erroneously mixed with other types led to a substantial fine of 25,000NOK for the hospital due to inadequate segregation practices. This issue may be rooted in the patterns of waste handling among hospital staff, influenced either by conformity—adhering to established practices—or compliance—altering behavior to avoid negative consequences. Effecting change in these established habits necessitates clear communication among staff members, leveraging their capability to address and rectify the situation.

   Another contributing factor could be a sense of carelessness, where despite the knowledge that waste should be separated, adherence to proper procedures is inconsistent. The moral responsibility for waste separation often hinges on two factors: understanding the consequences of specific behavior and self-ascription of personal responsibility (Kaiser & Shimoda, 1999). The lack of personal responsibility may stem from a broader belief that solving environmental problems is primarily the government's responsibility, rather than an individual's (Valle et al., 2004).

2. **Education and Training**: Despite the wealth of information available on proper waste management on the internet, the actual implementation leaves much to be desired. Fig 22 illustrates that training at St. Olav Hospital is suboptimal. Notably, temporary workers receive insufficient or no training at all, and there is a lack of follow-up on changes in waste management policies with employees. Participation in training programs is a unique social behavior, requiring individuals to invest personal resources such as time and effort, often without a genuine commitment to applying the knowledge in real life (Murrey, 2004).

   To address this issue, it is imperative to improve the training at St. Olav Hospital. Staff members need regular updates on waste management policies and changes, along with an understanding of how their actions impact the environment. Establishing a dedicated team or committee to ensure compliance with standards and overseeing training, monitoring, and feedback processes is crucial. Currently, a deficiency in monitoring and feedback exists, highlighting the need for a governing body to coordinate these aspects effectively. Providing information on environmental impacts and threats related to waste management can enhance awareness and serve as a catalyst for behavioral change (Åberg, 2000).

   However, in our case, the lack of continuous follow-up and feedback after the initial training sessions hinders the effectiveness of these programs. Over time, without additional information and reinforcement, individuals may gradually forget about training programs. To combat this issue, it is essential to establish a system that (1) consistently reminds the community about waste management practices and (2) provides ongoing feedback on the progress made in the waste management strategy (ACT Waste, 2000). This ensures that the knowledge and commitment gained during training are sustained and translated into consistent, environmentally responsible practices among staff members.

3. **Culture of communication**: Understanding and adapting to cultural nuances is crucial in addressing complex issues like waste management. Interpersonal communication, as highlighted by Windahl et al. (1992), plays a pivotal role throughout the stages of persuasion, decision-making, and implementation. Rogers (1983) emphasizes the importance of aligning communication with the values and beliefs of the audience. In the

context of Norway, a culture where communication tends to be reserved and purpose-driven, tailoring communication strategies becomes essential.

My personal experiences and field observations in Norwegian culture revealed a significant departure in the approach to interpersonal communication. Norwegians engage in communication sparingly, making it challenging for outsiders to interact and gather information, especially when compounded by a language barrier. To enhance the effectiveness of waste management communication, strategies must align with the cultural norms of Norway. Adapting communication to be similar to the people being addressed and speaking in a language resonant with their values and beliefs is crucial, as emphasized by Rogers (1983).

Within a hospital setting, interdepartmental communication emerged as a critical challenge. Staff members exhibited uncertainty regarding the handling of waste from their respective departments, perceiving waste management as outside their purview. This breakdown in communication adversely affected waste management processes within the hospital. A notable example involved the use of stickers for pathological waste as depicted in fig 11 and 12. Despite efforts to reduce waste mixing by changing stickers, recurring instances of mixing persisted. Investigation revealed that certain departments continued using the old stickers, showcasing a lack of communication. Staff members failed to perceive waste management as their collective responsibility. The hospital scenario underscores the need for effective interdepartmental communication. As advocated by McKenzie, communication programs must emphasize acceptable behaviors and provoke discussions to foster a sense of shared responsibility. Each individual's role in resolving environmental issues should be underscored, ensuring a collective understanding that every effort counts (Christchurch City Council, 2004; O'Leary & Walsh, 1995).

In conclusion, navigating the cultural landscape of Norwegian communication demands a nuanced approach, especially in addressing critical issues like waste management. By aligning communication strategies with cultural norms, emphasizing shared responsibility, and fostering open dialogue, communication gaps can be bridged, promoting sustainable practices within the healthcare system and beyond.

6 Solutions

Addressing the healthcare waste management challenges at St. Olav hospital requires a set of effective recommendations, coupled with a well-thought-out plan for their implementation. As we delve into these solutions, it becomes evident that one of the pivotal measures is to enhance training and foster improved communication across departments. Given St. Olav's status as a university hospital, the need for seamless coordination between its various units, including NTNU and St. Olav, cannot be overstated. This approach serves multiple purposes; not only does it ensure that all departments stay well-informed about forthcoming changes and updated procedures, but it also nurtures a spirit of collaboration and unity among the different segments of the hospital. The comprehensive solutions are elaborated upon below.

6.1 Formation of Healthcare waste Management Committee

The establishment of a dedicated healthcare waste management committee at St. Olav University Hospital, in collaboration with NTNU, represents a significant leap forward in addressing the challenges of communication and training effectively. This committee assumes a critical role in enhancing healthcare waste management practices and ensuring compliance with local regulations. The composition of the HCWM committee is of paramount importance, with members drawn from both NTNU and St. Olav Hospital. These members span various departments, encompassing waste management, infectious disease control, environmental health, nursing, and safety teams. Ensuring that committee members possess the requisite knowledge and expertise in waste management and infectious disease control is pivotal to their effectiveness in achieving the committee's objectives. See Fig 24 for a brief visual guide on HCWM committee Main highlights.

As we delve into how the committee tackles these challenges, it's essential to recognize the pivotal role this committee alone plays. The adoption of these approaches positions the committee in a central and transformative capacity, notably improving communication and coordination not only between NTNU and St. Olav Hospital but also within and among different departments. This collaborative approach transcends the mere resolution of problems; it becomes the driving force behind the cultivation of highly effective waste management practices.

Within this framework, there exists a steadfast commitment to strict compliance with regulations and the embrace of circular economy principles. This commitment goes beyond words; it represents a profound dedication to environmental sustainability. These collaborative endeavors resonate with our shared aspiration of creating a cleaner and healthier environment. Healthcare Waste Management (HCWM) committee offers a solution to the challenges surrounding training and communication in the following ways:

a**) Establishing Clear Communication Lines**:

In line with Figure 24, a Healthcare Waste Management Committee (HCWMC) is formed, comprising members from both within the hospital departments and in joint cooperation with NTNU. Proactively, the committee establishes robust communication channels between representatives. This includes routine meetings, designated points of contact, and efficient email correspondence. To enhance communication further, designated liaisons are appointed to facilitate seamless communication. Simultaneously, individual hospital departments prioritize open communication, empowering employees to express opinions without apprehension of workplace repercussions (Charaba, 2023). The committee actively cultivates a culture of transparent communication between the hospital departments and NTNU, providing platforms for staff to contribute feedback and propose enhancements, thereby reinforcing collaborative efforts.

b**) Developing a Comprehensive Communication Plan**:

The committee devises a well-defined communication plan, delineating the exchange of information between within the hospital departments and in joint cooperation with NTNU. This plan specifies communication channels, the frequency of updates, and key individuals responsible for conveying vital information. For instance, each department appoints a key individual to communicate collective information to the committee through established procedural standards.

c) **Facilitating Joint Training Sessions:**

To ensure consistency in waste management practices, the committee conducts joint training sessions for staff from both within the hospital departments and in joint cooperation with NTNU. These sessions ensure that all personnel are well-versed in their roles, responsibilities, and the policies and procedures governing healthcare waste management. Additionally, it is crucial to

extend education to visitors by incorporating informational videos on public monitors, as research indicates that observed behaviors influence subconscious tendencies (Bargh, 2013).

d) **Introducing a Standardized Reporting System**:

The committee implements a standardized reporting system to monitor various facets of waste management, including waste generation, disposal processes, and associated costs. Recognizing potential challenges in data presentation due to confidentiality concerns or data unavailability, a standardized reporting system allows for the organized recording of confidential and general information. This not only aids in identifying areas for improvement but also facilitates comprehensive decision-making (Morrison, 2022).

e) **Conducting Regular Policy Reviews:**

To align with local regulations and best practices, the committee conducts periodic reviews of waste management policies and procedures. To enhance this process, it is recommended to involve responsible individuals from Trondheim kommune. The evaluation engages all stakeholders in waste management, encompassing representatives from all departments and other relevant stakeholders under Trondheim kommune's oversight. Active participation of hospital departments and joint cooperation with NTNU representatives in these reviews fosters collaboration and ensures that policies are continually updated. Implementing a waste management qualification questionnaire, either online or physically, serves as a valuable tool for regular policy updates within departments.

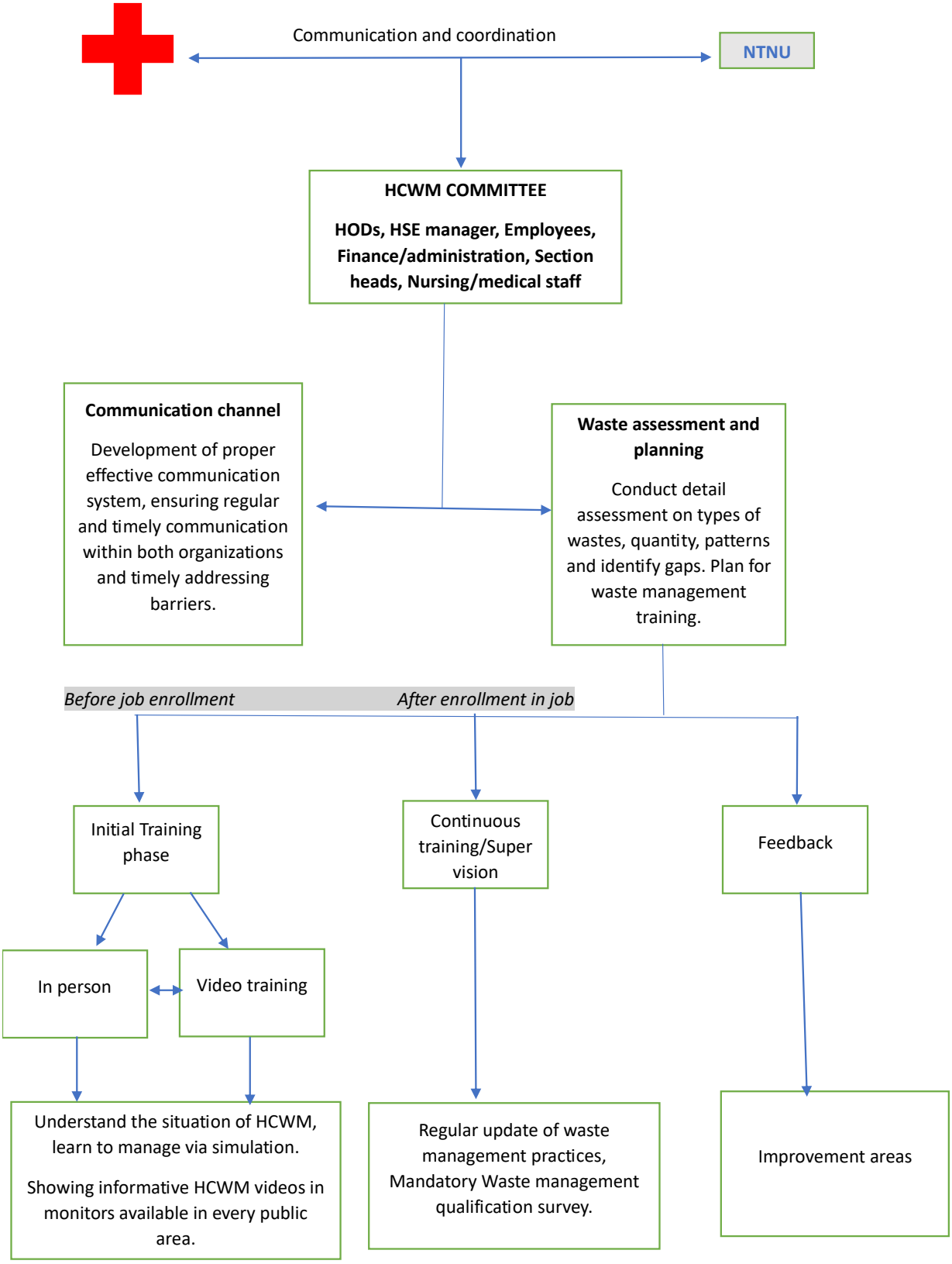

Figure 24: HCWM committee formation and task highlight

6.2 Waste Management Curriculum

Curriculum Outline:

I. Learning Objectives

- Identify the types of healthcare waste.
- Understand the hazards associated with healthcare waste.
- Develop a plan for safe healthcare waste management.
- Demonstrate the skills required for effective healthcare waste management.

The first year of study

Introduction to Healthcare waste management

- Definition of healthcare waste
- Types of healthcare waste
- Sources of healthcare waste
- Hazards associated with healthcare waste.

Healthcare Waste Management Practices

- Segregation of healthcare waste
- Collection and transportation of healthcare waste
- Treatment and disposal of healthcare waste
- Monitoring and record-keeping

Second year

Safe Handling of Healthcare Waste

- Personal protective equipment (PPE)
- Procedures for handling healthcare waste
- Decontamination and disinfection

Legal and Regulatory Frameworks for Healthcare Waste Management

- National and international laws and regulations
- Institutional policies and guidelines
- Roles and responsibilities of healthcare workers

Third year

Assessment and Evaluation

- Formative assessments
- Summative assessments
- Evaluation of the effectiveness of the curriculum

The curriculum plan above outlines how different aspects of healthcare waste management is distributed across each academic year. While the main idea is to progressively integrate the curriculum each year, an alternative approach to finalize content integration is by conducting surveys among students or employees. These surveys would gather insights into which specific aspects they believe are suitable for each year based on their perceptions. Building on this curriculum, a mandatory test, similar to HSE assessments conducted at the start of a course, could be developed for evaluation. The most effective solution for healthcare waste management would be a combination of solid theoretical education and practical training.

Healthcare waste management is a critical component of healthcare delivery, ensuring the safety of patients, healthcare workers, and the environment. It's imperative to equip both staff and students, particularly bachelor's students, with the necessary knowledge and skills to effectively manage healthcare waste. This curriculum aims to offer students a comprehensive understanding of healthcare waste management, encompassing various aspects such as the different types of healthcare waste, the associated hazards, and the safe disposal methods.

Given that the hospital is affiliated with a university, there is a continuous influx of students in the area. Providing them with information on waste management policies, the evolving landscape of waste management, and the importance of environmental sustainability is essential. Achieving a zero-waste goal is contingent upon everyone taking waste management seriously. Moreover, for local residents and other visitors to the hospital, imparting waste management education through informative videos on public monitors, featuring recent updates, can have a lasting impact on their awareness. Research has demonstrated that such approaches can influence people's attitudes subconsciously. while activation of human motivation does not necessarily involve conscious processes (Bargh, 1990).

This curriculum originates from a set of training modules developed within the framework of the Global Health-care Waste Project. This collaborative project is supported by UNDP, the Global Environment Facility, WHO, Healthcare Without Harm, and the University of Illinois School of Public Health. Despite the existence of various training programs for effective waste management, the most impactful results can be achieved when these programs are taken seriously and made

accessible to young people. This is because youth will play a crucial role in shaping a better future for our planet. Currently, most individuals, including students, have a basic understanding of waste management, such as knowing where to dispose of waste. However, there is still a prevailing sense of indifference because people are not fully aware of how their actions contribute to the gradual deterioration of our environment.

Our proposed curriculum, once finalized, has the potential to educate and inform young people about waste management. Furthermore, we can introduce training programs for the general population. Establishing a Healthcare Waste Management (HCWM) committee and integrating this curriculum into relevant courses at NTNU will instill a sense of responsibility in students. They will gain an understanding of how the world is transitioning toward a circular economy and how they can contribute to this transformation. With the HCWM committee overseeing all aspects of this curriculum, we can effectively address training and communication challenges. Ultimately, enhanced knowledge about the subject will reduce apathy and promote environmental sustainability.

7 Discussions and Conclusions

This study conducted at St. Olav University Hospital focuses on a comprehensive analysis of their waste management practices within the context of circular economy principles. The core objectives encompass identifying the hospital's waste strategies, assessing their alignment with circular economy tenets, and identifying areas for enhancement to facilitate a transition towards circular practices.

Central to the circular economy philosophy is the gradual reduction of incineration processes due to their environmental and health risks (World Health Organization, 2018b). Notable guidelines such as the World Health Organization's waste strategy, the Stockholm Convention, and the EU's directive (2010) advocate for the phasing out of incineration, starting with non-compliant entities. Aligned with other institutions in Norway, incineration holds a significant role in waste management. While it effectively removes pollutants and hazardous substances, its selective use is crucial, given the inclusion of recyclable materials in incineration (IFAT, 2022). The Fraunhofer Institute highlights its benefits, extracting energy and raw materials from non-recyclable waste (IFAT, 2022).

Recent Norwegian statistics (2021) show 1470 thousand tons incinerated, 666 thousand tons biologically treated, and 5611 thousand tons landfilled. Medical waste incineration remains common, yet its phased reduction is viable without compromising health or the environment, supported by available alternatives (HCWH Europe, 2020). Emphasizing alternative waste methods, off-site disposal, and hazardous waste treatment, HCWH Europe advocates a shift, recognizing incineration's current necessity. Though an immediate incineration ban for circular economy goals isn't feasible, strategies like limiting usage and implementing flue gas cleaning can mitigate environmental impact. Research and innovation offer hope for sustainable solutions in the future, shaping waste management practices in line with circular ideals.

To align with the Circular Economy Action Plan, Europe has embraced the waste-to-energy approach, a method where energy, typically in the form of heat and electricity, is generated using waste as a fuel source (Mosaic, 2021), also followed by St. Olav University Hospital. This approach comes with several advantages, such as harnessing a resource that would otherwise go to waste, reducing the need for landfilling, and the potential for resource recovery. However, it's crucial to acknowledge the growing awareness of the drawbacks associated with waste-to-energy in recent years. These disadvantages include the pollution and particulates generated by the process, the destruction of valuable materials, and the risk of disincentivizing more sustainable waste management solutions and renewable energy sources (Mosaic, 2021).

Nevertheless, it's important to note that St. Olav University Hospital, in line with the Circular Economy Plan, is diligently following standard waste management procedures to mitigate the downsides of waste-to-energy and move towards a more sustainable future. For instance, Heimdal incineration plant is equipped with advanced pollution control technologies known as flue gas cleaning to minimize emissions and protect the environment (waste management magazine, 2021). Despite the advancements in waste handling technologies, there remains a pressing issue concerning training, knowledge dissemination, and effective communication. These aspects are essential for improving waste reduction, reuse, and recycling efforts, which are areas where waste-to-energy plants often fall short. Achieving a circular economy demands a holistic approach that addresses not only the energy aspect but also the broader sustainability goals of waste management

and resource utilization.

One of the key discoveries in our study centered around the issue of waste associated with durable medical equipment (DME) and its management. This topic has gained prominence worldwide and is of particular concern in Norway due to its aging population (Vankar, 2022). Our research aimed to investigate the practices employed by St. Olav Hospital in managing unwanted DME and to gain insights into how healthcare providers perceived their role in minimizing DME waste.

In Norway, several companies and government entities are involved in acquiring and distributing medical equipment, as illustrated in Figure 17. While there exists a sustainability initiative known as the "take-back scheme" aimed at reducing DME waste by breaking down unwanted equipment into recyclable components, we encountered challenges in obtaining specific data on DME waste management. Officials we spoke with informed us that they were restricted from sharing such information.

Despite an apparent commitment to environmental concerns in the daily operations of hospitals, we discovered that healthcare providers were not actively educating patients about options for reusing and recycling DME (Ordway et al., 2018). The mere existence of a scheme was not sufficient; its implementation has been sluggish. Moreover, there is a clear need for more comprehensive policies and regulations to address the issue of DME waste. These findings suggest a potential gap between systemic efforts to reduce DME waste within healthcare institutions and the decision-making process at the clinical level for patient care, warranting further investigation. Rehabilitation providers should receive training in environmentally sustainable healthcare practices and play a crucial role in educating patients on sustainable methods for managing unwanted medical equipment (Ordway et al., 2018).

In this study, we gained valuable insights into waste management techniques and the waste management facility at St. Olav University hospital. However, our primary objective extended beyond mere observation – we aimed to provide recommendations that could enhance the existing waste management system at the hospital. To achieve this, our findings section was structured around three key areas for potential improvement: training and education, communication, and addressing issues related to carelessness. Specifically, we have recommended the establishment of

a dedicated Healthcare Waste Management Committee. Establishing a Healthcare Waste Management Committee can be a transformative step in enhancing waste management practices at St. Olav University Hospital. This committee not only takes on the critical role of training and educating the hospital staff, ensuring that they are well-prepared to handle waste responsibly, but it also serves as a hub for effective communication and collaboration. By convening experts and stakeholders in regular meetings, it creates a platform where insights can be shared, challenges can be addressed, and innovative solutions can be devised. This holistic approach fosters employee engagement and ensures that waste management is a collective effort, leading to improved waste handling, disposal, and overall management within the hospital, ultimately benefiting both the hospital's operations and the environment.

Furthermore, we suggest the creation of a comprehensive Waste Management Curriculum. This curriculum would have a pivotal role in arming students with the essential knowledge and competencies required for responsible waste management practices. By instilling this knowledge early in students, it can be a catalyst for changing human behavior towards the environment, as demonstrated by Ballantyne et al. in 1998. Through educational and training initiatives, it would empower healthcare professionals to reduce waste, effectively segregate it, and consistently apply safe disposal methods, thus fostering a more innovative approach to addressing waste management challenges. By implementing these proposals, we are confident that St. Olav University Hospital can substantially improve its waste management system. This proactive strategy will not only bolster environmental sustainability but also enhance the overall efficiency and safety of the hospital's operations.

The suggested measures, which include the formation of the Health Care Waste Management Committee (HCWMC) and the development of a curriculum, are substantiated by multiple studies and scholarly literature. The benefits of having healthcare waste management committees (HCWMC) have been extensively studied by the National Registry of environmental professionals, 2020. These studies have demonstrated that healthcare facilities that establish dedicated waste management committees observe enhanced waste segregation practices, improved adherence to regulatory requirements, and decreased occupational hazards. The significance of comprehensive training in waste management practices is underscored by the research conducted

by (Ravaghi et al., 2020) and (Kumar et al., 2016). The implementation of comprehensive training programs ensures that personnel are adequately equipped with the requisite knowledge and competencies to manage waste materials effectively and safely. The effectiveness of communication strategies in facilitating waste management coordination, ensuring compliance, and minimizing errors has been demonstrated in research conducted by (Howick et al., 2018) and (Vermeir et al., 2015).

In summary, the establishment of the Health Care Waste Management Committee and the formulation of a comprehensive curriculum will result in favorable outcomes for the waste management procedures at St. Olav Hospital. The implementation of these modifications will lead to enhanced adherence, diminished occupational hazards, heightened environmental sustainability, and a more integrated and accountable strategy for managing healthcare waste across the hospital.

8 Thesis contribution

The master's thesis on healthcare waste management practices at St. Olav University Hospital in Trondheim, Norway, represents a significant contribution to the field of environmental sustainability and healthcare management. Its in-depth qualitative study uncovered critical challenges and proposed practical solutions that can serve as a blueprint for not only St. Olav Hospital but also for healthcare facilities worldwide.

One of the central issues highlighted in the thesis is the challenge of communication within the hospital's waste management system. Effective communication is pivotal in ensuring that all staff members are aware of proper waste disposal procedures, environmental concerns, and regulatory requirements. The proposed establishment of a healthcare waste management committee can be instrumental in addressing this challenge. This committee would serve as a coordinating body, responsible for disseminating information, conducting regular training sessions, and fostering a culture of responsibility and accountability regarding waste management practices.

The emphasis on education and training is another crucial aspect of the thesis. By recommending the integration of a healthcare waste management curriculum into relevant study courses, the thesis

acknowledges the importance of starting education at the grassroots level. It recognizes that healthcare professionals of the future need to be well-versed in sustainable waste management practices, not just as a regulatory requirement but as an ethical responsibility. This approach not only benefits the hospital but also contributes to producing environmentally conscious healthcare professionals who can drive positive change in the industry.

The thesis's recognition of the emerging issue of rising waste, particularly durable medical equipment (DME), underscores its forward-thinking approach. While acknowledging that comprehensive data on this issue may be limited, the thesis provides a foundational understanding of DME within the context of St. Olav Hospital. This can serve as a starting point for further research, possibly leading to innovative solutions for DME waste management in healthcare settings.

Moreover, the thesis advocates for the incorporation of high-tech solutions in waste management while emphasizing the importance of a knowledge-driven approach. It recognizes that technology alone is not the panacea; it must be complemented by informed decision-making and a well-educated workforce. This holistic approach aligns with the broader trend in healthcare towards sustainability and efficient resource utilization.

In conclusion, this master's thesis is a commendable effort that not only identifies challenges in healthcare waste management but also provides thoughtful and actionable recommendations. It goes beyond mere problem identification and delves into practical solutions that can drive positive change. As healthcare facilities worldwide grapple with waste management issues, this thesis serves as a valuable resource and a model for promoting sustainable practices and environmental responsibility in healthcare settings. Its findings and proposals contribute significantly to the ongoing dialogue on healthcare waste management and underscore the need for a multifaceted approach that integrates technology, education, and collaboration.

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9 Appendix

9.1 Interview guide

Aim of the study

To investigate healthcare waste management at St. Olav's Hospital and explore the benefits of improving medical waste management for both the hospital and the environment.

Engagement Questions

1. How long have you been working as a staff in a healthcare facility?
2. Have you received any formal training related to healthcare waste management?
3. If you answered "No" to Question 2, do you think that training related to healthcare waste management should be included in the regular nursing curriculum?
4. How confident are you in your knowledge and skills related to healthcare waste management?
5. In your current healthcare facility, are there adequate resources (e.g., waste management equipment, personal protective equipment, training materials) available to support proper healthcare waste management practices?
6. How important do you think it is for healthcare facilities to implement and maintain proper healthcare waste management practices?

Exploration questions:

1. If you answered "Yes" to the previous question, please specify the type of training you received.
2. In your opinion, which of the following healthcare waste management practices are most important to ensure patient and staff safety? (Select all that apply.)
3. Have you observed any improper healthcare waste management practices in your healthcare facility?
4. If you answered "Yes" to the previous question, please describe the improper practices you observed.
5. How frequently do you receive training or updates related to healthcare waste management?
6. What training methods do you find most effective for healthcare waste management training? (Select all that apply)

7. How do you stay up to date with changes or updates related to healthcare waste management practices?
8. How often are you involved in the decision-making process for healthcare waste management practices in your facility?
9. Have you ever encountered any barriers or challenges related to healthcare waste management in your facility? (Select all that apply)
10 How important do you think it is for healthcare facilities to be environmentally sustainable in their waste management practices?
11 How do you think healthcare facilities can be more environmentally sustainable in their waste management practices?
12. In your opinion, what improvements could be made to the healthcare waste management training programs in your facility?

Exit questions.

1. Have you ever seen or came across the waste management instructional video made by St. Olav hospital?
2. Do you think temporary workers during summertime go through all these training processes?
3. Do you have any additional comments or suggestions related to healthcare waste management practices in your facility?

9.2 Coding Frame

Table summarizing the initial codes, mid-codes, and final categories that emerged from the survey responses and interviews.

Initial codes	Mid-codes	Final categories
Lack of training	Ineffective training, lack of practical training, lack of updates	Training
Communication issues	Lack of transparency, lack of coordination, poor leadership	Communication
Careless behavior	Improper labeling, improper segregation, poor storage	Carelessness

And here is a more detailed table showing how the initial codes evolved into mid-codes. And eventually into final categories:

Initial Codes	Mid-Codes	Final categories
Lack of training	Ineffective training methods	Training
	Lack of practical training	

Initial Codes	Mid-Codes	Final categories
	Lack of updates	
Communication issues	Lack of transparency	Communication
	Lack of coordination	
	Poor leadership	
Careless behavior	Improper labeling	Carelessness
	Improper segregation	
	Poor storage	

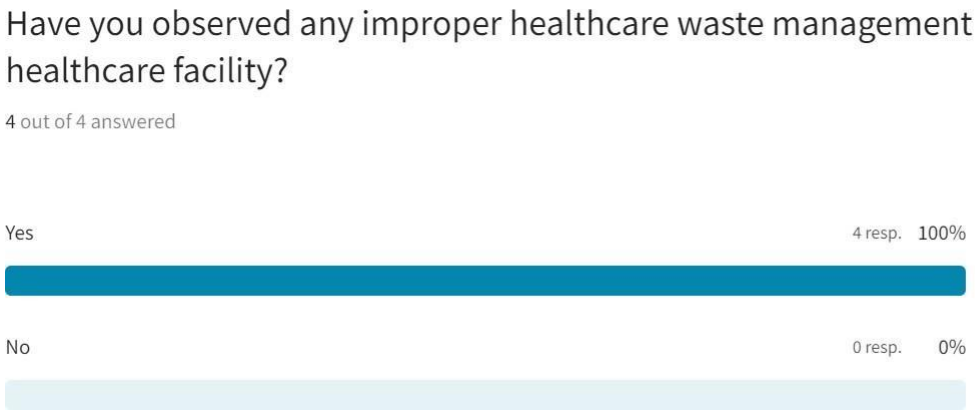
Mid-Codes	Final categories
Ineffective training methods	Training
Lack of practical training	Training
Lack of updates	Training
Lack of transparency	Communication
Lack of coordination	Communication
Poor leadership	Communication
Improper labeling	Carelessness
Improper segregation	Carelessness
Poor storage	Carelessness

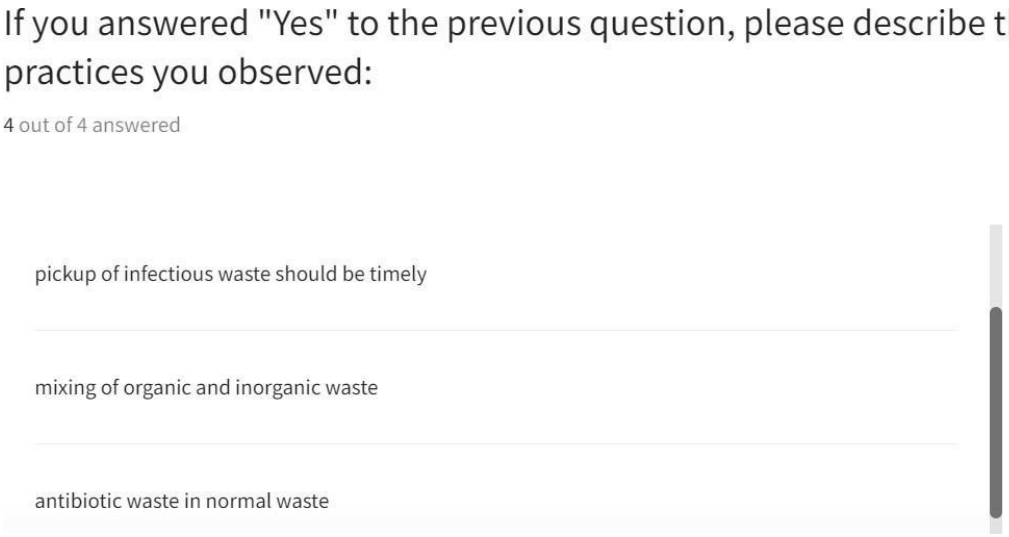
Table 9:Evolution of main categories

9.3 Survey Responses

some of the major questions regarding the issues and improvement areas at St. Olav hospital is shown by the survey responses which are shared. Full survey responses can be viewed using the link:

https://02g0xyseehz.typeform.com/report/OxoMoUz1/3kjpn9GRlVcpgZjO





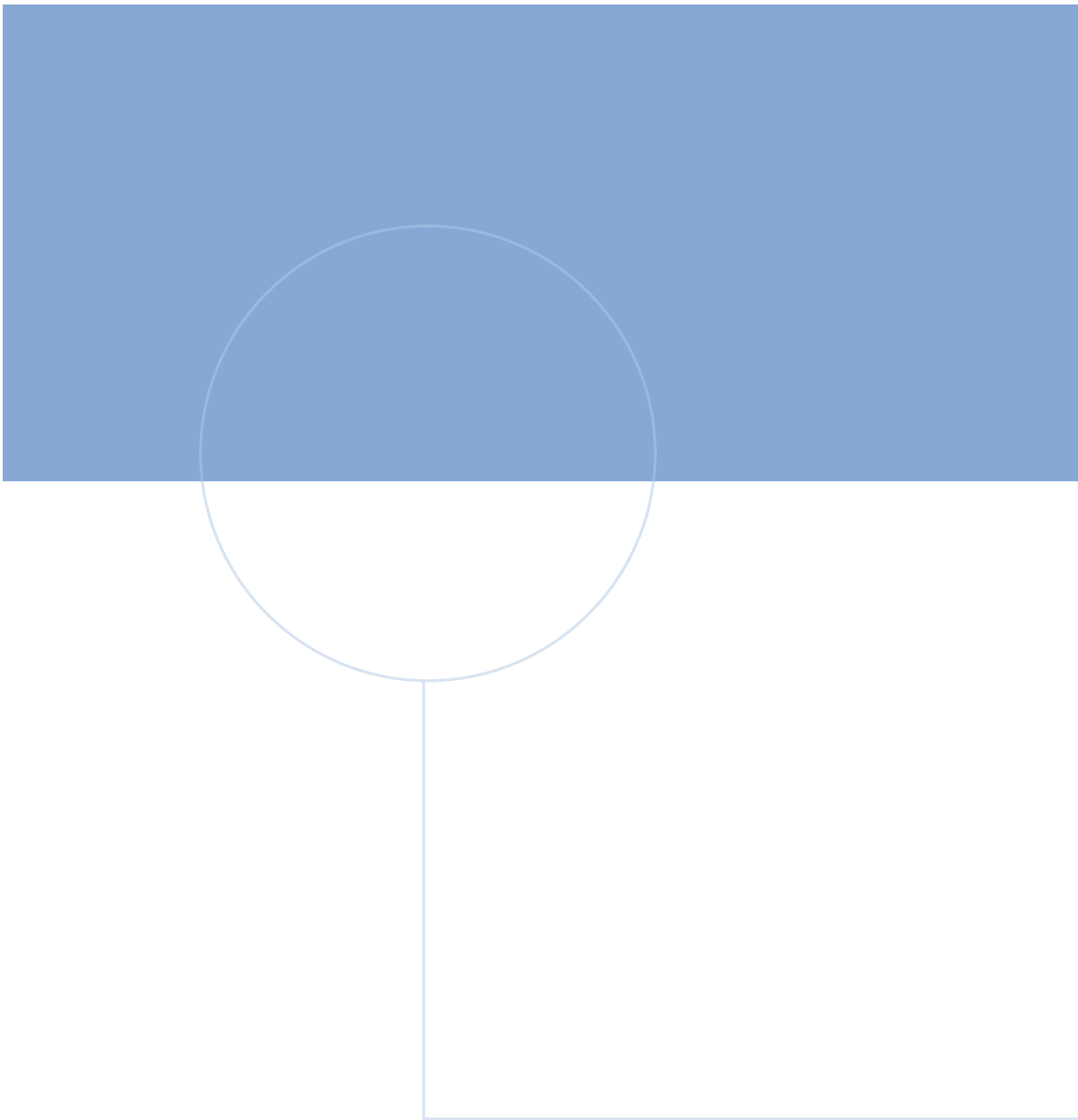
In your opinion, what improvements could be made to the healthcare waste management training programs in your facility?

4 out of 4 answered

- fixed time schedule for waste transmission and pickup
- formulating a supervison team for healthcare waste
- more practical trainging

Have you ever encountered any barriers or challenges related to healthcare waste management in your facility? (Select all that apply)

4 out of 4 answered



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