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DrugWise

a sustainable approach towards reducing medicine waste in the operating rooms

Noor van Amelsfort
Master thesis
Design for Interaction
TU Delft

Author
Noor van Amelsfort

Master thesis
MSc Design for Interaction
Faculty of Industrial Design Engineering
Delft University of Technology

In collaboration with
Medical Delta
LDE Centre for Sustainability
Leiden University Medical Centre

Graduation Committee
Chair: Prof. Dr. Ir. Jan-Carel Diehl
Mentor: Dr. Ir. Sonja Paus-Buzink
LUMC supervisor: Dinemarie Kweekel

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Preface.

Dear reader,

This project allowed me to take a deep dive into the world of sustainable healthcare. I learned so much about the inner workings of the Leiden University Medical Centre (LUMC) and the many positive and sustainable changes they're already making.

My interest in design for sustainability was the reason for selecting this assignment. I had no experience conducting research within the hospital setting, making it a great opportunity to do this for the first time. My first ever visit to the operating rooms was an experience that I will never forget!

I hope the experiences and insights I share resonate with you and perhaps inspire you to think about sustainable healthcare.

Enjoy the read!

Greetings,
Noor

Abstract.

What?

Medicines are used for all types of surgeries in the operating room (OR). They are needed to provide safe and effective care. However, the use of medicines also results in waste. Research conducted by Barbariol et al. (2021) highlighted that a substantial proportion, ranging from 20% to 50%, of medications prepared in the OR ultimately remain unused and are consequently discarded. The Leiden University Medical Centre (LUMC) and 'Nationaal Netwerk de Groene OK' **aim to minimize the waste of medicines at the OR**.

In order to reduce medicine waste at the source, this thesis project will look into the existing state of medicine waste in the LUMC operating rooms (ORs). The results of this project will contribute to a better understanding of the challenges associated with medicine waste in the OR and provide practical guidelines that can be implemented in the LUMC.

Why?

The environmental impact of...

...**Healthcare**
Healthcare plays a vital role in curing illnesses and improving human health. However, it is crucial to recognize that healthcare itself can also contribute to negative impacts on both human health and the environment. The Dutch healthcare industry is responsible for 7,4 % of the total environmental footprint (RIVM, 2022).

...Medicines
Research conducted last year by RIVM presented that the contribution of chemical products, including medicines in particular, is responsible for 41.2% of healthcare CO2 emissions, out of all the goods and services that are acquired in the industry (RIVM, 2022).

Medicine scarcity

The 'Koninklijke Nederlandse Maatschappij ter bevordering der Pharmacie' (KNMP), presened that last year in 2022 the **highest number of medicine shortage ever occurred**. They predict that these kind of issues will only grow more in the further, so it is important to stay mindful about medication prescription, use and disposal.

Ethical obligation

Medication waste raises ethical concerns within the healthcare context. The waste of medications **contradicts the principles of equity and justice**, as resources that could have been allocated to patients in need are wasted.

How?

Measuring the waste

The medicine waste at the Leiden University Medical Center (LUMC) was measured in quantity and volume, which revealed that seven medications accounted for 78% of the waste. The predominant reasons for this wastage are limited resources for appropriate prescribing, unconscious behaviours in the routine practices of OR staff and lack of awareness and knowledge. Expired medicines can also be attributed to improper adherence to the First-In-First-Out (FIFO) principle and suboptimal storage handling.

DrugWise

Consequently, a final concept called 'DrugWise' was devised. This sustainable approach targets medicine waste prevention in the OR through a holistic approach. DrugWise consists of five critical steps as shown in the figure below:

1. **Measure** the waste to gain an understanding of the current situation.
2. **Prioritize** areas for action based on the measurements.
3. **Raise awareness** amongst OR staff regarding the extent and implications of medicine waste.
4. **Initiate action** in four key areas: medicine use, prescribing practices, stock management, and disposal.
5. **Evaluate** the effectiveness of the interventions implemented.

The target audience of the approach is the Anaesthesia Green Team. The DrugWise approach was developed in collaboration with the primary stakeholders involved in medication use - anesthesiologists and anesthetic nurses. This collaboration ensured that the solution was rooted in their practical experience and professional knowledge.

Future steps

Looking ahead, LUMC will serve as the pilot hospital for the DrugWise approach. Upon successful implementation and review, the intention is to broaden the reach to other hospitals, advocating for a nationwide effort in reducing medicine wastage in the OR.

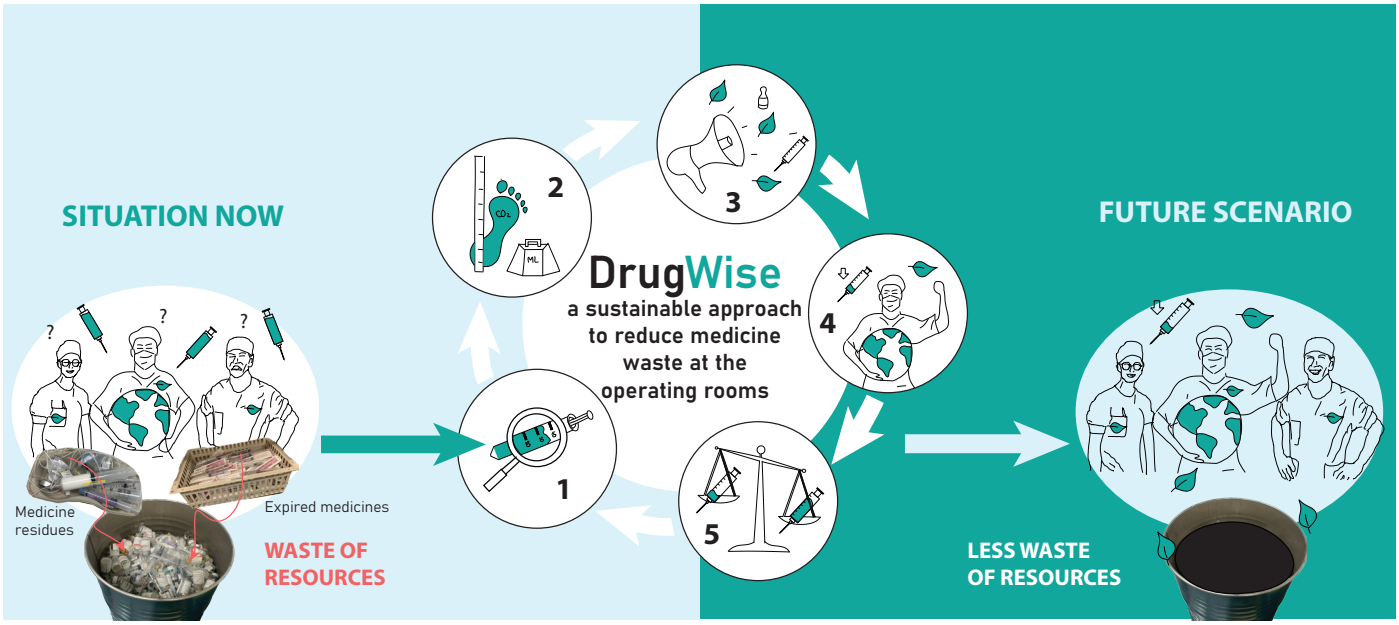


Figure 1: DrugWise: a sustainable approach to reduce medicine waste in the OR

Table of contents.

Glossary

OR	An operating theater (also known as an operating room (OR)) is a facility within a hospital where surgical operations are carried out in an sterile environment.
LUMC	Leiden **University** Medical Centre**, the academic hospital of Leiden.**
Green Team	A Green Team aims to bring sustainability to the attention of a healthcare institution. A Green Team is usually a team of 4-8 people who meet regularly and thus make sustainability visible in the health care institution.
Medicine waste	Within this thesis medicine waste is described as wasted intravenous medicines—fluid-based treatments administered directly into the veins, most frequently used in the operating room (OR) setting.
Medicine residue	Wasted medicines which include (partially) full syringes, ampoules, and vials.
Expired medicines	Medicines that are expired **and thus have to be disposed.**
Anaesthesia	Anaesthesia means “loss of sensation”. Medicines that cause anaesthesia are called anaesthetics. Anaesthetics are used during surgical operations to numb sensation in certain areas of the body or induce sleep. This prevents pain and discomfort, and enables a wide range of medical procedures to be carried out.
Anaesthesiologist	A medical doctor specialized in anaesthesia care. They oversee the administration of medications in the OR and are responsible for making critical decisions regarding anaesthesia management, medication selection, and dosage adjustments based on patients’ specific needs.
Anaesthesia nurse	A nurse anaesthetist supports anaesthesiologist during the procedure. They are mainly concerned with checking operating equipment and preparing medicines.

INTRODUCTION

01

1. Introduction

This project is part of LDE Centre for Sustainability's and Medical Delta's 'Interdisciplinary thesis lab 2022-2023: **Sustainable Hospitals'**. This partnership aims to address the imperative of promoting sustainability within the healthcare sector. The Interdisciplinary Thesis Lab brings together ten master's students from diverse academic backgrounds, representing interdisciplinary universities such as Erasmus University, Delft University of Technology, and Leiden University. Each student is engaged in an individual research topic that contributes to advancing sustainability in healthcare. The specific focus of this master's thesis is centred on the **reduction of medicine waste in the operating room**, acknowledging the significance of mitigating waste generation and fostering sustainable practices within this critical healthcare setting.

Project assignment

Medicines are used for all types of surgeries in the operating room (OR). They are needed to provide safe and effective care. However, the use of medicines also results in waste. Research conducted by Barbariol et al. (2021) highlighted that a substantial proportion, ranging from 20% to 50%, of medications prepared in the OR ultimately remain unused and are consequently discarded. The Leiden University Medical Centre (LUMC) and 'Nationaal Netwerk de Groene OK' aim to minimize the waste of medicines at the OR.

In order to reduce medicine waste at the source, this thesis project will look into the existing state of medicine waste in the LUMC operating rooms (ORs). The research will look at prescribing procedures, use and inventory management that lead to wasted medication in the OR. The results of this project will contribute to a better understanding of the challenges associated with medicine waste in the OR and provide practical guidelines that can be implemented in the LUMC.

Scope: medicine waste in the Operating Room

Medicine waste is a multifaceted issue that encompasses the inefficient use, disposal, and management of pharmaceuticals throughout their lifecycle (WHO,2018). The problem of medicine waste extends beyond the boundaries of individual healthcare settings

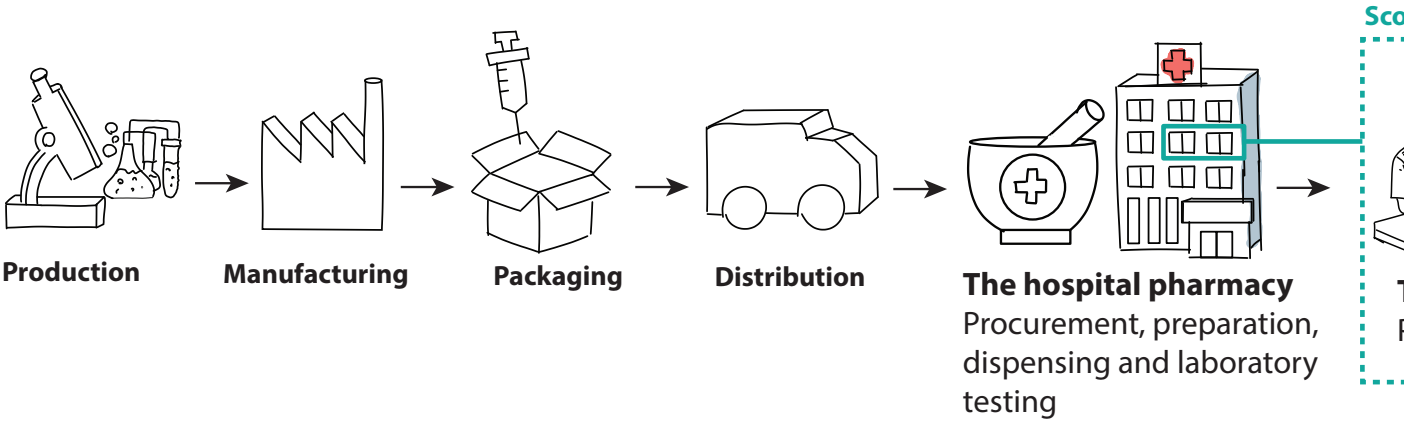


Figure 2: Simplified view of the medicine supply and use chain with the scope of the project marked in green

and involves various stakeholders, including pharmaceutical manufacturers, healthcare providers, and patients. Understanding the different aspects of medicine waste is crucial for developing effective strategies to reduce it.

The lifecycle of medication waste starts with the **production of pharmaceuticals** as shown in figure 1, where resources, such as raw materials, energy, and water, are consumed. The manufacturing process contributes to the carbon footprint and environmental pollution through the emission of greenhouse gases, wastewater, and the generation of hazardous byproducts. Additionally, the **packaging and labeling** of medications also result in waste, including plastic containers, blister packs, and information leaflets.

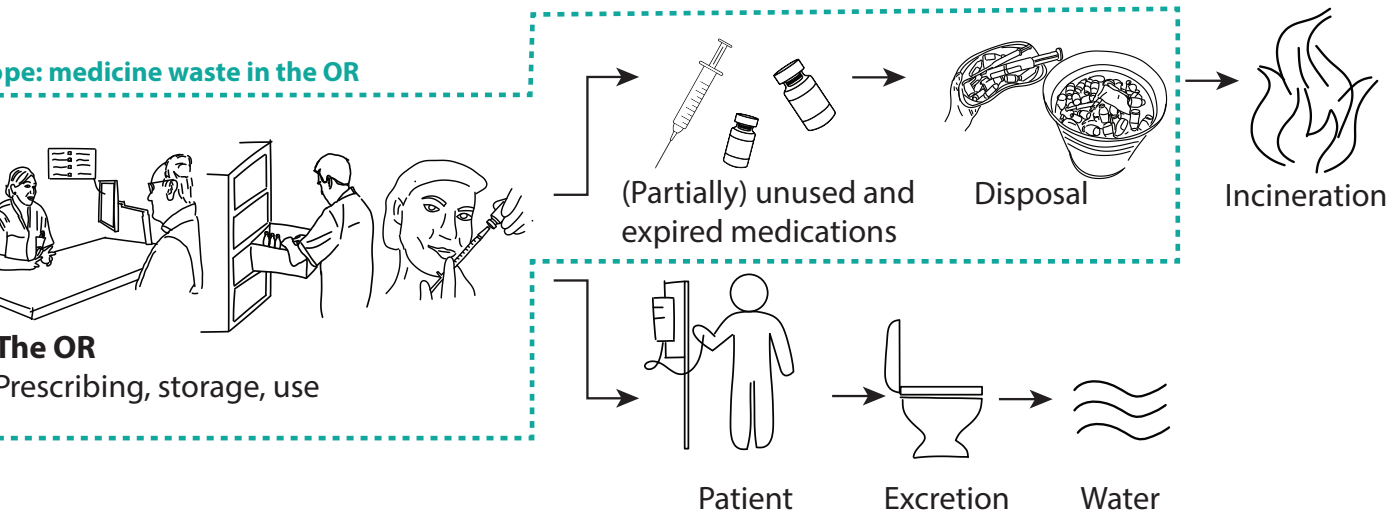
After production, medications are **distributed to healthcare facilities**, including hospitals and pharmacies, where they are prescribed, dispensed, and administered to patients. During this utilization phase, medication waste can arise due to several factors.

This thesis focuses specifically on medicine waste in the operating room (OR) setting, with particular emphasis on the utilization phase, the scoped is marked with a green border in figure 2. The operating room is a critical component of healthcare facilities where a wide range of surgical procedures are performed. These procedures often necessitate the use of medications to induce anaesthesia, manage pain, prevent infections, and facilitate the surgical process. With the diverse range of medications used for various purposes, the OR presents an environment with a high potential for waste generation.

The focus of this project is on the wastage of **intravenous medicines**—fluid-based treatments administered directly into the veins, most frequently used in the operating room (OR) setting.

Within this thesis, medicine waste is defined in two specific aspects:

- Medicine residues, which include (partially) full syringes, ampoules, and vials.
- Expired medicines.



Aim and objectives

The primary aim of this thesis project is to develop effective strategies and interventions that will **minimize medicine wastage in the OR** at Leiden University Medical Center (LUMC). To achieve this, the following objectives have been outlined:

1. **Understand Medicine Waste in the OR:** This objective encapsulates the initial stages of the project, focusing on understanding and evaluating the current practices and systems related to medicine usage and waste in the OR. It also involves developing a methodology to effectively quantify the scale and types of medication waste, which will serve as a basis for subsequent improvements.
2. **Quantification of Medicine Waste and identification of the causes:** Measure the extent of medicine wastage in the LUMC OR through data collection and analysis, aiming to accurately determine the volume and types of medicine waste. Identify the causes and sources of medicine wastage in the OR.
3. **Designed Interventions:** Based on the findings, the next part of this objective is to develop targeted interventions and strategies to address the identified issues, with the ultimate aim of reducing medication waste.

Approach

This thesis project used a combined method to explore the complex problem of medicine waste in the operating room (OR). This method included direct observation, informal interviews, a review of relevant literature, and real-time waste measurement.

Observations: The first step involved watching what happens in the OR to understand how people interact with medicines and how waste is produced. This direct observation helped to create a clear picture of the current processes and identify key factors leading to waste.

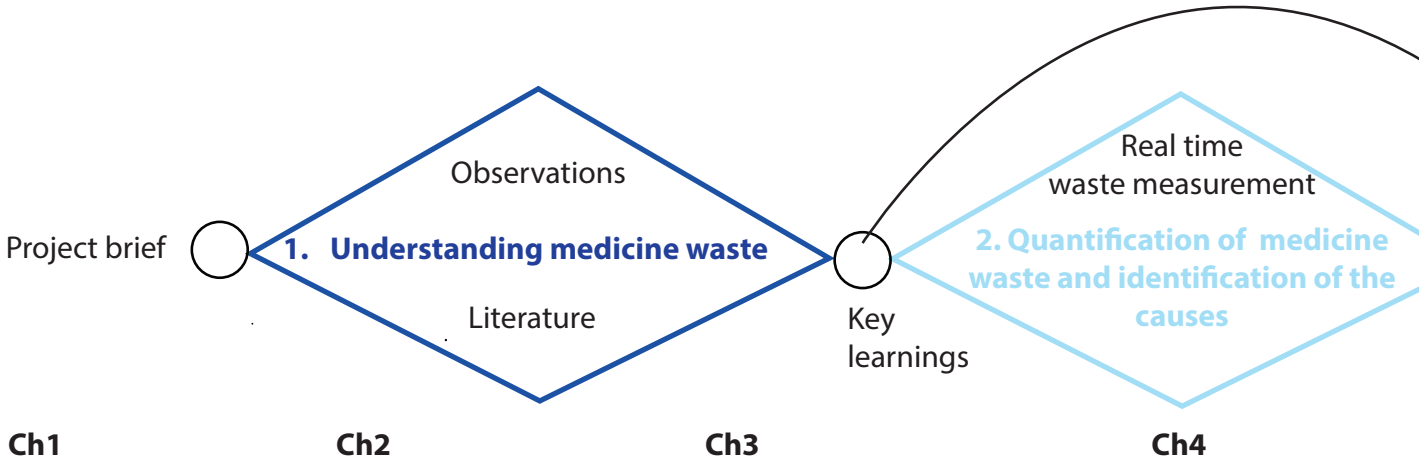


Figure3: The approach

Informal Interviews: Along with observation, informal chats were held with the people involved in the OR. These conversations provided more insights into their thoughts, attitudes, and any challenges they face in dealing with medicine waste.

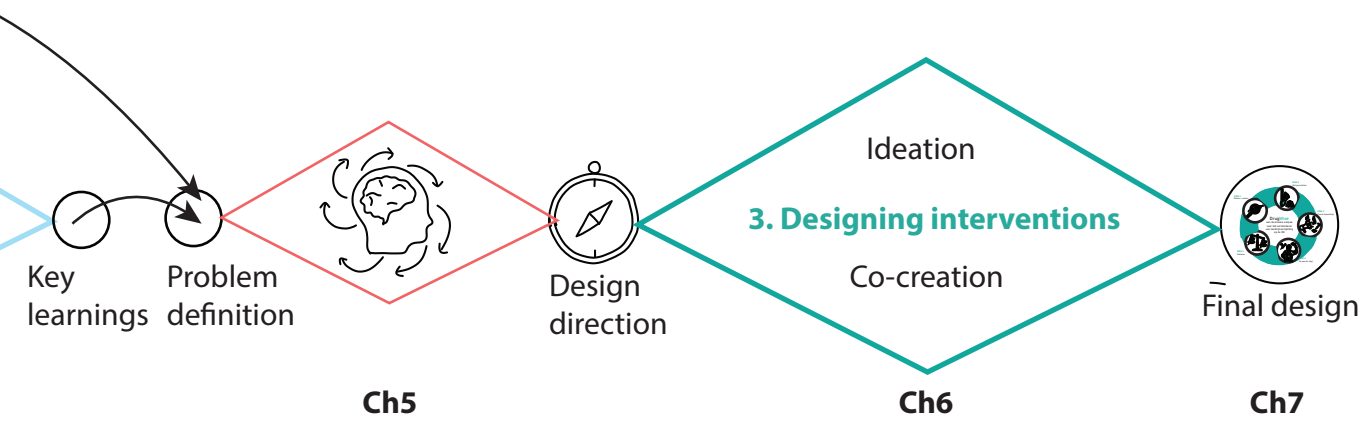
Literature Study: A detailed review of existing research on medicine waste was carried out. This provided more context and understanding of the issue, existing solutions, and potential ways to tackle it. It also informed the approach for measuring waste in the OR.

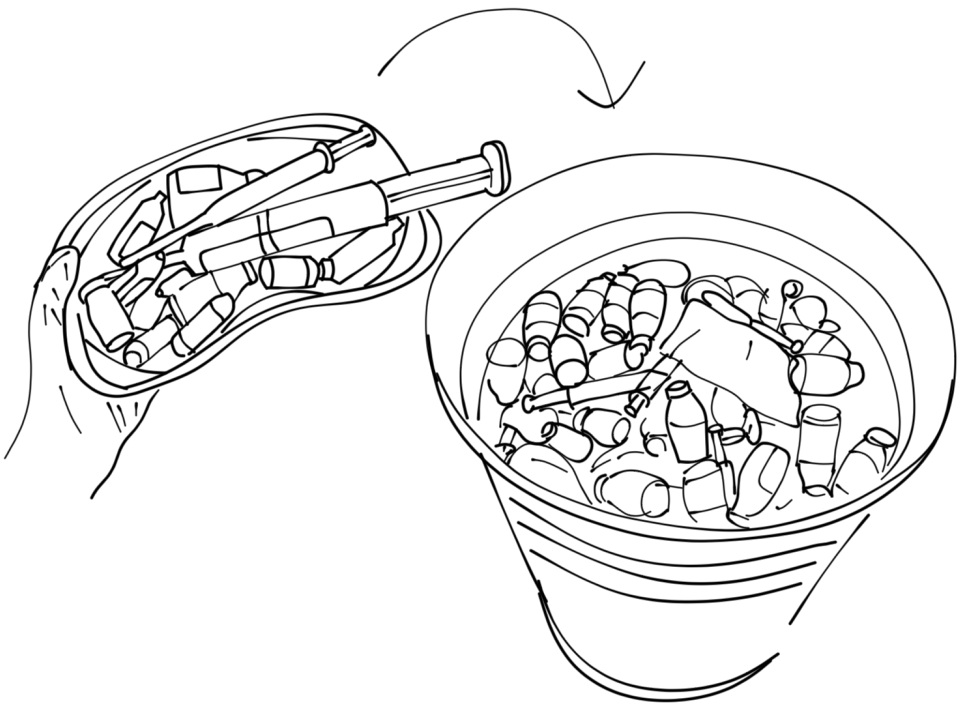
Real-Time Waste Measurement: The study also included measuring waste as it happened during surgical procedures. This allowed for a precise calculation of the amount and types of medicine waste. It helped identify the medications and steps in the process that contributed the most to waste. These insights guided the creation of specific strategies to reduce waste.

The combination of these different techniques offered a full view of the problem, allowing for a well-informed and targeted strategy to reduce medicine waste in the OR. The strategies developed were built on a solid understanding of the problem, ensuring that they addressed not just the surface issue of waste but also the root causes.

Collaborative sessions were conducted involving professionals including anaesthesiologists and anaesthetic nurses from the Leiden University Medical Centre (LUMC). These co-creation sessions allowed participants to contribute their unique perspectives, enriching the solutions and ensuring that the devised strategies would be applicable within the OR environment.

An overview of the approach is illustrated in the figure below.





BACKGROUND

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2. Project background

Partners

The assignment is initiated by Dinemarie Kweekel, hospital pharmacist at the LUMC, in collaboration with the LDE Centre for Sustainability's and Medical Delta's 'Interdisciplinary thesis lab 2022-2023: Sustainable Hospitals'. They are joining forces in their mission to make healthcare more sustainable. This assignment is in line with the vision of the "National network the Green OR". Dinemarie is a member of the "anaesthesia vapours and medicine residues" working group. "National network the Green OR" mission is to accelerate sustainability of care processes in ORs in the Netherlands.

Medical Delta: 'Sustainable hospitals thesis lab'
Medical Delta is an interdisciplinary collaboration of researchers from Erasmus University, Erasmus MC, TU Delft, LUMC, Leiden University and four universities of applied sciences in the province of Zuid-Holland. Together with companies, healthcare organizations and governments, they work on technological solutions for sustainable healthcare. In order to get a bottom-up grip on the phenomenon of 'helping to green hospitals', Medical Delta and the LDE Centre for Sustainability started the Interdisciplinary Thesis Lab 'Sustainable Hospitals'. Ten master's students from various disciplines at the universities of Leiden, Delft, Rotterdam are presented with this problem and asked to write their master's thesis on this topic.

Leiden University Medical Centre (LUMC)
The hospital where this study took place is the LUMC, an academic hospital that maintains a collaborative relationship with Leiden University. The hospital is dedicated to fulfilling three primary functions: patient care, scientific research, and healthcare professional training and education.

Within the LUMC, the focus of this study was on the operating room (OR) center, which encompasses a total of 20 operating rooms. Specifically, 16 of these operating rooms are situated within the operating room complex (ORC), while the remaining four are part of the CardioVascular Intervention Center (CVIC) (LUMC, 2018). The ORC serves as a central hub for surgical procedures, while the CVIC is dedicated to cardiovascular interventions.

National Network the Green OR
"The National Network the Green OR" encourages and supports individual healthcare professionals working in the OR to engage in sustainable ways (National Network the Green OR, 2022). They want to achieve sustainability gains and aim for CO2-neutral care. The working group "anaesthesia vapours and medicine residues" focusses on reducing the environmental impact of anaesthesia vapours and minimizing medicine waste.

The aim for the following result in 2025: Nationwide a significant reduction in wastage of medications used in the OR (National Network the Green OR, 2022).

LDE centre for sustainabilty
The Leiden-Delft-Erasmus Centre for Sustainability is an interdisciplinary research centre formed by Leiden University, Delft University of Technology, and Erasmus University Rotterdam, with the aim of advancing the transition to a circular economy. Recognizing the complexity of this transition, the centre advocates for a systematic and holistic research approach that entails interdisciplinary collaboration and engagement with stakeholders from practice. To facilitate this, the centre has established the "Knowledge & Innovation Themes," an open research format that encourages collaboration, knowledge exchange, and active involvement of practitioners. By fostering interdisciplinary collaboration and

stakeholder engagement, the centre strives to generate comprehensive knowledge and innovative solutions to accelerate the shift towards a sustainable and regenerative economy.

Relevance

The environmental impact of...

Healthcare
Healthcare plays a vital role in curing illnesses and improving human health. However, it is crucial to recognize that healthcare itself can also contribute to negative impacts on both human health and the environment. The Dutch healthcare industry is responsible for 7,4 % of the total environmental footprint (RIVM, 2022). The effects of climate change may increase the likelihood of new diseases, longer hay fever seasons and more infectious diseases. This intricate relationship between healthcare, the environment, and human well-being necessitates careful consideration and balanced decision-making (see figure 4).

Medicines
According to research conducted by Gupta Strategists (2019), the production, distribution, and consumption of pharmaceuticals contribute to approximately 18% of this carbon footprint. Consequently, pharmaceuticals rank as the third-largest source of CO2 emissions within the healthcare sector, following the energy consumption of healthcare facilities (38%) and the travel activities of patients and healthcare workers (22%).

However, research conducted last year by RIVM presented that the contribution of chemical products, including medicines in particular, is responsible for 41.2% of healthcare CO2 emissions, out of all the goods and services that are acquired in the industry as shown in figure 5 on the next page (RIVM, 2022). The consumption of raw materials and clean water within healthcare is also attributable to this category (79.7% and 63.2%, respectively) (RIVM, 2022). Also, at least 190,000 kg of drug residues enter surface and groundwater (RIVM, 2020).

The LUMC signed the **Green Deal Sustainable**

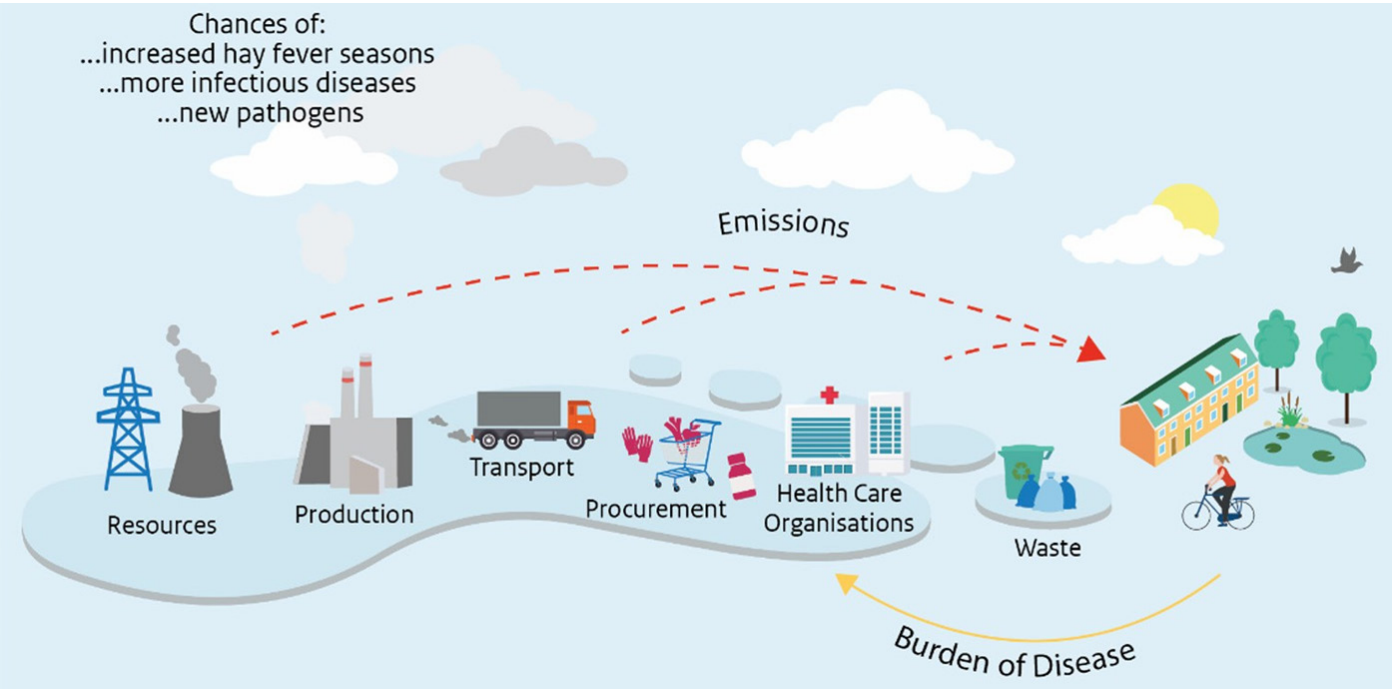


Figure 4: the paradoxical relationship of healthcare and the environment (RIVM, 2022)

Healthcare 3.0, together with all the university medical centres in the Netherlands (NFU,2022). The purpose of the Green Deal is to bring about an irreversible transition to healthcare with minimal impact on climate, the environment and living conditions by 2050. Signatories of the Green Deal commit to five commitments. One of them is especially related to medicines:
Reduction of the environmental damage caused by (the use of) medication

Waste of resources
The production of medications involves resources, energy, and labour. When medications are wasted, these means are also wasted, which is a concern in terms of both environmental sustainability

Medicines in the OR
Studies have revealed a significant issue of medicine wastage within the operating room (OR) environment. Research conducted by Barbariol et al. (2021) highlighted that a substantial proportion, ranging from 20% to 50%, of medications prepared in the OR and ICU ultimately remain unused and are consequently discarded.

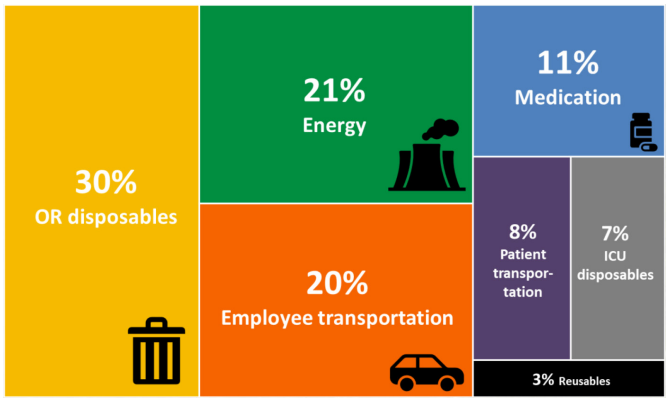


Figure 6: Distribution of the 531 kg CO2 emissions from open-heart surgery (ZonMw, 2023)

Furthermore, an investigation conducted by Hans Touw (2023) shed light on the environmental impact of medications during open heart surgeries. The study revealed that medications contribute to approximately 11% of the total carbon dioxide equivalent (kgCO2) emissions associated with the procedure as shown in figure 6. This amounts to an alarming 58 kgCO2 per operation attributed solely to medicine usage. These findings underscore the urgent need to address the issue of medicine wastage in the OR, not only from an environmental perspective, to promote sustainable healthcare practices and mitigate the associated environmental burden.

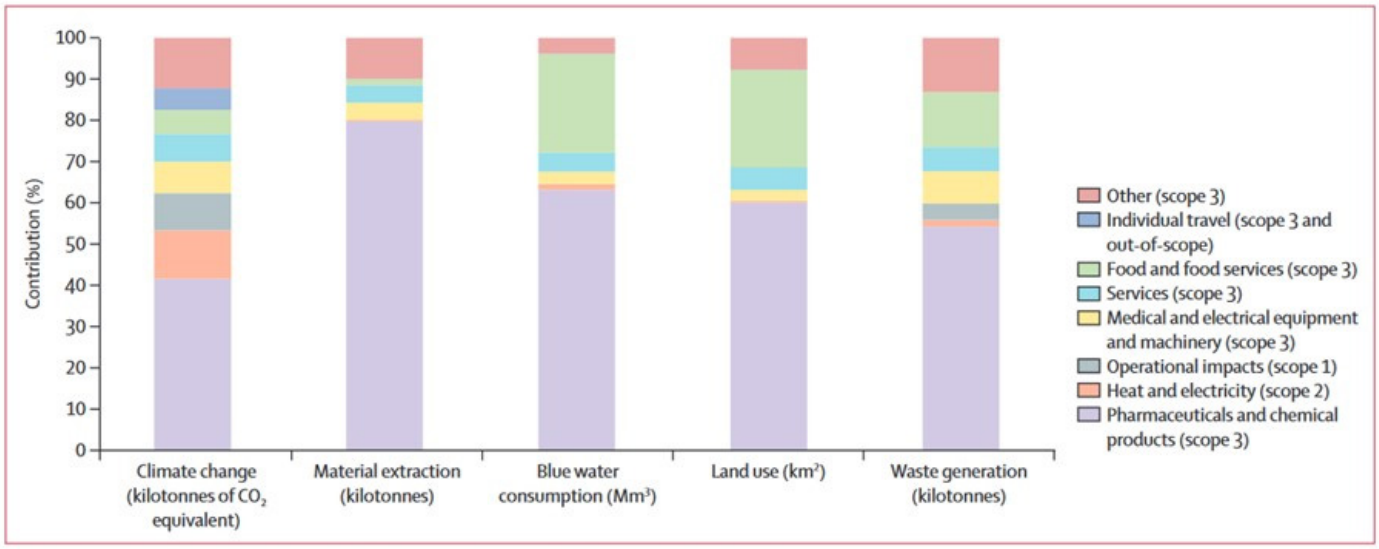


Figure 5: KgCO2 emmisions of healthcare in the Netherlands (RIVM, 2022)

Medication scarcity and the growing population

The 'Koninklijke Nederlandse Maatschappij ter bevordering der Pharmacie' (KNMP), presented that last year in 2022 the highest number of medicine shortage ever occurred as shown in the news article presented in figure 7. They predict that these kind of issues will only grow more in the further, so it is important to stay mindful about medication prescription, use and disposal.

NOS Nieuws • Maandag 3 juli, 12:51

Apothekers slaan alarm: 'Medicijntekort stijgt naar recordhoogte'

Apothekersorganisatie KNMP waarschuwt dat het gebrek aan geneesmiddelen dit jaar naar recordhoogte stijgt. Vorig jaar registreerde de organisatie 1514 medicijntekorten. Dit jaar was al 1179 keer een medicijn minstens twee weken niet beschikbaar.

Figure 7: News article on medicine shortage (NOS, 2023)

Besides, the Dutch population is expected to grow from 17.3 million in 2020 to 19 million in 2050 (CBS, 2021). With a larger population, there will be an increased demand for medication, and medication waste could have a more significant impact on the healthcare system, the environment, and patient safety. Therefore, it is crucial to address medication waste in Dutch healthcare and to implement effective strategies to reduce it.

Ethical Considerations

Medication waste raises ethical concerns within the healthcare context. The waste of medications contradicts the principles of equity and justice, as resources that could have been allocated to patients in need are wasted. Addressing medication waste aligns with the ethical obligation of healthcare professionals to optimize resource utilization, promote fairness, and ensure equitable access to healthcare services (Van Norman & Jackson, 2020).

Key learnings

Environmental impact

- The production, distribution, and consumption of chemical products including pharmaceuticals account for a significant portion of healthcare's carbon footprint, contributing up to 41.2% of healthcare CO2 emissions.
- LUMC and other Dutch medical universities have committed to minimizing environmental damage caused by medication as part of the Green Deal Sustainable Healthcare 3.0.

Medicine shortage

- Medication shortages pose an increasing challenge, necessitating mindful prescription, use, and disposal of drugs.

Ethical

- Medication waste raises ethical issues, as the misallocation of resources contradicts principles of equity and justice.

Shift towards sustainable healthcare

Circular economy

In recent years, there has been a growing recognition within the healthcare sector of the urgent need to transition from a linear economy to a circular economy. The prevailing linear economy model follows a “take-make-dispose” approach, where resources are extracted, products are manufactured, utilized, and eventually discarded as waste. Figure 8 shows this process on the left side. However, this linear approach is unsustainable and exerts considerable pressure on the environment and finite resources.

In contrast, the concept of a circular economy offers a viable alternative, seeking to maximize resource utilization, minimize waste generation, and establish a regenerative system. Within a circular economy, the aim is to keep products and materials in use for as long as possible through practices such as recycling, re-purposing, and reusing. By closing the loop and creating a circular flow, valuable resources are conserved, waste is minimized, and overall environmental impacts are reduced.

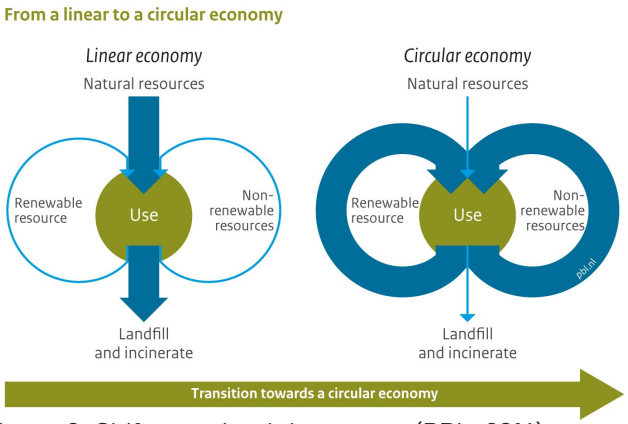


Figure 8: Shift to a circulair econmy (PBL, 2016)

Frameworks

Moving from a linear to a circular economy is a complex endeavour that requires systemic changes. It demands new ways of thinking, innovative technologies, and novel business models. To facilitate this transition, various frameworks have been proposed, providing both strategic direction and practical guidance

Value Hill approach

An approach to shift to a circular economy is the Value Hill strategy as shown in figure 9, which encompasses the 9R framework: Rethink, Refuse, Redesign, Reduce, Reuse & Repair, Refurbish & Manufacture, Re-purpose and Revalorise, Recycle, and Recover. The lower the R number, the higher the level of circular value. This framework will be used in chapter X to explore the environmental value of the design interventions.

Waste hierarchy

In addition to the Value Hill strategy, another effective framework for waste management

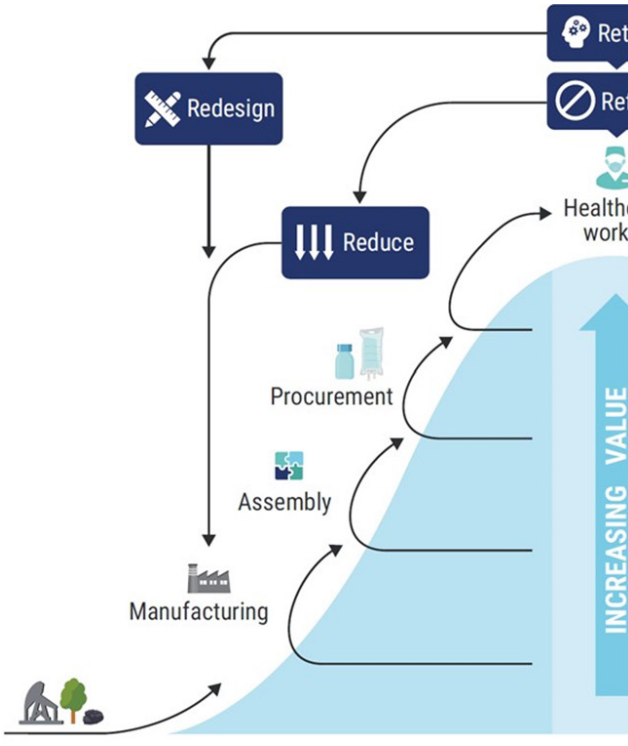
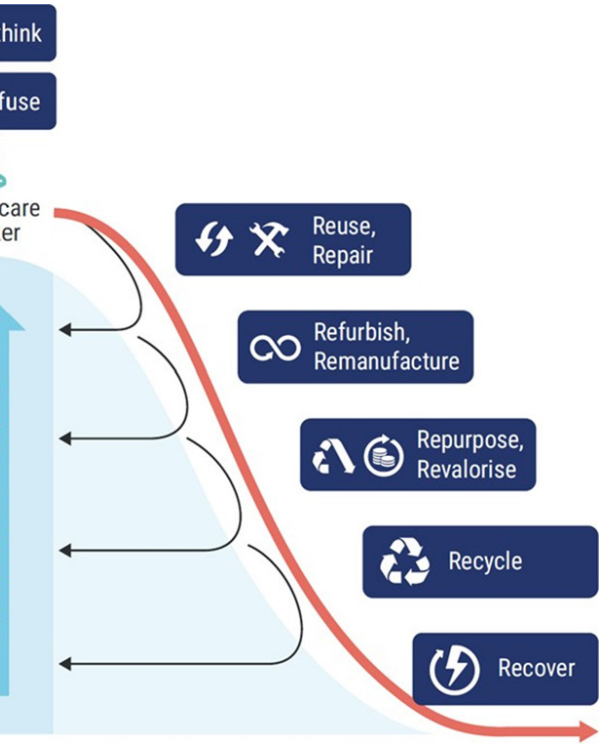


Figure 9: Adapted Value Hill for Healthcare (Van Bure (Achterberg, 2016) (Kirchherr, Reike, & Hekkert, 2017 Metabolic (2021

Figure 10: Waste framework directive (European Union (EU), 2018)

is the waste hierarchy illustrated in figure 10. This hierarchy outlines a series of steps to be taken in order to minimize waste generation. At the top of the hierarchy is waste prevention, which aims to eliminate waste altogether. Preventing waste is the preferred option, and sending waste to landfill should be the last resort. Considering the environmental impact and spillage associated with medicine waste, this thesis will primarily focus on preventing and reducing medicine waste in the operating room (OR). By prioritizing waste prevention, the aim is to achieve the highest value in terms of environmental sustainability.



en, Demmers, Van der Heijden, & Witlox, 2016)
) (Potting, Hekkert, Worrell, & Hanemaaijer, 2017) by

Sustainable initiatives

Green Teams
In a positive stride towards sustainability, various sustainable initiatives, such as the establishment of Green Teams, have emerged within healthcare institutions. Typically, a Green Team comprises a group of healthcare professionals within a single institution who concentrate on a specific theme or area of expertise. These teams engage in either project-based or ongoing efforts to address sustainability concerns. The presence of Green Teams varies across institutions, ranging from none to as many as twenty teams in academic hospitals.

Green Team OR LUMC
The Green Team known as **Green OK Leiden** operates within the OK (Operating Room) centre at the Leiden University Medical Centre (LUMC). Established in 2016, this team is dedicated to fostering sustainability within the OR centre. Collaboratively, the Green Team and stakeholders explore sustainable solutions aimed at reducing the carbon footprint associated with the OR.

Key learnings

- Shifting from a linear to a circular economy is vital in healthcare to optimize resource use and reduce waste.
- Using Value Hill strategy and waste hierarchy frameworks will guide waste reduction efforts:
  Prevention, refuse, rethink and reduce have the highest value.
- Green Teams in healthcare institutions, like at LUMC, are crucial for promoting sustainability and provide and opportunities for a positive change.

Literature on measuring medicine waste in the OR

In order to facilitate the research design of quantifying medication waste in the OR, literature on the topic was identified. The primary objective of this was to provide a basis for future comparison and analysis of the study's findings.

Eight academic papers were found that fitted to the research topic at hand, namely reducing medication waste in the OR:

1. Preventable drug waste among anaesthesia providers (Atcheson et al., 2016)
2. Evaluation of Drug Wastage in the Operating Rooms and Intensive Care Units of a Regional Health Service. (Barbariol et al., 2021)
3. Drug Use Inefficiency: A Hidden Source of Wasted Health Care Dollars. (Gillerman & Browning, 2000)
4. Better Pairing Propofol Volume With Procedural Needs: A Propofol Waste Reduction Quality Improvement Project. (Kicker et al., 2018)
5. Propofol Wastage in Anaesthesia. (Mankes, 2012)
6. The Wastage and Economic Effects of Anaesthetic Drugs and Consumables in the Operating Room. (Peker, 2020)
7. The anaesthesiologist and global climate change: an ethical obligation to act. (Van Norman & Jackson, 2020)
8. Drug wastage contributes significantly to the cost of routine anaesthesia care. (Weinger, 2001)

The papers were reviewed by comparing the; study period, definition of drug waste, drugs measured, tracking method, results and waste minimizing strategies. These findings were summarized in a table that can be found in (see appendix A).

The key findings of the comparison were:

Definition of drug wastage
It is important to clearly state what the definition of medicine waste is. It could exclude or include partially full syringes.

Medicines included in the study
The medications that were followed in the study varied depending on the study. Some studies simply kept track of the medications that were wasted the most, per prior research. Others tracked all medications used.

Method of waste tracking
The tracking of medication waste in various studies employed different methods. Most studies utilized a retrospective approach, where medication administration data was obtained from computerized anaesthesia record systems. The total amount of drugs distributed by the pharmacy over a year served as an indirect measure of wasted drugs.

However, more recent studies adopted prospective methods, such as "the Evaluation of drug wastage in the operating room (OR) and intensive care units (ICU)" by F. Barbariol (2021). This study involved nurses filling out forms to record the number of drugs prepared, used, and discarded, providing a more direct measurement of wasted drugs.

Results
The results of these studies presented various metrics to demonstrate drug waste. The notable findings included:

- Value of wasted medications in terms of dollars (measured in all papers)

- Number of syringes wasted
- Weight of the waste in kilograms
- Time dedicated to the preparation of unused drugs
- Median volume of remaining medicine in millilitres
- Percentage of waste for each medicine compared to the total waste

Medications with the highest associated costs in terms of waste were typically:

- Emergency medications: ephedrine, phenylephrine, atropine
- Propofol
- Rocuronium
- Midazolam
- Thiopental

Proposed waste minimizing strategies:
The studies proposed several strategies to minimize medication waste, including:

- Utilizing pre-filled syringes for commonly used drugs (proposed in 5 of the 8 papers)
- Providing education and awareness programs for staff
- Implementing real-time tracking of medication waste to identify areas for improvement
- Considering the use of smaller vials or ampoules for medications (proposed in 6 of the 8 compared papers)

Key learnings

- A clear definition of 'medicine waste' is key in studying waste in the OR.
- Different studies track various medicines, indicating a need for an inclusive approach.
- Waste tracking has evolved to **real-time methods**, highlighting the importance of immediate data collection.
- Multiple medicines, including emergency drugs and anaesthetics, often get wasted, indicating potential targets for intervention.
- Proposed strategies span from pre-filled syringes to smaller packaging, suggesting a comprehensive approach to tackle wastage.
- These findings highlight the need for nuanced, targeted strategies for effective waste management, promoting OR sustainability.

This gathered understanding is invaluable for the approach of measuring waste in the OR, which will be elaborated upon in Chapter 4.

Conclusion

In this chapter, the project partners, the importance of the study, and the need to transition to more sustainable practices in healthcare were discussed. The key learnings are summarized below:

Relevance

The environmental impact of chemical prodcuts, including medicines is significant, contributing up to 41.2% of healthcare's carbon emissions (RIVM, 2022). The commitment by Dutch medical universities, including the LUMC, to the **Green Deal Sustainable Healthcare 3.0** underscores the importance of this issue.

Meanwhile, an ongoing challenge with medicine shortages calls for judicious use of these resources, intertwined with **ethical considerations** about the fair allocation of medical supplies. This concern is further compounded by the urgent need to transition from a linear to a **circular economy** in healthcare, emphasizing the importance of resource optimization and waste reduction.

Opportunities

Key actors in this shift include **Green Teams**, like the one at LUMC, which champion sustainability efforts within healthcare institutions. Strategic frameworks such as the **Value Hill strategy** and **waste hierarchy** provide guidance, highlighting the importance of prevention, refusal, rethinking, and reduction.

Different studies and tracking methodologies reflect the varied facets of this issue, from the types of medicines involved to the strategies for waste reduction.

It's clear that a comprehensive approach is necessary, from adopting **real-time waste tracking** to considering varied i**nterventions** like the use of pre-filled syringes and smaller packaging sizes. The focus needs to be on nuanced, targeted strategies to efficiently manage waste and promote OR sustainability.

In the next chapter, the context of medication waste in the operating room (OR) will be explored. This exploration will provide valuable insights into the specific types of medicines wasted, the key people involved, and potential ways to address the issue. By understanding the factors that contribute to medication waste in the OR, targeted strategies and interventions to reduce waste can be invented.

Medicines in the OR

03

3. Medicines in the OR

The aim of this chapter is to delve into the context of the operating room (OR) environment and explore the various stakeholders involved, as well as their roles in contributing to medicine wastage. The operating room (OR) is a critical healthcare environment where surgical procedures take place and patient care is provided as shown in figure 11. By gaining a comprehensive understanding of the contextual factors influencing medicine To gain a deeper understanding of the OR environment, **two observation days were conducted**, allowing for direct observation and identification of the stakeholders involved. wastage, valuable insights can be obtained to inform the development of effective interventions and strategies.

Observation Methodology

To gain valuable insights into the OR setting and its connection to medicine waste, two observation days were conducted. **The first observation** day aimed to familiarize oneself with the OR space without specific prior preparations, allowing for an unbiased and natural observation of the activities. By immersing in the environment and observing the unfiltered flow of procedures, interactions, and practices, authentic data was captured.

Building upon the insights gained from the initial observation, **the second observation day was more structured and prepared. An observation form was developed to systematically docu**ment relevant

Figure 11: The operating room (LUMC,2016)

information pertaining to medicine waste. This form facilitated the recording of specific observations related to medication handling, disposal processes, and the roles and interactions of stakeholders involved in managing medicine waste in the OR.

These observations provided insights into the dynamics at play, as well as the perspectives and behaviours of the individuals involved. The information gathered during these observations serves as a foundation for further analysis and the development of effective interventions and strategies to address medicine waste in the OR setting. disposal processes, and the roles and interactions of stakeholders involved in managing medicine waste in the OR.

Medicines in the OR

Medications play a crucial role in the operating room (OR) environment, where they are administered by **anaesthesia practitioners**. The term "anaesthesia" refers to the loss of sensation and can encompass various techniques and medications.

Intravenous (IV) medicines are essential in the Operating Room (OR) due to their rapid onset and precise control they offer over a patient's physiological state. These medications, delivered directly into the patient's bloodstream, allow for immediate effects, crucial in the dynamic environment of the OR. IV medicines encompass a broad range of drugs, including anaesthetics, analgesics, antibiotics, and vasoactive agents.

Anaesthetics induce temporary loss of sensation or consciousness for surgery, while analgesics manage pain during and after the procedure. Antibiotics prevent infections, and vasoactive drugs manage blood pressure. The careful selection and administration of these medications, often in fluid form, require the expertise of anaesthesia professionals to ensure optimal patient outcomes and safety.

Anaesthesiologists

Anaesthesiologists are medical doctors specializing in anaesthesia care. They oversee the administration of medications in the OR and are responsible for making critical decisions regarding anaesthesia management, medication selection, and dosage adjustments based on patients' specific needs.

Anaesthesia Nurse

Anaesthesia nurses play a vital role in medication administration within the OR. They are responsible for preparing and administering medications to patients during surgery. These nurses ensure the accurate dosage and timely delivery of medications, monitor patients' responses to anaesthesia, and collaborate with anaesthesiologists to optimize patient care.

Preparation of medicines

The preparation of medicines in the operating room (OR) is a critical process that requires careful attention to ensure patient safety and efficient work-flow. Anaesthesiologists and anaesthesia nurses play key roles in this process. The preparation of medicines typically takes place at designated medication preparation areas within the OR.

During the preparation phase, medications are retrieved from the designated storage units, named “day carts” and made ready for use on the tray shown on figure 12. The medications are carefully measured, drawn into syringes, or prepared in other appropriate forms for administration. This step requires adherence to precise dosing instructions and strict aseptic techniques to maintain the sterility and integrity of the medications.

The preparation process also involves verifying the accuracy of medication labels and ensuring that the correct medications and dosages are prepared for each patient. Attention to detail and effective communication between the OR staff members are crucial to minimize the risk of medication errors and maximize patient safety.

The picture on the left shows a medicine tray prepared with medicines for the procedure.

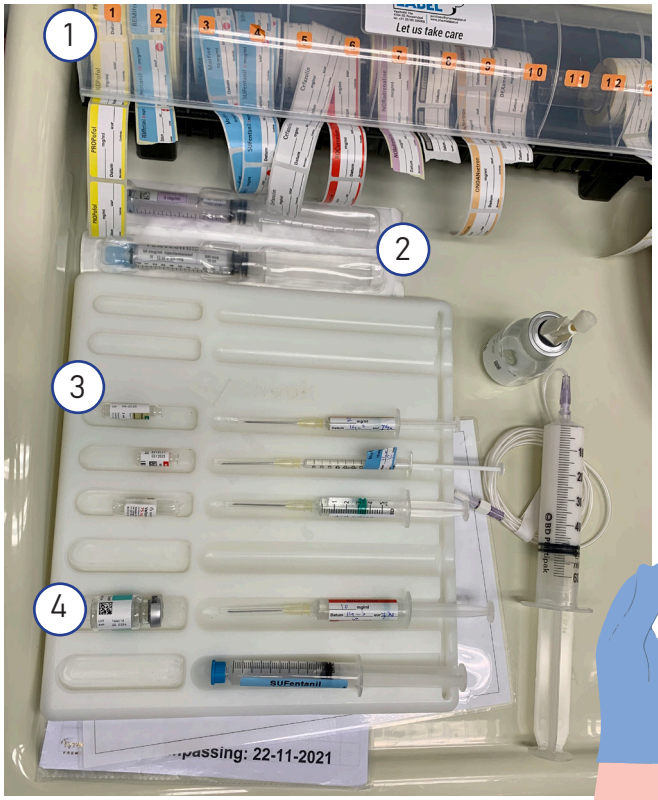


Figure 12: Medicine tray at the LUMC

1. **Label:** Medicines are labelled to ensure accurate administration, guaranteeing that the correct drug is dispensed to the intended patient.

2. **Pre-filled syringe:** Pre-filled syringes are convenient drug delivery systems where the syringe comes pre-packaged with the specified medication. They require no preparation - once the packaging is opened, the syringe is ready for use. These are particularly beneficial for emergency medications like ephedrine and phenylephrine, offering quick and efficient administration.

3. **Ampoule:** An ampoule is a small, sealed glass container that typically holds a single dose of medication, which can be accessed by breaking the top. Its design ensures the medicine’s sterility until use.

4. **Vial:** A vial is a small, cylindrical container, often made from glass or plastic, used to store and dispense liquid medications. It’s sealed with a rubber stopper.

Storage of medicines

During the observation period, an investigation was conducted to trace the origins of medicines within the operating room (OR) environment.

The OR logistics department has the responsibility of filling medications. To gain a comprehensive understanding of this aspect, the second observation day provided an opportunity to closely follow the OR logistics team during their regular working hours, allowing for valuable insights from their perspective.

The supply of medications in the OR is facilitated through a coordinated process involving multiple stakeholders and departments. Specifically, the medications are obtained from dedicated storage units known as “day carts,” which are designed to accommodate the medications present at the OR. These day carts consist of two drawers that house the necessary medications, as depicted in Figure 13.

Figure 13: Day cart with medicines

The replenishment of medications in the day carts is carried out through a coordinated effort between the OR stock and the **hospital pharmacy**. The OR stock serves as the primary repository of medications within the OR department, maintaining an inventory of commonly used pharmaceutical products. The logistics employees utilize bar-code scanning technology to place orders for medication resupply from the hospital pharmacy.

OR logistic employees

They play a crucial role in managing medication waste within the operating room (OR) setting. As part of their responsibilities, they oversee the storage, and distribution of medications used during surgical procedures. Their actions and decisions directly impact the availability, utilization, and potential waste of medications within the OR.

Efficient management of the OR stock and seamless **coordination between the OR logistics department and the pharmacy** are critical components of the medication supply chain within the OR. The OR logistics department assumes a pivotal role in overseeing the stock, monitoring medication levels, and liaising with the pharmacy to address any restocking requirements. Their responsibilities encompass maintaining the integrity and availability of medications in the OR, ensuring the smooth functioning of preoperative medication administration processes.

Origin of medicines

The hospital pharmacy holds a central and multifaceted role in the effective functioning of the Operating Room (OR). As a primary source for all necessary medications, the pharmacy plays a crucial part in coordinating the medical activities within the OR. The supply chain of these critical medicines is maintained in a two-pronged manner. Firstly, a portion of these **medicines is produced in-house**, within the hospital pharmacy itself. This aspect ensures a direct, reliable source for certain medications, tailored specifically to the hospital's needs.

Secondly, to ensure a comprehensive inventory of medications, the hospital pharmacy procures an array of medicines from external suppliers. This process requires planning, coordination, and extensive pharmaceutical knowledge. The hospital pharmacy works closely with anaesthesiologists, understanding their requirements for various OR treatments.

Beyond this web of **procurement** and production, the hospital pharmacy also shoulders the significant responsibility of maintaining medication safety. This facet involves testing and verification processes to ascertain the safety and efficacy of the medicines being used in the OR. These measures safeguard against potential adverse drug reactions, ensure quality control, and ultimately protect patient health.

In essence, the hospital pharmacy's role extends far beyond simple supply provision. It is a cornerstone of hospital operations, particularly within the OR, ensuring the safe and efficient use of medications, thus, playing a vital role in patient care and treatment outcomes.

Hospital pharmacy

The hospital pharmacy plays a critical role in procuring, preparing, and dispensing medications for surgical procedures. They are responsible for maintaining adequate inventory levels and ensuring medication quality and safety.

Key learnings

Key actors:

- **Logistics Department**: Responsible for the timely supply and proper distribution of medicines in the OR.
- **Anaesthetic Nurses**: Critical in the preparation and administration of medications.
- **Anaesthesiologists**: In charge of decision-making regarding the types and amounts of medication required.
- **Pharmacy:** Engaged in procuring, preparing, and dispensing medications for surgical procedures.

Timeline of medication use OR

This section presents a comprehensive timeline that highlights the various stages and perspectives involved in the use of medications within the operating room (OR) environment. It encompasses two key viewpoints: the aesthetics team responsible for administering the medications and the logistics department tasked with managing the inventory of medicines. By examining the timeline from these two perspectives, it becomes possible to identify critical pain points and touch points that may warrant intervention to improve medication management practices.

The perspective of the anaesthetic team

From the perspective of the aesthetics team, the timeline begins with the preoperative phase, where preparations for surgery are underway. During this stage, the anaesthesiologist assesses the patient's medical history, allergies, and specific medication requirements. This information informs the selection and preparation of the appropriate medications to be administered during the surgical procedure. Once the patient is in the OR, the administration of medications is carried out under the close supervision of the anaesthetics team, ensuring optimal patient comfort and safety throughout the procedure. Following the surgery, the team monitors the patient's recovery and administers any necessary postoperative medications.

The perspective of logistics

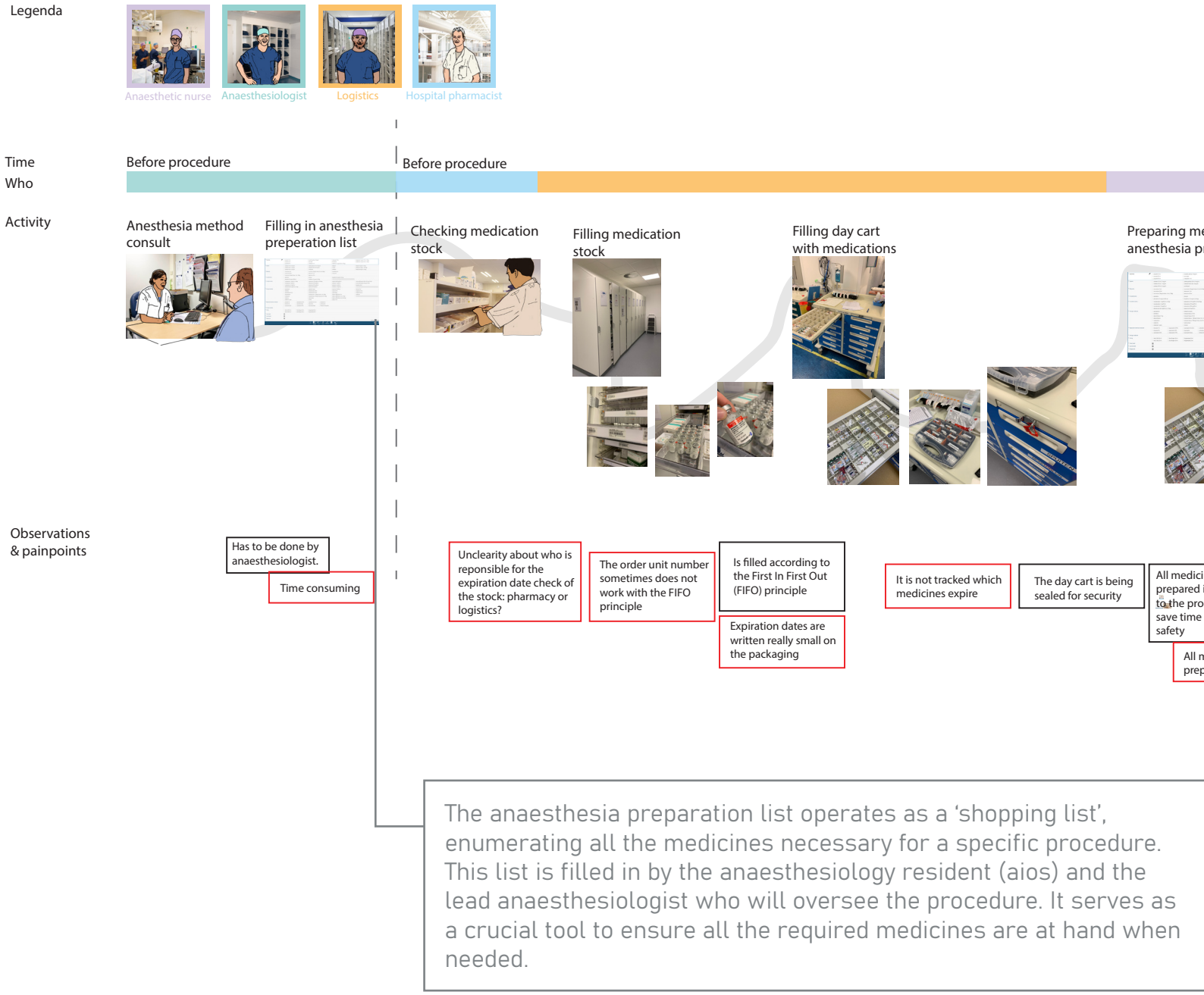
On the other hand, from the logistics perspective, the timeline focuses on the management of medication inventory within the OR setting. It encompasses activities such as storage, and distribution of medications. The logistics department collaborates closely with the hospital pharmacy to ensure a timely and accurate supply of medications to the OR. This involves monitoring stock levels, replenishing supplies, and managing expiration dates to prevent wastage and ensure a continuous availability of medications. Additionally, the logistics team plays a crucial role in optimizing medication storage practices.

The timeline

By examining the timeline from these dual perspectives, potential pain points and touchpoints within the medication management process can be identified. These pain points and touchpoints serve as opportunities for intervention and improvement, allowing for the implementation of targeted strategies to enhance medication management efficiency, minimize waste, and ultimately improve patient care outcomes within the OR setting.

The timeline can be found on the next pages. The painpoints are marked with a red border.

TIMELINE of medicine use at the OR



The anaesthesia preparation list operates as a 'shopping list', enumerating all the medicines necessary for a specific procedure. This list is filled in by the anaesthesiology resident (aios) and the lead anaesthesiologist who will oversee the procedure. It serves as a crucial tool to ensure all the required medicines are at hand when needed.

Figure 14: timeline of medicine use in the LUMC OR

During procedure

After procedure

edications from reperation list

Getting the patient from

Performing anesthesia method

Preparing a new dose

Taking the patient to the verkoever

Disposal of medications

nes are in advance cedure to & for patient

Preparing one medicine can take a while because you also have to label it and this has to be double checked to avoid errors

They keep track of the vitals signs to see which extra medication is needed

There can be unclearity about how long the procedure takes so it can be hard to estimate the medication dose correctly

Used medications are collected in a 'nierbekkenbakje'

Anaesthetic nurses and logisitcs dispose the medications in the waste bins in the waste rooms

Unclearity about what can and what can not be thrown in the bins

Special Medication Waste: = expensive €1/kg

At the LUMC CVIC they are doing a pilot with PreZero using a bin for the SZA
Lower disposal cost
+ the bin can be reused

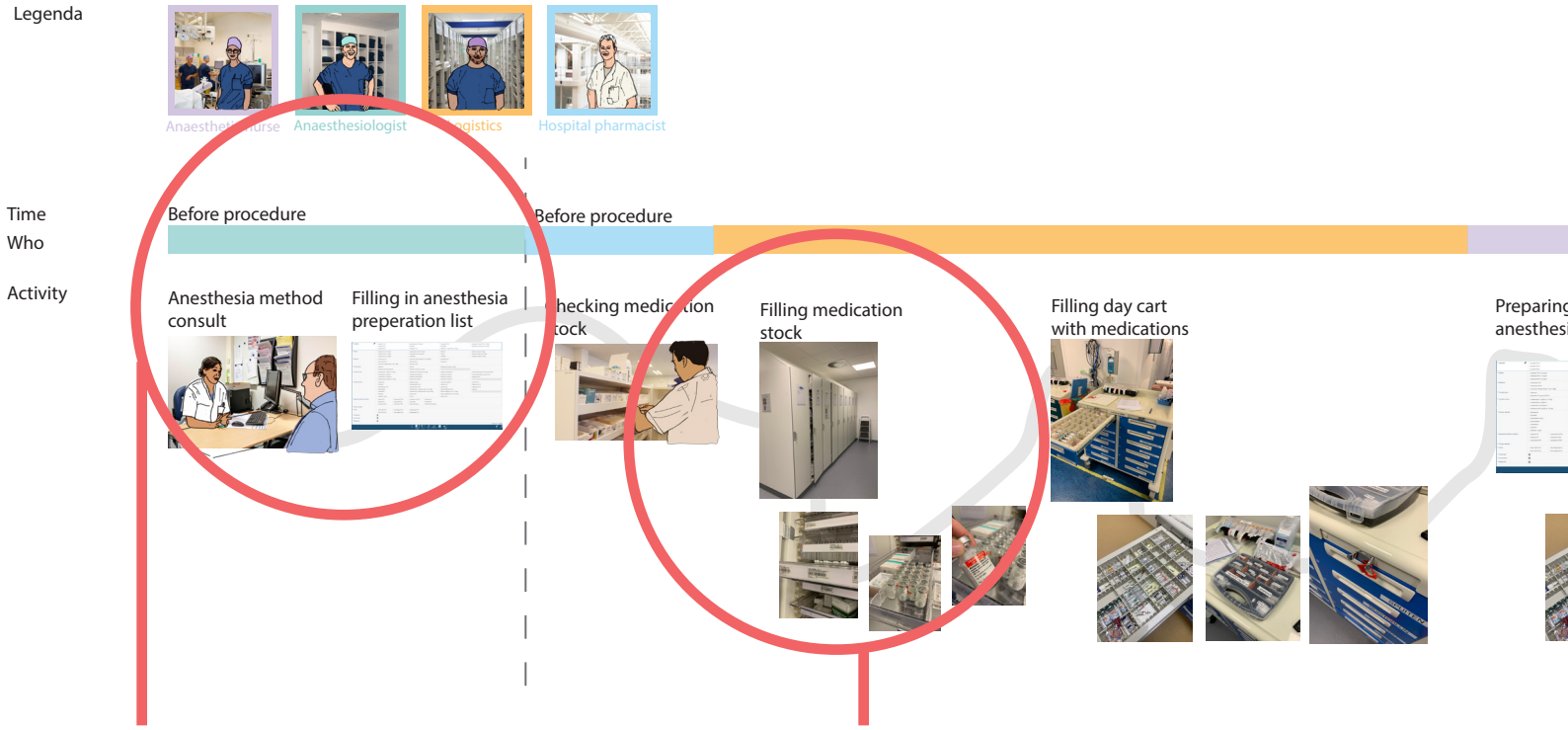
edicines from the peration list are prepared

Preparation of the medicines, in accordance with the list, is carried out by the anaesthesia nurse. This is done before the procedure starts to save valuable time during the procedure.

Touchpoints for intervention

Looking at the painpoints, several moments were medicine waste occurs arise. These moments are highlighted in the timeline below.

TIMELINE of medicine use at the OR



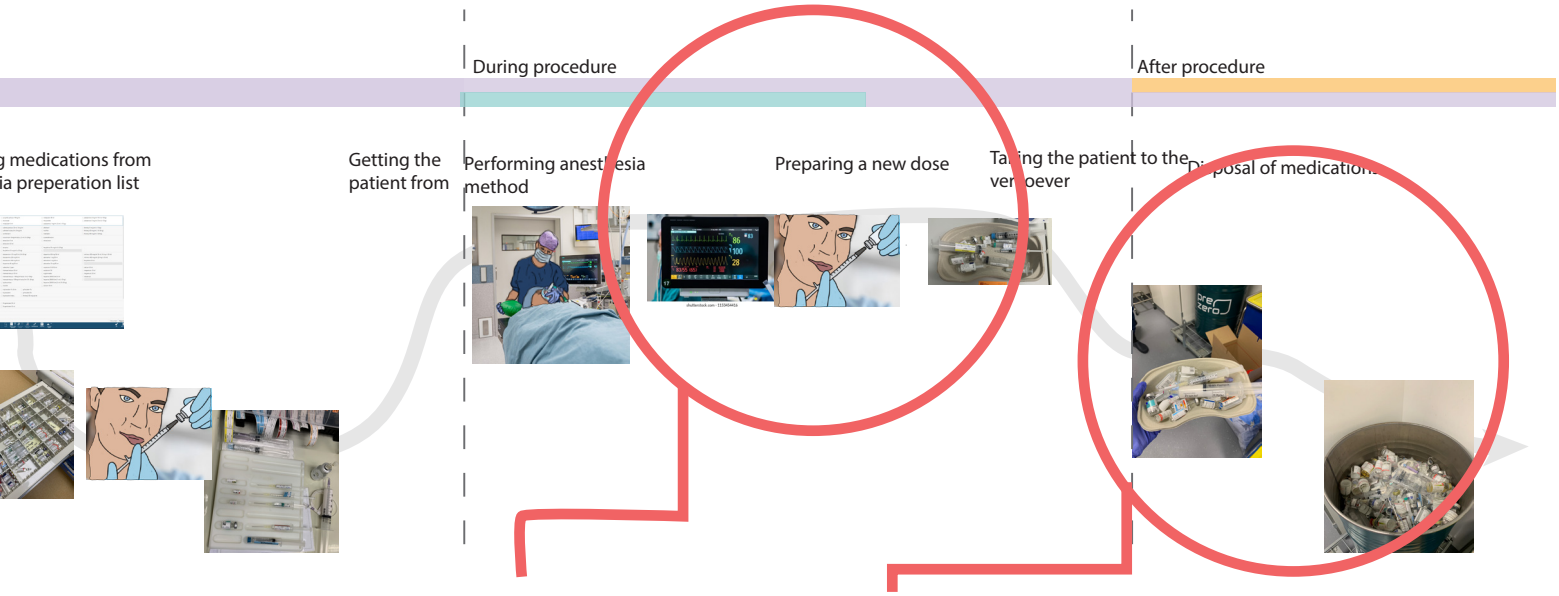
Prescribing medication:

If the anaesthesia preparation list is filled in with inaccuracy or laxity, it can become a source of medicinal waste.

Careful consideration and precision in formulating the medication requests, followed by adherence to the list, can prevent medicine waste. As such, the spotlight is on the quality of prescribing - ensuring that each medication request is precise, accurate, and thoroughly considered. Appropriate prescribing habits offers an opportunity for both waste minimization and optimal resource utilization within the OR.

The OR stock

In the day cart and OR stock presents a challenge and opportunity for waste reduction. The efficient management of stock is crucial to ensure that an adequate supply of medications is available when needed. However, poor stock management practices can result in medicine waste. By implementing effective stock management strategies and ensuring accurate inventory control, healthcare facilities can optimize resource utilization, minimize expired medications, and reduce unnecessary waste in the day cart and OR stock.



Preparing a new dose of medication

In the operating room (OR) poses a challenge and opportunity for waste reduction. The accurate preparation of medication doses is essential to ensure patient safety and optimal treatment outcomes. However, improper preparation and estimation practices can lead to medication waste. By emphasizing precise dosage calculations, avoiding over-preparation, and implementing efficient medication handling protocols, healthcare professionals can minimize medication waste and promote resource efficiency in the OR.

Disposal:

Upon the completion of procedures, it's not uncommon to find medicines that are fully or partially unused. Proper disposal of these leftover substances is critical to prevent them from inadvertently entering our surface waters, posing potential harm to the environment.

Moreover, full syringes may be re-purposed for upcoming procedures or redistributed to other ORs, thus maximizing their usage. Implementing such mindful practices around disposal and reuse can play a significant role in curtailing unnecessary waste. This reduces the wastage of valuable resources.

Key learnings:

The process of managing medicines is divided into four crucial moments, each offering potential areas for waste reduction:

- **Precise Prescribing:** Inaccuracy or laxity in filling the anaesthesia preparation list can lead to waste. Quality prescribing - with each medication request being accurate, precise, and well-considered - is crucial for waste minimization and optimal resource utilization in the OR.
- **Efficient Stock Management:** The day cart and OR stock present both a challenge and opportunity for waste reduction. Effective stock management and accurate inventory control can optimize resource utilization, reduce expired medications, and minimize unnecessary waste.
- **Accurate Use:** The preparation of new medication doses in the OR can contribute to waste if not carried out accurately. Emphasizing precise dosage calculations, avoiding over-preparation, and implementing efficient medication handling protocols can minimize medication waste and promote resource efficiency.
- **Mindful Disposal:** Proper disposal of leftover substances is necessary for preventing potential environmental harm. Also, re-purposing full syringes for upcoming procedures or redistributing them to other ORs can maximize their usage, thus reducing waste of valuable resources.

Stakeholders

While these direct actors and moments offer an understanding of the immediate processes contributing to waste, an equally important revelation of this exploration pertains to the network of indirect stakeholders involved. These stakeholders, while not involved in direct handling of medicines, significantly influence the processes and practices related to medicine waste. The overview is illustrated in figure 15 and the full analysis can be found in appendix B.

- **OR Management**: Influences budgeting and policy-making processes that indirectly affect waste levels.
- **Governmental and Regulators**: Shape institutional practices through rules and guidelines for handling and disposal of medical waste.
- **Pharmaceutical Companies**: Their packaging choices, production processes, and provision of information on medicine storage and handling can affect waste levels.
- **Infection prevention**: Infection control prevents or stops the spread of infections in healthcare settings
- **Green Teams:** their practices and initiatives contribute to the hospital's overall sustainability goals, including minimizing medicine waste.
- **Patients**: Can indirectly impact waste through their individual health conditions and responses to medications.

In conclusion, identifying and understanding the indirect stakeholders, their respective roles, motivations, and values is instrumental to elucidating the intricacies of the system surrounding medication waste in the Operating Room. This awareness not only promotes a holistic view of the challenge but also aids in the development of effective and inclusive strategies that take into account the various

perspectives and interests involved in this context.

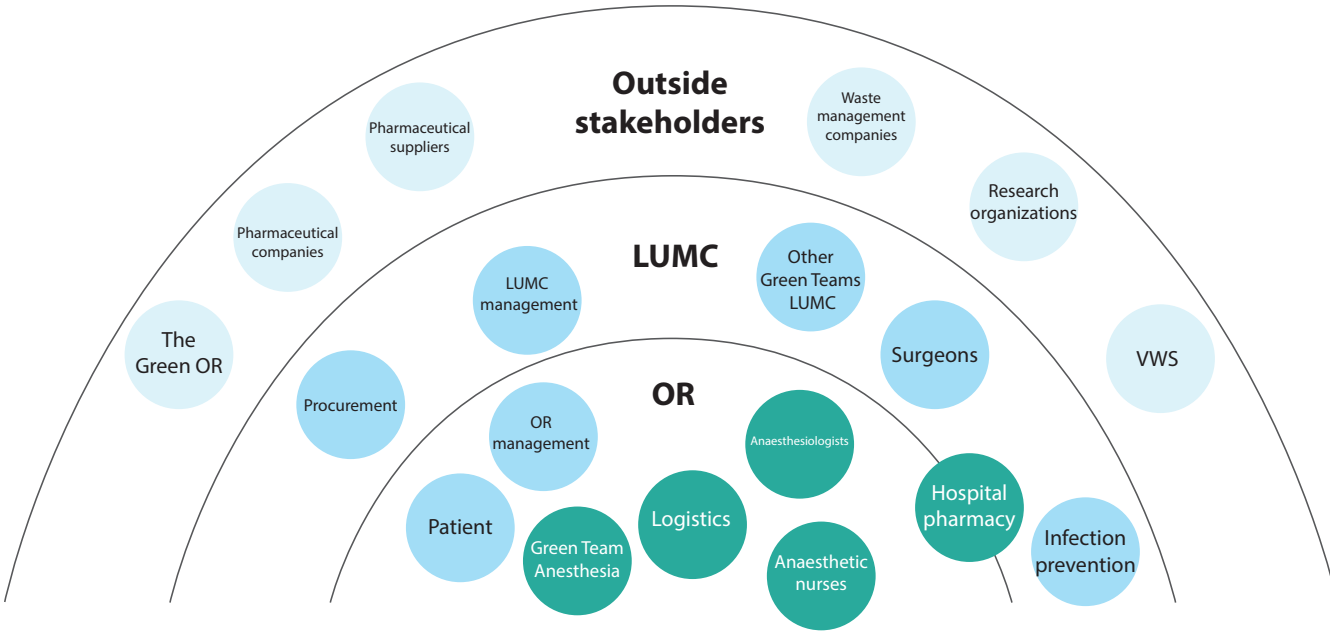


Figure 15: stakeholders involved in medicine waste in the OR

Conclusion

As this chapter concludes, these findings serve as a robust foundation for further research. Understanding the stakeholders, both direct and indirect, and the key moments in the medicine life-cycle, paves the way to accurately define the problem of medicine waste and identify opportunities for intervention.

Prescribing Medication:

Waste can be generated when medication requests on the anaesthesia preparation list are inaccurate or filled out carelessly. By ensuring each medication request is precise, accurate, and thoroughly considered, wastage can be prevented, leading to optimal resource utilization within the operating room (OR).

OR Stock Management:

The day cart and OR stock present both a challenge and an opportunity for waste reduction. Efficient stock management is key to ensuring the availability of necessary medications and avoiding wastage due to expiration. Implementing effective inventory control strategies can optimize resource utilization and minimize unnecessary waste.

Medication use:

Wrong estimations in dosage calculation or over-preparation can result in medication waste. By refining dosage calculations, avoiding over-preparation, and adopting efficient medication handling protocols, wastage can be minimized and resources utilized more efficiently.

Medication Disposal:

Proper disposal of fully or partially unused medicines following procedures is crucial to prevent environmental contamination. Re-purposing or redistributing full syringes for upcoming procedures or to other ORs can help maximize usage. Implementing conscious disposal and reuse practices can significantly reduce unnecessary waste and optimize the usage of valuable resources.

The roles of other stakeholders such as OR management, infection prevention teams, and pharmaceutical companies are also acknowledged. Each of these entities influences this intricate system from different perspectives - financial, risk management, and supply.

Through an exploration of these key actors and processes within the medicine management, a comprehensive view of the system is revealed. This understanding is foundational in devising targeted strategies for waste reduction and sustainable practices, creating a more efficient and environmentally conscious OR.

In the subsequent chapter, a quantitative analysis to measure the extent of medicine waste in the OR will be done. Understanding the scale of the issue and assessing the effectiveness of current practices will be useful in devising strategies that reduce the waste. Besides, the causes of medicine waste will be explored to gain deeper understanding.

MEASURING MEDICINE WASTE IN THE LUMC OR

04

4. Measuring medicine waste in the

This chapter centres around medicine waste measurement and cause analysis within the context of in the OR. The research is segmented into distinct sections, corresponding to different waste types elaborated in the introduction, specifically expired medications and medication residues. Each study employs a plan of approach to investigate these waste categories thoroughly and comprehensively.

Method

Measurement of medicine residues

In collaboration with anaesthesiologist Hans Friedericy and hospital pharmacist Dinemarie Kweekel a plan of approach was made to track the medication residues.

Type of Research: This study utilizes a mixed methods approach, combining quantitative and qualitative elements. The quantitative component involves the measurement of the quantity of remaining medications, while the qualitative component focuses on identifying the causes contributing to medication waste. The research design is primarily exploratory and descriptive, aiming to gather comprehensive insights into medication waste in the LUMC OR.

Research Goals

1. Measure the amount of medication residues in [ml] after procedures in the LUMC OR.
2. Identify the causes contributing to medication waste.

Duration of Research

The research was conducted in March 2023 over a period of four days. Each day, the medication residues from four ORs was measured, resulting in a total of sixteen ORs being tracked. This selection aimed to represent a "standard" day in the LUMC OR complex.

Research collection procedures

Medication waste was manually tracked to gain a comprehensive understanding of the factors contributing to wastage. Through direct observation and documentation of disposal, real-time and accurate data on quantities and reasons for wastage were collected.

A standardized data collection form was developed and utilized by the researcher to document medication waste at the start and end of each surgical operation (see Appendix C for the measurement form). The form underwent multiple iterations to refine its design and ensure effectiveness. Additionally, a pilot test was conducted to assess usability and comprehensiveness. Based on the pilot test findings, necessary revisions were made to the form, and the final version was implemented for data collection in the actual study.

Data analysis

The quantitative data collected on the quantities of remaining medications were analysed using descriptive statistics. Measures such as means, medians, and percentages were computed to summarize the data and identify any trends or patterns. This analysis provided insights into the overall extent of medication waste in the LUMC OR. The data collected on the data collection form were inserted into Microsoft Excel for further analysis. By organizing and manipulating the data in Excel, patterns and relationships within the remaining medication waste could be explored and identified.

The qualitative data collected through short interviews with the nurse anaesthetises were analysed using thematic analysis. The

e LUMC OR

interview responses were imported in Excel. This involved a systematic process of reading and re-reading the responses, identifying meaningful units of data, and grouping them into themes. These themes were then further refined and categorized to capture the key factors contributing to medication waste in the LUMC OR.

For a more comprehensive view of the data analysis, please refer to the separate appendix, which is available in an Excel format. It's important to note that the listed prices for medications may vary from what you expect. This is because the actual procurement prices at Leiden University Medical Center (LUMC) are confidential, and therefore, the prices from the standard Pharmaceutical Compass are used as a substitute.

Measurement of expired medications

Developing a concrete plan for addressing expired medications posed certain challenges as it relied on the availability of logistics staff to conduct the necessary checks. The responsibility for verifying expiration dates of medications rested with the logistics staff, necessitating coordination with the head of logistics to allocate suitable time for this task.

To address this issue, a specific day in March was scheduled to comprehensively check all the expired medications in the OR stock. A logistics employee was assigned to assist in the process, thoroughly examining approximately 4/5 of the medication stock. During this inspection, all expired medications were identified and subsequently collected for proper disposal.

Research collection procedures:
The collection of data on expired medications involved a real-life observation and subsequent analysis of the associated costs. The process included systematically counting and documenting the expired medications found within the healthcare facility over a specified period. This data collection procedure aimed to provide a comprehensive understanding of the extent of medication expiration and its financial implications.

Data analysis
Once the expired medications were identified and recorded, the subsequent data analysis focused on quantifying the costs associated with these expired drugs. The analysis aimed to determine the financial impact of medication waste due to expiration, taking into account the value of the unused medications that had to be discarded.

Results

This section presents the findings of the study on medication waste in the LUMC operating room (OR), focusing on both remaining medications and expired medications. The results provide comprehensive insights into the quantities of expired and remaining medications, the causes of medication waste, and the prevalence of expired medications. These findings contribute to a deeper understanding of medication waste management within the LUMC OR and inform strategies for waste reduction and improved medication utilization. The results can be found on the next pages.

Discarded per year:

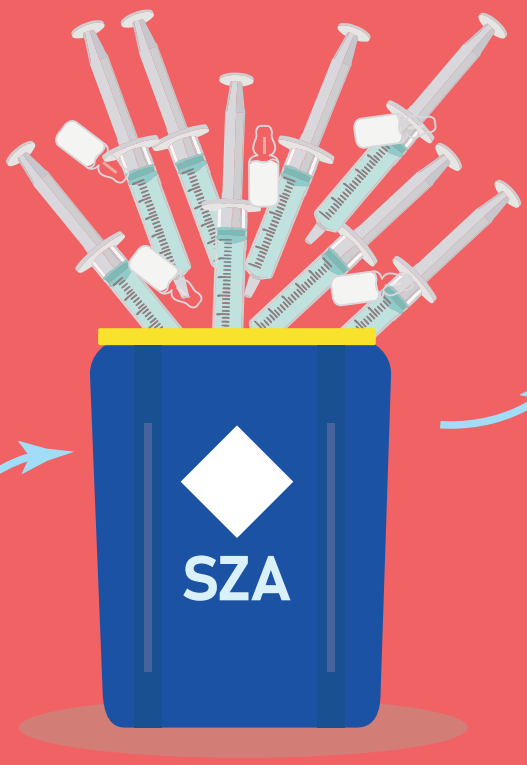
478 L
of medicine residue

=

22.011
syringes of 50 ml

=

€70.708
Waste disposal costs included



78%
of the total waste i
quantity is due to

Propofol	22
Sufentanil	12
Remifentanil	12
Noradrenaline	10
Rocuronium	10
Fenylefrine	9
Efedrine	4

TOP 5
median volume of waste in %

1. Noradrenaline	85%
2. Efedrine, Fenylefrine	80%
3. Propofol, Rocuronium	60%
4. Sufentanil	55%
5. Remifentanil	45%

TOP 5
volume discarded a day

1. Propofol 50 ml	667 ml
2. Remifentanil 50 ml	378 ml
3. Noradrenaline 50 ml	371 ml
4. Sufentanil 10 ml	92 ml
5. Fenylefrine 10 ml	80 ml

TOP 5
costs of medicine residue per year

1. Fenylefrine	€14.747
2. Noradrenaline	€ 8.662
3. Propofol	€ 3.640
4. Efedrine	€ 3.588
5. Remifentanil	€ 3.538

19 full syringes
discarded per day

Bridion is used in 54% of the time rocuronium is used.

Bridion costs €85 per vial.
This is €287.300 per year.

108 expired medicines
of which 45 prefilled syringes
in the OR stock

Figure 16: Results of the medicine waste measurement in the LUMC OR

Causes medicine residues

11% **Wrong estimation**, choosing a smaller vial was also possible.

11% A smaller size would have been too small, leaving no alternative choice then choosing the 50 ml.

44% This is the **only or the smallest medication size available**, leaving no alternative choice.

13% This is a **single-size pre-filled syringe** that cannot be adjusted or modified according to specific dosage requirements

Causes expired medications

"The tray is **hard to fill First-In, First-Out (FIFO)** ."
- Logistics employee

Regular monitoring of expiry dates in the OR stock is absent, leading to a lack of understanding about the quantity of expired medications. Consequently, a clear overview of expired drugs is missing.

General observations

Lack of knowledge
The act of conducting the measurements at the LUMC marked a new initiative, with no pre-existing information available regarding the amount of the waste. This drew considerable attention, as everyone was keen on to see the results due to their lack of knowledge on the matter.

Lack of awareness
It was also noteworthy that pinpointing the reasons for leftover medicines proved challenging. Given that the preparation of medicines is largely an automated process, most staff members seldom pause to consider the issue of waste.

Pictures of the waste

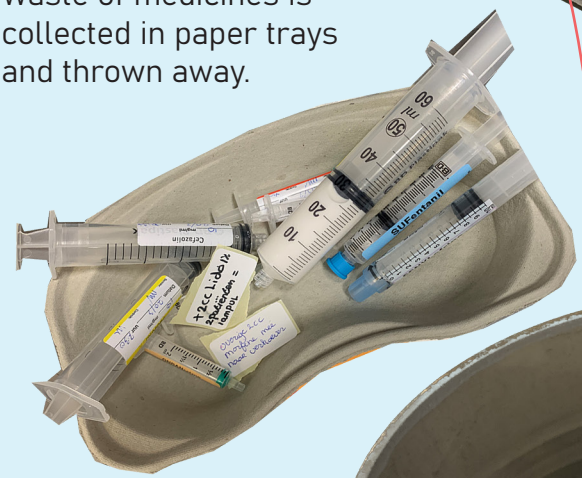
This figure shows some pictures of the waste captured. On the left the medicine residues are shown. Propofol particularly stands out because of the white colour and because the syringes that are still half full. On the right some of the expired medicines are shown such as Ephedrine which is a pre-filled syringe for emergencies. This syringe is expensive and costs about €8 per syringe. It was found expired 35 times.

Medicine residues

Expired medicines

35 prefilled Ephedrine syringes were expired.

Waste of medicines is collected in paper trays and thrown away.



They were kept in this tray that was hard to fill

Figure 17: Medicine waste

Discussion

In this section the results will be compared and discussed with the findings from the literature in chapter 2 and during the context exploration of chapter 3.

Smallest/only size available:

Medications such as reminfentail, sufentanil, rocuronium, and noradrenaline collectively accounted for 44% of the total waste. A predominant cause of waste for these medications appears to be the lack of diverse dosage sizes. For most of these medications, only one or the smallest size is available. Fenylefrine and ephedrine, used primarily in emergencies, accounted for 13% of the waste, reinforcing that the currently available sizes do not meet practical usage needs.

Literature from Barbariol et al. (2021), Atcheson et al. (2016), and Kicker et al. (2018) underscores the significance of diverse medication sizes to enhance dosing accuracy and reduce waste. Research conducted by Mankes (2012) further supports this observation by demonstrating considerable wastage linked with limited size options.

Unconscious/automatic choice of larger dose for propofol

Regarding propofol usage, it was found that about 11% of total waste was due to automatic selection of larger doses, aligning with Weinger's (2001) and Peker's (2020) findings. With a median of 30 ml propofol often remaining unused in the syringe, it would seem beneficial to introduce intermediate sizes like 30 ml and 40 ml, as suggested by Kicker et al. (2018) and Mankes (2012), to curtail this waste.

Difficulty in filling FIFO:

The study also observed challenges in implementing the FIFO (First In, First Out) principle in stock management due to physical constraints, such as unsuitable box sizes and order units exceeding box capacity. This issue warrants further examination and potential solutions to optimize stock management.

Lack of knowledge

Throughout conversations with anaesthetic nurses, it became increasingly apparent that there's a substantial knowledge gap surrounding sustainable practices pertinent to reducing medication waste. Upon inquiry about the reasons behind medication residues, the responses predominantly revolved around lack of awareness or indifference, indicating a clear gap in understanding the importance of the issue.

However, it's crucial to recognize that this situation is not solely due to apathy or negligence. The research revealed an additional challenge - the lack of appropriate medication sizes for prescribing precisely. This issue contributes to unnecessary leftovers, further exacerbating waste.

Evidently, this problem indicates more than just a lack of individual awareness. It highlights a **systemic lack of accessible, pertinent information and training around waste reduction in the OR**. When the necessary knowledge about optimal prescribing practices and the environmental impact of waste is not widely disseminated, it's unsurprising that unconscious habits continue unchecked.

Addressing this knowledge gap is thus a critical step towards medicine waste reduction. Providing adequate education about the environmental implications of waste, the importance of precise prescribing, and the benefits of using the right medicine sizes could foster more sustainable practices, ultimately leading to a substantial reduction in medicine waste in the OR.

Conclusion

The findings of this study have provided valuable insights into the magnitude of medication waste in the LUMC OR. The analysis revealed that **seven specific medications,** namely propofol, noradrenaline, sufentanil, remifentanil, rocuronium, fenylefrine, and efedrine, accounted for approximately 78% of the total waste. Consequently, focusing efforts on minimizing

waste for these medications would yield substantial waste reduction.

The analysis of the results has revealed several key factors contributing to medication waste, including the **unavailability of different sizes for medications**, unconscious or automatic selection of larger doses, and lack of knowledge and awareness about waste generation and reduction.

These findings align with previous research studies that have highlighted similar issues and their impact on medication waste in healthcare settings. Potential measures could include introducing a variety of medication sizes, tackling automatic dosing habits, optimizing pre-filled syringe usage, addressing physical constraints in stock management, and enhancing knowledge and awareness about waste generation and reduction.

In the upcoming chapter, these identified potential opportunities will be explored in more detail. Furthermore, based on the key learnings found in the previous chapters a design direction will be selected.

DESIGN DIRECTION

05

5. Design direction

This previous chapters have focused on understanding medicine waste in the Operating Room (OR), the people involved, and how much waste there is in the OR at LUMC. This chapter will translate these findings into key areas for intervention, potential opportunities, and eventually a design direction.

Problem Definition

The issue of medicine waste is nestled within the broader environmental footprint of healthcare, which is substantial. The production, distribution, and consumption of chemical products, including **medicines contribute to an alarming 41.2% of healthcare's carbon emissions**. This striking statistic, derived from the RIVM's (2022) report in Chapter 2, highlights the pressing need for sustainable practices in the healthcare sector.

In addition to the environmental impacts, **medicine shortages** - as discussed in Chapter 2 - present a challenge to healthcare systems, requiring mindful usage and disposal of medicines. This, paired with the **ethical obligation to ensure equitable resource distribution**, calls for a shift from a linear to a circular economy in healthcare, a transition urged by numerous institutions, including LUMC, as part of the **Green Deal Sustainable Healthcare 3.0**.

Chapter 3 further dissected the concept of 'medicine waste,' accentuating the need for a clear and comprehensive understanding. The exploration of the management of medicines identified four crucial moments - **prescribing, use, stock management, and disposal** - each offering potential targets for waste reduction efforts.

The quantitative assessment of waste in Chapter 4 illustrated the scale of the problem within the OR at LUMC. It revealed that seven specific medicines - propofol, noradrenaline, sufentanil, remifentanil, rocuronium, fenylefrine, and efedrine - represent approximately 78% of the total waste. Clearly, interventions focused on these medications could significantly decrease waste.

Contributory factors to medicine waste identified include the **lack of varied medication sizes, unconscious or automatic selection of larger doses, and gaps in sustainability knowledge**. These elements, if addressed, could lead to considerable waste reduction. Besides, regular monitoring of expiry dates in the OR stock is absent, leading to a lack of understanding about the quantity of expired medications. This highlights that there is a lack of knowledge on this.

Opportunities

The prior chapters also identified several opportunities for the transition towards more sustainable healthcare. Key actors in the sustainability drive are **the Green Teams**, like the one at LUMC, whose role was highlighted in Chapter 2. They can champion waste reduction initiatives within healthcare institutions, influencing change from a bottom-up approach.

Frameworks such as the **Value Hill strategy and waste hierarchy**, discussed in Chapter 2, provide valuable guidance for shaping these endeavours. They emphasize the importance of **prevention, refusal, rethinking, and reduction** - actions that hold high value in reducing waste.

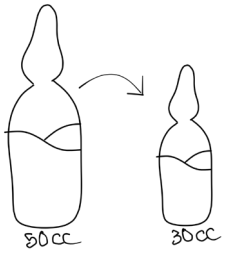
Potential interventions to reduce medicine waste, as derived from the findings in Chapter 4, range from process changes to awareness initiatives. These include adopting real-time waste tracking methods, using pre-filled syringes, **offering different medication sizes,** managing stock constraints, and **enhancing knowledge and education about waste reduction**.

Possible directions

The findings from the previous chapters have unearthed a spectrum of possibilities for addressing the issue of medication waste in the OR. These can be categorized into four possible design directions, each addressing a different facet of the problem.

1. Creating awareness and providing knowledge about medicine waste:

Due to the lack of varied medication sizes and unconscious or automatic selection of larger doses it became clear that there is a lack knowledge and awareness about waste generation and reduction. There is an opportunity to provide this knowledge and foster more awareness!



2. Need for research on alternatives to make appropriate prescribing possible

There's a clear requirement for alternative solutions to facilitate appropriate prescribing. As discovered in Chapter 4, the primary cause of medicine leftovers is the lack of different medication sizes. Exploring alternatives like multi-dose vials and check valves for infusion medications could prove beneficial in future investigations. This need for innovative solutions presents a compelling opportunity to shape a design direction.

3. Optimization of medication prescribing practices and use:

This involves addressing factors such as:

- Dosage selection.
- Ensuring appropriate prescription practices based on patient needs and procedural requirements.
- Re-visioning the anaesthesia prescription list.

4. Enhancing stock management:

Efficient stock management plays a significant role in reducing medication waste. The design direction suggests strategies for improving stock management, including optimizing inventory levels, implementing first-in-first-out (FIFO) practices, and enhancing communication and collaboration between stakeholders responsible for medication procurement and storage.

The final design direction

The comprehensive exploration and ideation process undertaken around the four proposed design directions brought forth some critical insights. These insights, thoroughly detailed in the subsequent chapter, highlighted a crucial requirement for an approach that addresses medicine waste in the Operating Room (OR) in **a more holistic, systemic manner.**

Guidance from the academic supervisors, underscored the complex interdependence of the factors contributing to medicine waste in the OR. It became evident that individual actions, while valuable, may not be potent enough to address the breadth and depth of the issue.

The four directions initially proposed — spreading knowledge and awareness, exploring alternatives for appropriate prescribing, improving medication prescribing practices and use, and enhancing stock management — emerged not as isolated solutions, but as interwoven elements within a complex system. **Each one influences, and is influenced by, the others.**

This realization led to a critical pivot in the design approach. **Instead of focusing on individual solutions, the final design direction is a comprehensive 'sustainable approach' that blends the four initially outlined directions.**

So, the final design direction chosen is a comprehensive approach that encapsulates the complexity of the problem. It offers a robust framework that can handle this complexity, setting the stage for the creation of a more sustainable OR environment...

A Sustainable Approach

At the core of the chosen design direction is the overarching goal of sustainability. Rooted in the principle of prevention and reduction – the most impactful methods of waste reduction – the primary aim of the interventions will be to prevent waste generation if possible to minimize the waste. This approach aligns with the ethos of maximizing value and understanding that the **most efficient way to handle waste is to avoid its creation in the first place.**

Persona

The Green Team Anaesthesia is selected as the primary target audience due to their crucial role in the OR. Their understanding of OR processes, coupled with their ability to influence practices, makes them central to the success of this sustainable approach.

PERSONA

NEEDS
Making a positive impact on the world
Having access to the right knowledge and the right tools that support sustainable initiatives
Actionable steps

CHALLEN
Time constr
Keeping up-
Regulations
Money: man
Not sure wh

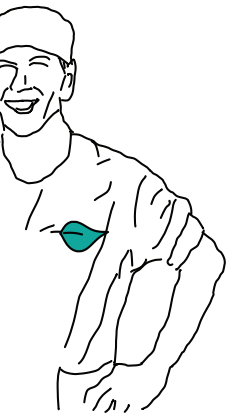
Figure 18: Persona of the Green Team Anaesthesia

Furthermore, their hands-on experience is invaluable for ensuring that the design solutions are not just theoretically robust, but also practically implementable. As leaders promoting sustainability, they are poised to inspire and motivate others towards greener practices. Their needs and challenges are illustrated in figure 18.

Design Goal

The design goal, derived from the design direction, is

"to **guide** the Green Team Anaesthesia by providing a **sustainable approach** that provides **knowledge** and **actionable steps** with the objective of **minimizing medicine waste in the OR"**



GES
raints due to high work pressure at the OR
-to-do date with sustainable initiatives
s: infection prevention
nagement
here to start tackling the problem

This goal encapsulates the overarching aim of the final design, which is to provide the Green Teams Anaesthesia with a comprehensive framework and practical tools to promote sustainable medicine use and minimize waste generation in the OR.

Design requirements

The ensuing design requirements emerged from a thorough understanding of the problem statement, an identification of potential opportunities, and the chosen ultimate design direction. These prerequisites serve as benchmarks for developing the sustainable approach, ensuring the proposed solution efficiently addresses the identified problems while capitalizing on the opportunities to reduce waste in the operating room (OR).

Building from the time constraints of the Anaesthesia Green Team and the recognized need for both knowledge and actionable strategies, the first design requirement was formulated as follows:

- The design should provide the Anaesthesia Green Team with a strong basis to begin the process of reducing medicine waste in the OR.

Given the recognized lack of knowledge and awareness about medicine waste and effective strategies to mitigate it, the second requirement was drawn:

- The design should function as a comprehensive knowledge base, supplying crucial information to assist in reducing medicine waste.

Considering the identified causes of medicine waste, such as lack of knowledge, unconscious habits, and the unavailability of appropriate prescribing methods, the third requirement was identified:

- The design must address the diverse causes of medicine waste to ensure a holistic approach.

Furthermore, the design must address various stages identified in Chapter 3 – prescribing, usage, disposal, and stock management – where waste might occur:

- The design should tackle the various stages of medication handling that might lead to waste.

Lastly, in line with the Green Deal Sustainable Healthcare 3.0's goal of nationwide reduction, the design should be adaptable for other hospitals as well:

- The design should be customizable for implementation not only in the LUMC but in other hospitals too, to optimize its reach and impact. (The original task was to develop practical guidelines suitable for implementation in the LUMC and adaptable for other hospitals)

With these design requirements in mind, the next section discusses the design process to reduce the medicine waste.

DESIGN PROCESS

06

6. Design process

This chapter describes the iterative process employed to ideate and conceptualise the intervention aimed at reducing medication waste in the operating room (OR). Underpinned by the design direction, which draws upon insights from literature reviews, context exploration, and waste measurement, the design process unfolded in stages of ideation, co-creation, guide development, and expert feedback sessions.

Design for behaviour change

Following the exploration forming the design direction in the previous chapter, this section delves into the crucial aspect of behaviour change in the context of promoting sustainable medicine practices. Understanding the psychological factors and barriers that influence behaviour may ultimately lead to a more sustainable and efficient use of medication resources.

This section examines theories and frameworks related to behaviour change

COM-B MODEL

The COM-B model, which stands for Capability, Opportunity, and Motivation, provides a comprehensive framework for understanding behaviour and identifying intervention points for promoting sustainable medicine practices. By analysing the capabilities (knowledge, skills, and physical abilities), opportunities (environmental and social factors), and motivations (emotions, beliefs, and incentives) that influence behaviour, interventions can be designed that address the underlying determinants of medication waste (Michie et al., 2011). The COM/B model is illustrated in figure 19.

Behaviour change within healthcare panel discussion

To know more about behaviour change in healthcare, a panel discussion on behaviour change in healthcare settings was attended. Four experts shared their perspectives on behaviour change and sustainable practices. This section highlights key learnings from the panel discussion, offering valuable insights and strategies for promoting sustainable behaviour change in healthcare organizations.

Tiny Habits for Sustainable Behavior Change (Willemijn van Gastel):
Willemijn introduced the concept of tiny habits, derived from B.J. Fogg's theory, as a means of fostering sustainable behaviour change. She emphasized the importance of small, easily achievable actions that can be seamlessly integrated into existing routines. By experimenting with sustainable practices and celebrating small achievements, behaviour change can be effectively sustained over time.

Creating Awareness through Facts and Conversations (Leendert-Jan Doornbos):
Leendert-Jan shared examples from the Haga Hospital, highlighting the power of creating awareness through factual information and engaging conversations. By displaying facts throughout the hospital and encouraging discussions, sustainable practices become a prominent and ongoing topic. He emphasized the need for inclusivity and stakeholder involvement in the implementation process to ensure no perspectives are overlooked.

Balancing Autonomy and Regulations for Behavior Change (Guido Gand):
Guido discussed the various approaches to behaviour change, including the consideration of autonomy versus regulations. He emphasized the importance of providing options and allowing employees to choose

from different sustainable practices. Finding a balance between autonomy and regulations, healthcare organizations can effectively drive behaviour change and sustainability.

Using art (Maria Koijck):

In addition, during a conversation with Maria Koijck, an expert in creating awareness about medical waste through art, five additional tips were highlighted: breaking habits, educating about alternatives, keeping it simple, fostering collaboration, and taking action without delay. These tips further contribute to the transition toward a more environmentally sustainable hospital setting.

Translating these findings to the COM-B model

The findings of the COM-B model and panel discussion are combined in the illustration below. These findings combined with the design requirements guide the ideation process.

Ideation Phase

With the knowledge gained from the behaviour change research in mind, the ideation phase started.

Goal: ideate and validate which ideas are preferred the most by anaesthesiologists and anaesthetic nurses

Method: the focus areas of the ideation were defined as three four moments: awareness, usage, ‚prescription and disposal. By utilising the 'How-To' questions framework (Van Boeijen et al., 2020), multiple perspectives on the problem were established, which facilitated the ideation process. Additional brainstorming sessions were conducted with

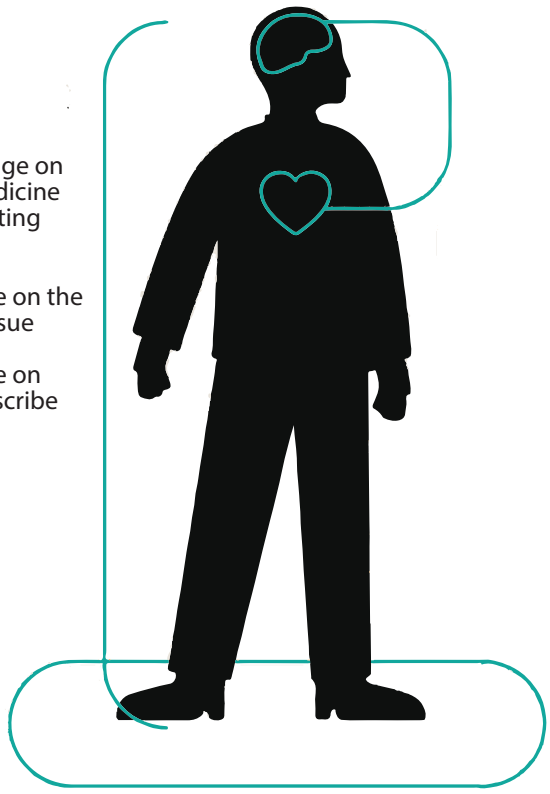


Figure 19: COM-B model with opportunities for medicine waste reduction

fellow Industrial Design Engineering (IDE) students, contributing to a diverse array of solutions that could potentially foster a shift in behaviour.
The outcomes of these ideation sessions can be found in appendix D.

Co-Creation Sessions
Following the initial generation of ideas, collaborative sessions were conducted involving professionals including anaesthesiologists and anaesthetic nurses from the Leiden University Medical Centre (LUMC). These co-creation sessions allowed participants to contribute their unique perspectives, enriching the solutions and ensuring that the devised strategies would be applicable within the OR environment.

Session 1: one anaesthesiologist
Duration: one hour

Session 2: the head of anaesthesia nursing and 2 anaesthesia nurses
Duration: one hour

Key Insights from the Co-Creation Sessions
These sessions led to three key insights:

- The imperative need to increase awareness and provide knowledge about medication waste: they really do not know where to start
- The need for a comprehensive guide to address this issue and change protocols: it is unclear what the rules are
- The necessity to re-evaluate the current medication prescription list.

Approach development phase

As touched upon in the preceding chapter, the ultimate decision was made to combine the insights collected during the ideation sessions and into one unified, holistic strategy. More details on how this approach was developed and integrated can be revisited in the earlier 'design direction' chapter. An illustration of this process and the process of the approach development is shown in figure 20.

The sustainable approach

The development of the approach involved merging key learnings, insights, and relevant literature to target identified medication waste moments and their underlying causes. This design process underwent multiple feedback sessions to iteratively refine the guide, ensuring its accuracy.

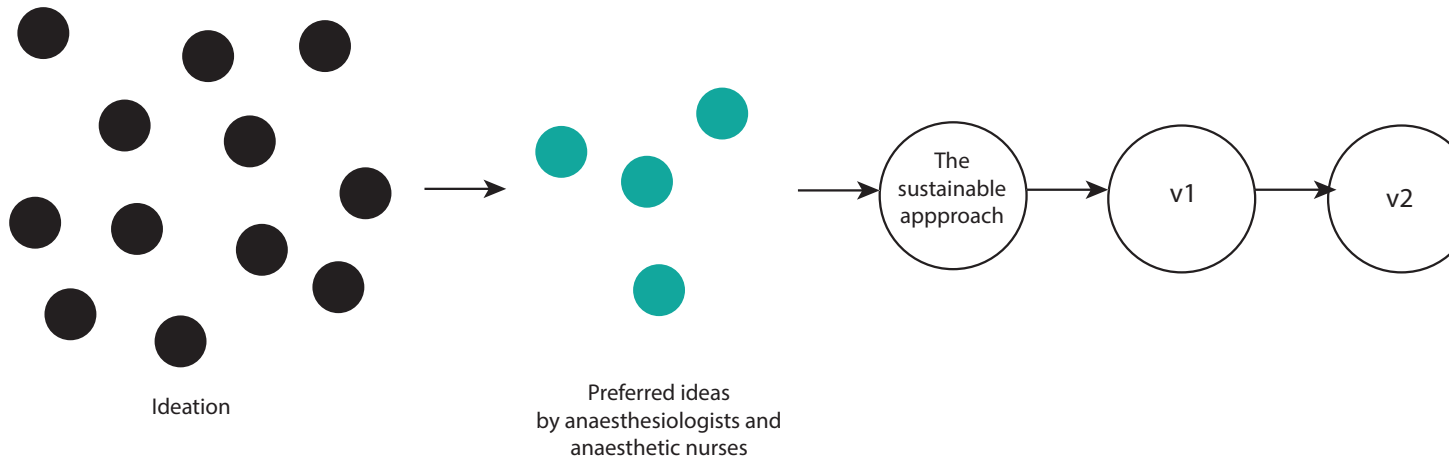
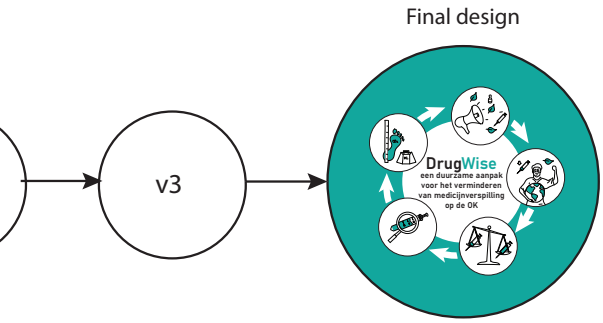


Figure 20: The ideation and 'sustainable approach' design process

Experts including anesthesiologists, anaesthetic nurses, and members of the Anesthesia Green Team critically evaluated the guide in three feedback sessions. Their expertise was instrumental in refining the content, format, and relevance of the approach.

Method
Prior to the feedback sessions, the approach was shared with the participants, providing them with the opportunity to review it in detail and highlight any areas that could potentially be improved or were confusing. This preparation allowed the participants to be fully engaged and ready for a comprehensive discussion during the feedback session.

The session itself was methodically organised to go through each aspect of the approach, inviting participants to share their insights, tips, and suggestions. The emphasis during these discussions was not on the visual aspect of the approach but rather on its accuracy and practical relevance. The main aim was to ensure the accuracy and effectiveness of the information provided by the approach and its alignment with the realities of the operating room environment. This feedback process ensured that the approach was not only theoretically sound but also had the potential to be effectively implemented in real-world scenarios.



v1 - The first session
The first version of the approach was evaluated by an anaesthesiologist. This session underscored the importance of giving a clear picture of the benefits of minimizing medicine waste and offering a compelling reason to adopt the approach recommended in the guide. Besides, the importance of regularly tracking the effect was highlighted! With this in mind the approach was adapted and a new version was made (v2).

v2 - Second session
The second review session involved the head of anaesthetic nursing. He offered insights from his perspective, affirming the inclusivity and relevance to anaesthetic nurses. Furthermore, he expressed appreciation for the presentation of alternatives in the guide, which helped to visualize the effects of different choices. During the session he said:

"Sent it to me and I will sent it in the newsletter to the employees"
- Team leader Anaesthesia OR

From this feedback a new version of the approach was made (v3).

v3 - Final session
The final evaluation session was conducted with the Head of the Green Team Anaesthesia and two team members. This session primarily focused on how the guide would be implemented and used. Feedback from this session not only confirmed the accuracy of the approach but also affirmed its effectiveness further aligning it with the practical needs and goals of the Green Team.

"This is super cool, I am amazed! This is really super insightful and valuable to us. We can use this as a guide during our Green Team meetings"
- Head of the Green Team Anaesthesia LUMC

Final design

These iterative sessions, enriched by the expertise and feedback of various stakeholders, refined the approaches design, resulting in a comprehensive and accurate tool. The subsequent chapter will present the finalized design, a culmination of these valuable collaborations and insights.

1.

THE FINAL DESIGN

07

7. The final design

This chapter provides an overview of the concept developed to support the Green Team Anaesthesia in addressing the issue of medicine waste in the operating room (OR) and fostering a more sustainable future. The concept was developed through a iterative design process, ensuring accurate contextualization and effective guidance through the steps of the process. The methods employed throughout the design process are presented in the previous chapter.

The full design can be found in the separate appendix: 'DrugWise'.

Goal of the approach

The primary aim of this approach is to offer a comprehensive and systematic method to combat the issue of medicine waste in the Operating Room (OR). By presenting a five-step plan, this approach is designed to provide users with clear instructions on how to effectively mitigate medicine waste. The ultimate goal is to heighten awareness of the problem and offer practical, implementable solutions that can be applied immediately.

The components

The approach is structured around five crucial steps:

1. **Measuring Waste**: Quantifying the scale of waste for informed decision-making.
2. **Setting Priorities**: Determining key areas for intervention based on the measurement results.
3. **Raise Awareness**: Educating on the significance of the problem and the necessity for change.
4. **Taking Action**: Implementing specific, practical measures to reduce waste.
5. **Evaluating:** Assessing the impact of the implemented actions and making necessary adjustments.

In addition to these steps, **templates** are provided that can be utilized immediately, enabling to **put these actions into practice straight away**.

Format

The chosen format for the approach is an interactive PDF due to its accessibility, adaptability, easy tracking, and user-friendly features. This format ensures that the guide can be conveniently accessed on any device and updated as required, while also providing an engaging experience for users. Its interactive elements facilitate ease of navigation and its adaptability allows for easy revisions to reflect any changes or new information.

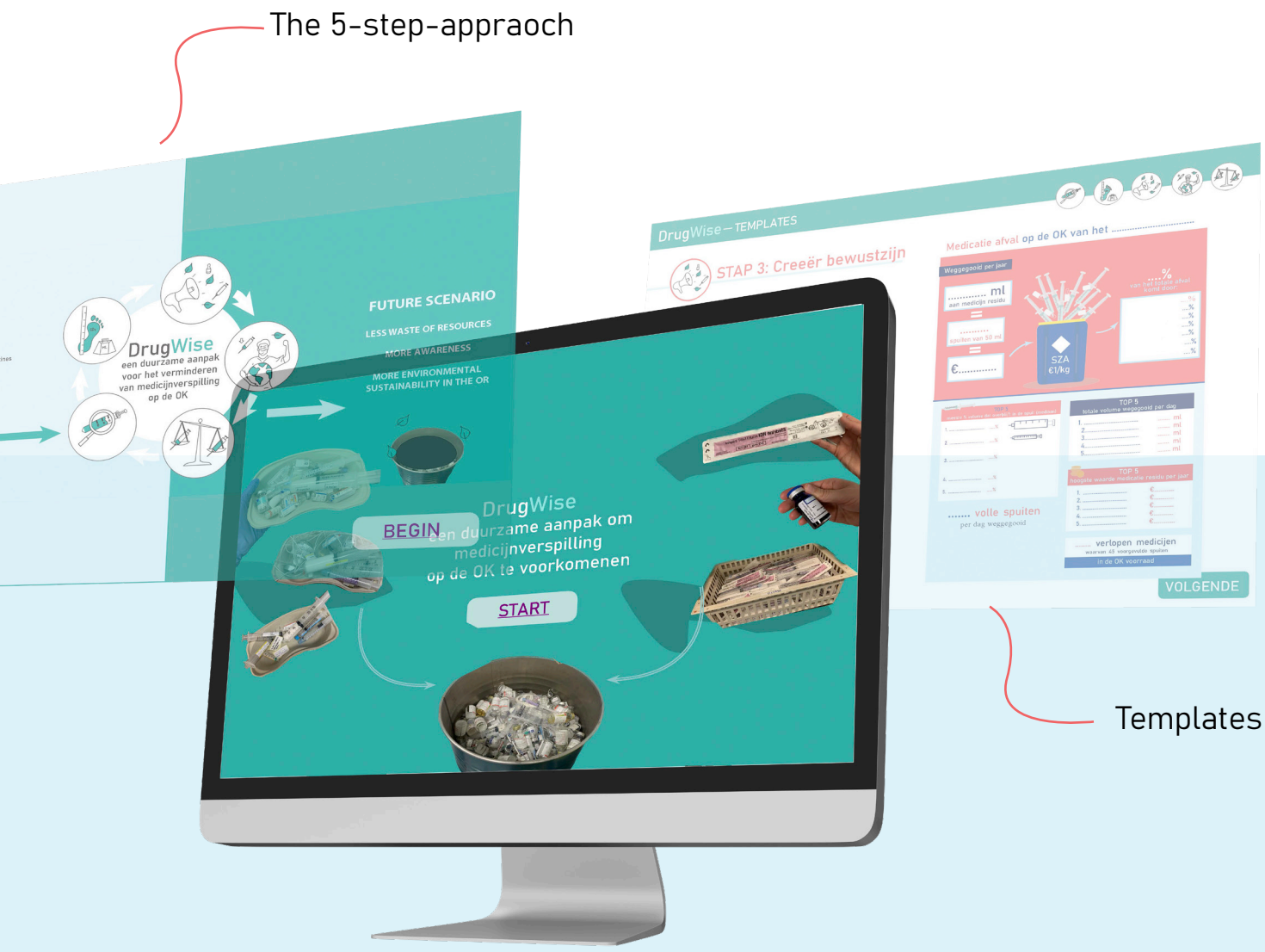


Figure 21: An overview of 'DrugWise'

Value

The guide's inherent value is multifaceted, catering to the varied needs of the Anaesthesia Green Team while aspiring to reduce medicine waste in the OR. To outline the value more clearly, the approach has been designed around key specifications.

Firstly, the guide is designed to **give the Anaesthesia Green Team a solid foundation to start**. It outlines a straightforward five-step process and provides relevant templates, intentionally designed to simplify the process of addressing medicine waste, thus making it accessible for teams to get started.

Secondly, **it integrates the four moments were medicine waste can occur into its framework**. This specification is met in the 'action' stage (step 4), where action steps are identified for each of the four crucial moments. The comprehensive approach ensures that the complex problem of medicine waste is tackled from multiple angles, acknowledging the systemic nature of the problem.

In the third place, step 4 of the approach **addresses the various causes of medicine waste**. It offers solutions tailored to different causes of wastage, yet encourages hospitals

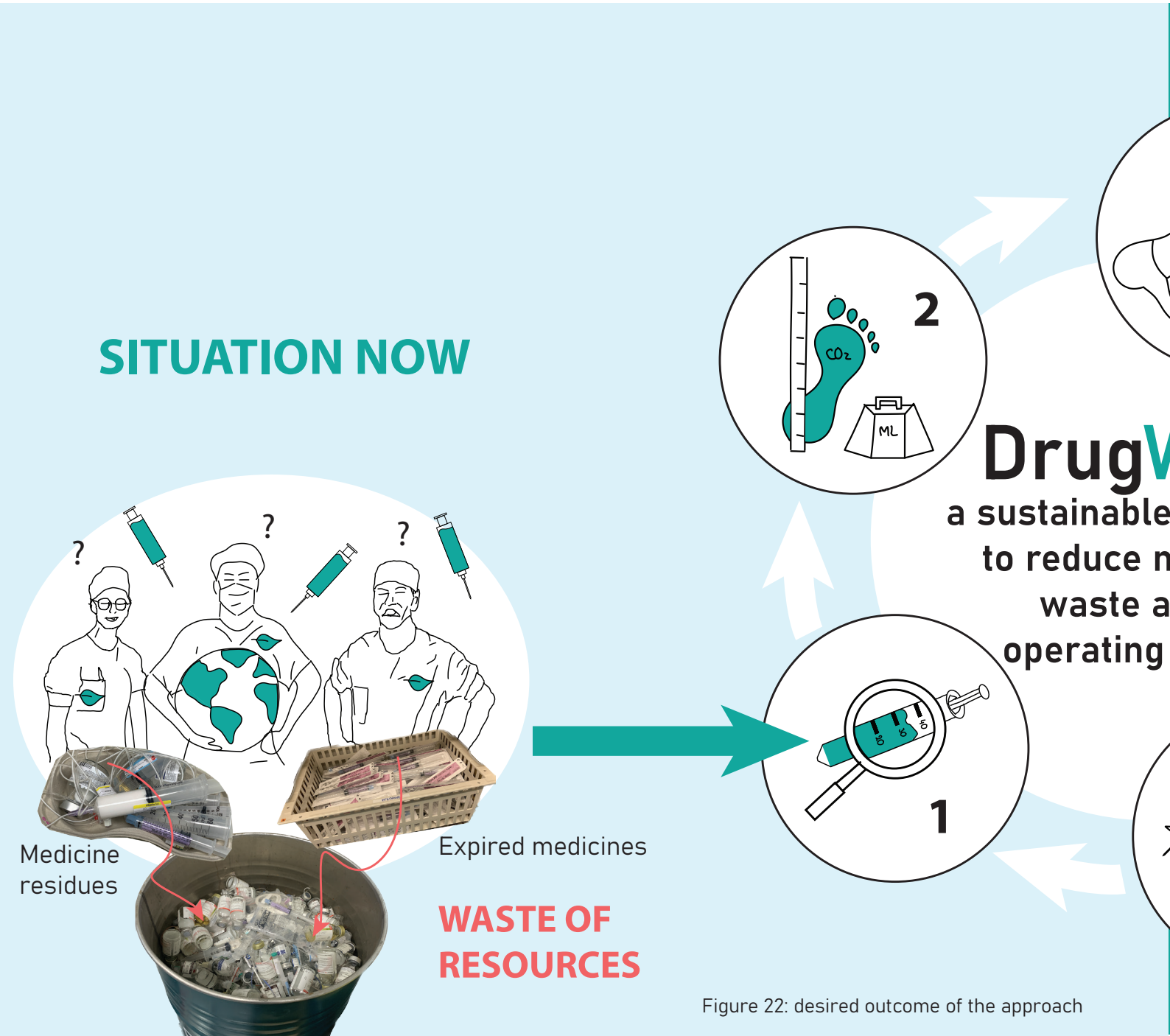
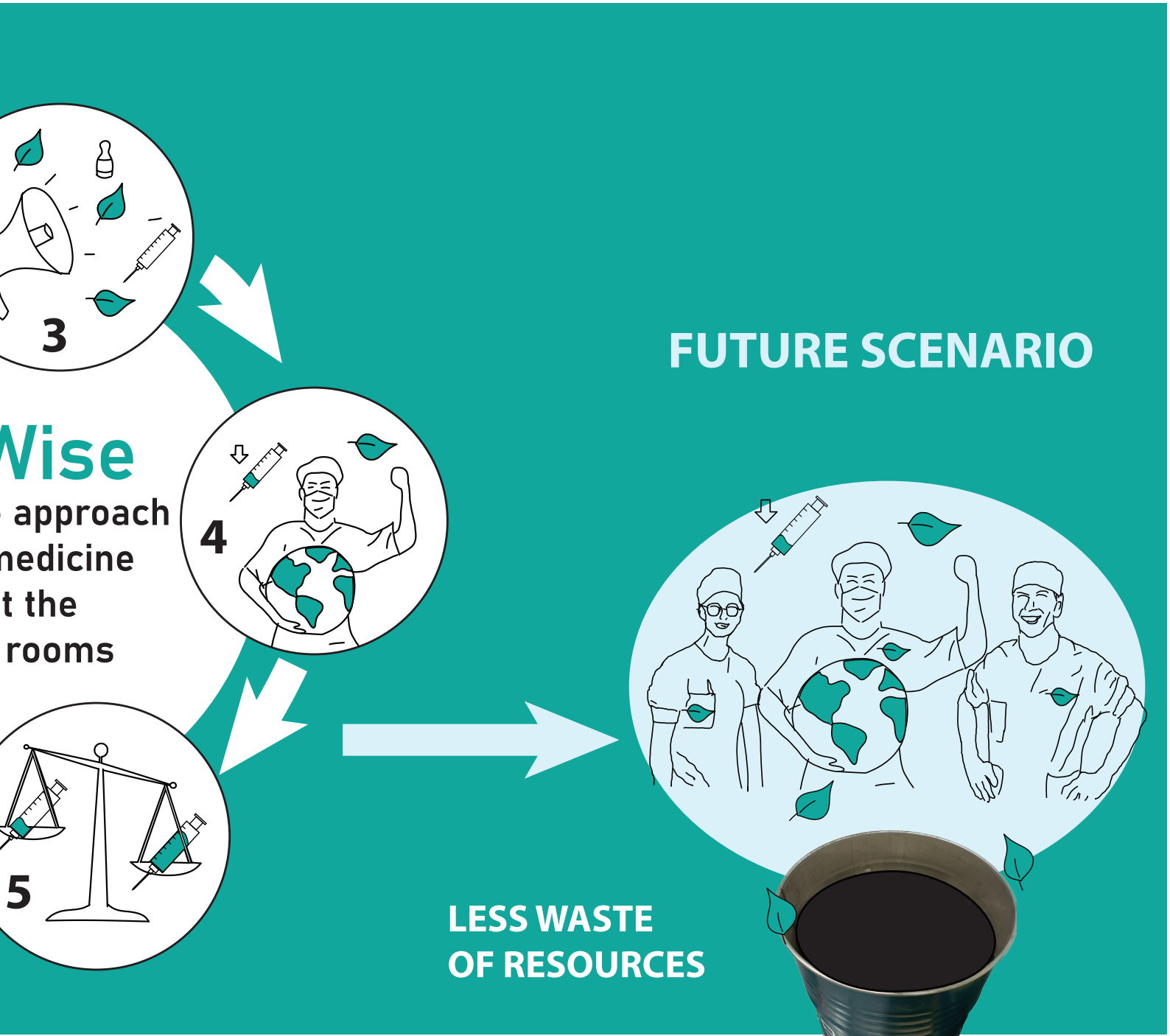


Figure 22: desired outcome of the approach

to determine the best solutions suited to their unique context. While the guide is designed to inspire and motivate action, it does not serve as a decision-making tool, recognizing that anaesthesia expertise is crucial to making the most informed and suitable decisions.

Lastly, the guide serves as a vessel **to impart valuable knowledge gained from the master's thesis researc**h. This knowledge shared aims to inspire and motivate users towards the reduction of medicine waste in the OR. The information contained within the guide aids in forming a solid foundation for informed action, ensuring that teams are equipped with the knowledge necessary to make impactful changes.

By addressing these specifications, the guide aims to deliver comprehensive, actionable value to the Anaesthesia Green Team and others interested in sustainable practices within the OR, empowering them to take effective steps towards reducing medicine waste. The effect of the approach is shown in the figure below. The current scenario involves wastage of valuable resources, whereas the future scenario is designed to minimize waste and enhance sustainability!



The approach

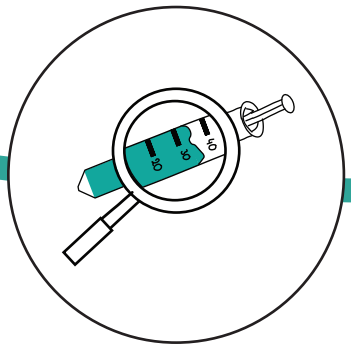
Figure 23: The Green Team Anesthesia

"

The Green Team Anaesthesia is at the forefront of the journey towards medicine waste reduction. However, there are certain obstacles that they face in this mission. Firstly, there is a **lack of a consolidated overview of knowledge and actionable steps** which makes it challenging to understand the landscape of possibilities. Secondly, despite their high motivation, they encounter roadblocks like **limited resources and time constraints**.

This is where the **'sustainable approach'** comes in. It's a comprehensive plan devised to aid teams like the Green Team Anaesthesia in their quest to reduce medicine waste. This approach recognizes their motivation and seeks to augment it by **providing knowledge and actionable guidelines** needed to make sustainable practices an integral part of their work. It serves as a guide to navigate the challenges and maximize the impact of sustainable efforts in the field of anaesthesia and beyond.....

"



1.

Measure the waste

This initial step is crucial as it provides the necessary **awareness and insight into the amount of waste and the most commonly wasted medications**. By quantifying the waste, valuable data is obtained, enabling a better understanding of the problem and facilitating the development of effective solutions. Besides **the causes** of medicine waste are being identified! This allows for more targeted interventions in step 4.

This step offers a comprehensive approach and provides an **example of how to measure and track medication waste in the operating room (OR) setting**. This measurement process builds upon the findings discussed in the previous chapters, namely the literature review, context exploration, and waste measurement, ensuring a robust and evidence-based approach.

TEMPLATES

In this step there are different templates that can be downloaded and used.

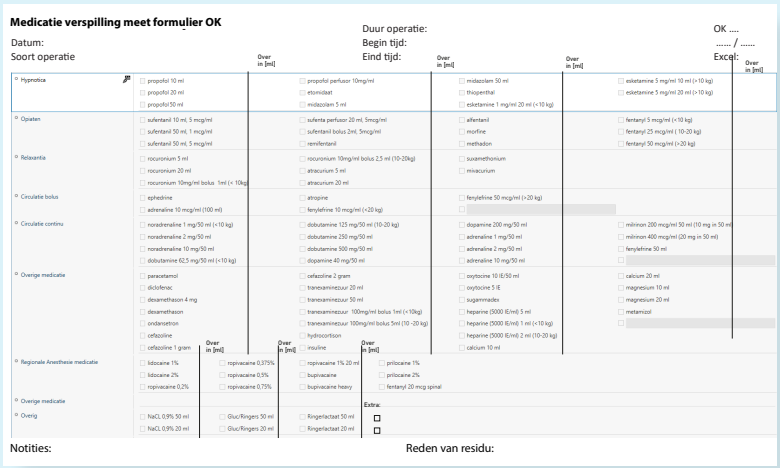
Waste measurement form:

can be used to measure the medicine waste of medicine residues in the LUMC OR.

Poster:

can be used to fill in the results from the waste measurement and create overview.

Medicine waste measurement form



Medicine waste top 5 fill in poster

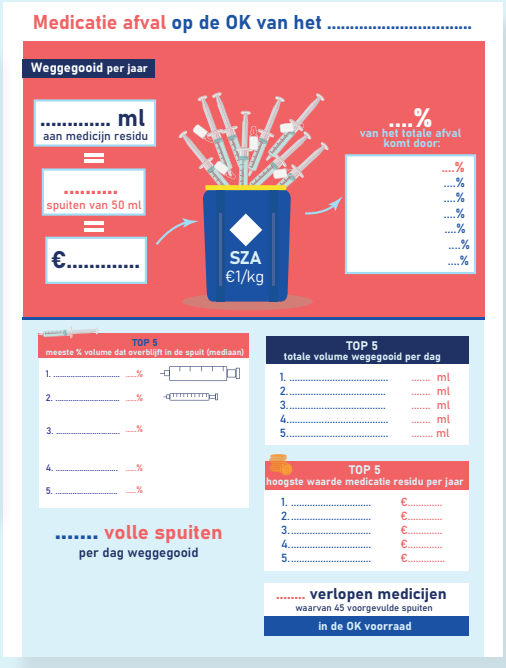
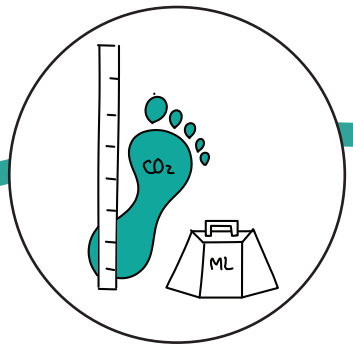


Figure 24: Templates to measure the waste



2.

Set priorities

To effectively address the issue of medication waste, it is essential to establish priorities. By setting priorities, the focus is narrowed, enabling a **more targeted and efficient evaluation of waste reduction efforts.** This step takes into account the knowledge gained from the waste measurement, allowing for a strategic selection of areas with the highest potential for waste reduction. By referring back to the findings of the waste measurement chapter, **specific medications or practices that contribute significantly to waste can be identified and prioritized**. This ensures a well-informed decision-making process and provides clear guidance for subsequent steps

TEMPLATES

In this step there are different templates that can be downloaded and used.

Visualize the goal!
can be used to show what the waste reduction will look like

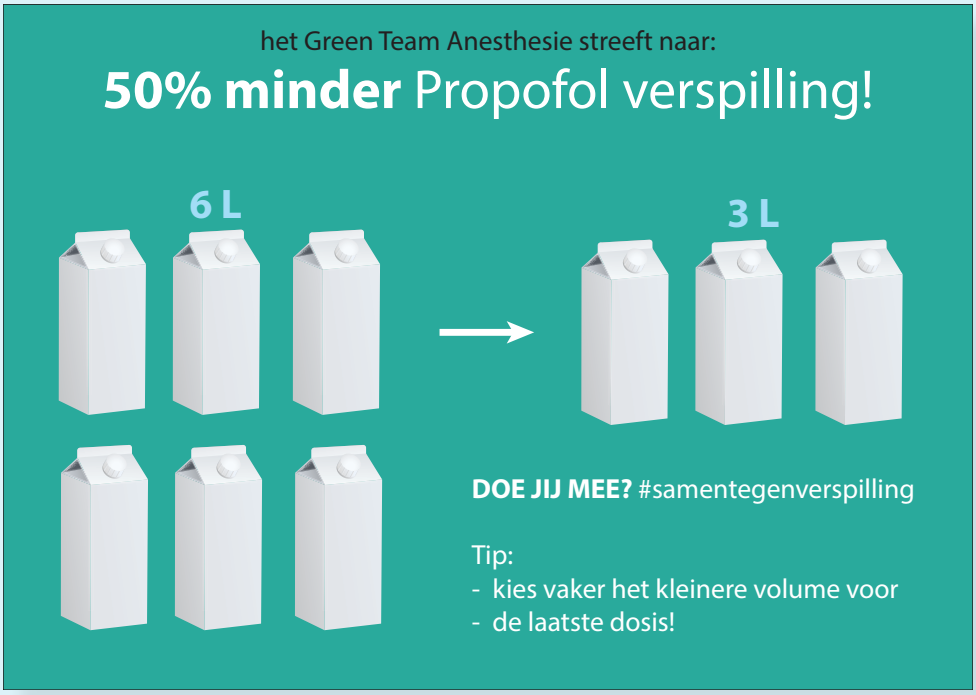
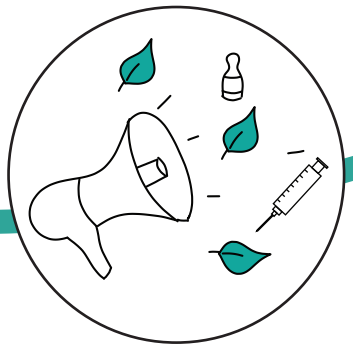


Figure 25: Templates to set priorities



3.

Raise awareness

Creating awareness among employees is a critical step in driving change and **fostering a collaborative environment** to address medication waste. Building upon the insights gained from the literature review and context exploration chapters, this step emphasizes the importance of communicating the findings related to waste measurement and priority areas. By sharing the results and engaging employees in discussions, awareness is raised about the magnitude of the issue and the potential impact of their actions. This awareness **helps to motivate employees and instill a sense of collective responsibility**, encouraging them to actively participate in finding solutions.

TEMPLATES

In this step there are different templates that can be downloaded and used.

Awareness by using art

For example making an artwork from the waste (inspired by Maria Koijck)

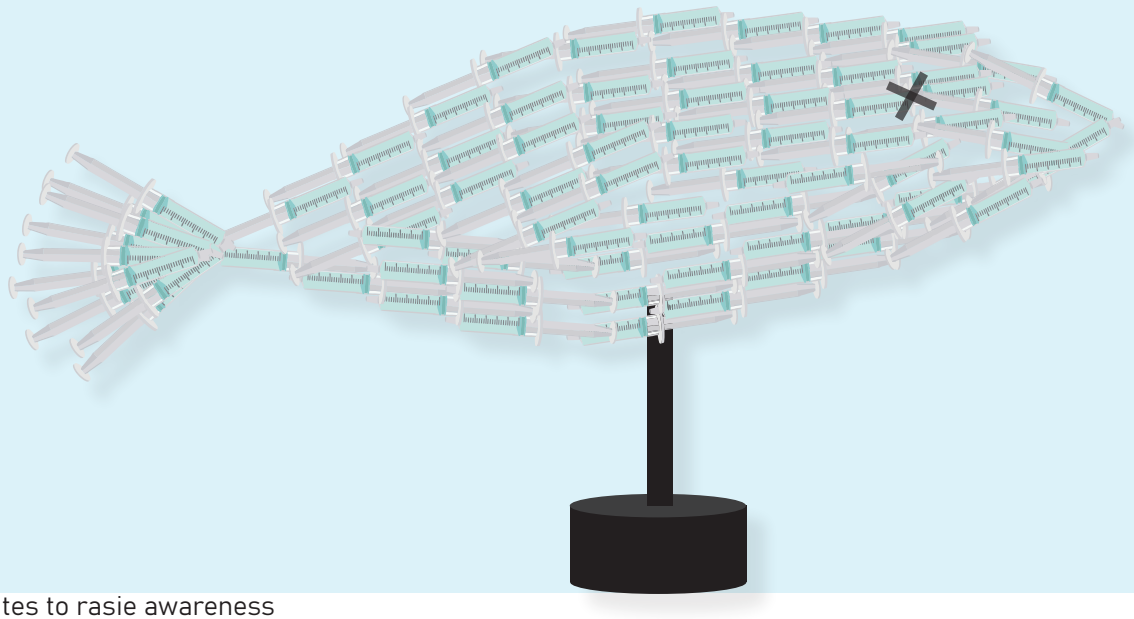


Figure 26: Templates to rasie awareness

4.

ACTION

In this step actions are chosen. The selection of specific strategies and interventions is informed by the priorities identified in Step 2. By aligning the interventions with the identified priority areas, the approach provides a targeted approach to tackle medication waste effectively.

STRATEGIES TO PREVENT MEDICATION WASTE

PRESCRIBING

Make appropriate prescribing e

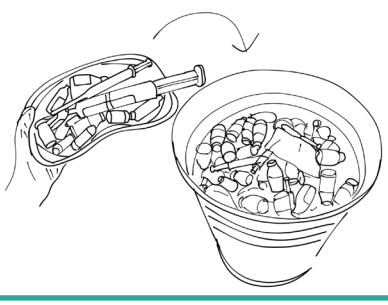
USE

LESS = MORE

STOCK MANAGEMENT

Be cautious of expired medicati

DISPOSAL



Dispose medicines appropriatel

1. Revise the prescribing protocols
2. Facilitate appropriate prescribing by utilizing the right resources and tools
3. Review the anaesthesia preparation list

easier!

1. Make use of visual aids
2. Doubting the last dose? Opt for the smaller quantity!
3. Explore alternatives for medication use

1. Keep track of expired medication
2. Consistently follow the FIFO (First In, First Out) principle

ons

1. Use full and unused syringes for the recovery room or the next surgery
2. Create a separate waste stream for medicines
3. Dispose of medication correctly

ly

5.
Evaluate

The final step focuses on measuring the waste again to **assess the effectiveness of the interventions** proposed in Step 4. By conducting a follow-up waste measurement and comparing it to the initial measurement, the impact of the implemented interventions can be evaluated. This evaluation reinforces the importance of measuring and tracking waste, allowing for continuous improvement and a culture of sustainable behaviour within the OR. The results obtained from this evaluation serve as valuable feedback and motivation for further improvements, creating a cycle of waste reduction and sustainable practices.

Accessibility of the approach

The intention of the approach is to transcend its origins at the Leiden University Medical Centre (LUMC) and serve as a useful tool for other hospitals across the nation. An integral part of this vision is the approach's planned availability on the Green OR website, as depicted in Figure 27. The website acts as a comprehensive resource hub for hospital green teams across the country, supporting their endeavours to embed sustainable practices within their operations.

By sharing the approach on this platform, its reach extends beyond the LUMC, offering valuable insights and practical waste reduction strategies to a wider audience and further amplifying its impact. This expansion of access is a vital step towards more widespread sustainable practices within the healthcare sector.

However, it is crucial to understand that while the design of the approach aims to be broadly applicable, its effectiveness in different hospital settings might fluctuate due to the inherent diversity of practices and policies. The approach was primarily developed based on insights and information collected from the LUMC, which might not necessarily mirror the specifics of other institutions.

Hence, the approach encourages adaptation and modification according to local contexts, as its actual degree of adaptability can only be fully realised through practical implementation. Consequently, while the approach is designed to be widely applicable, its effectiveness across different hospital environments is not wholly established at this point. As hospitals begin to implement and adapt the approach to their specific needs, their feedback and experiences will be vital in refining its design and validating its nationwide applicability.

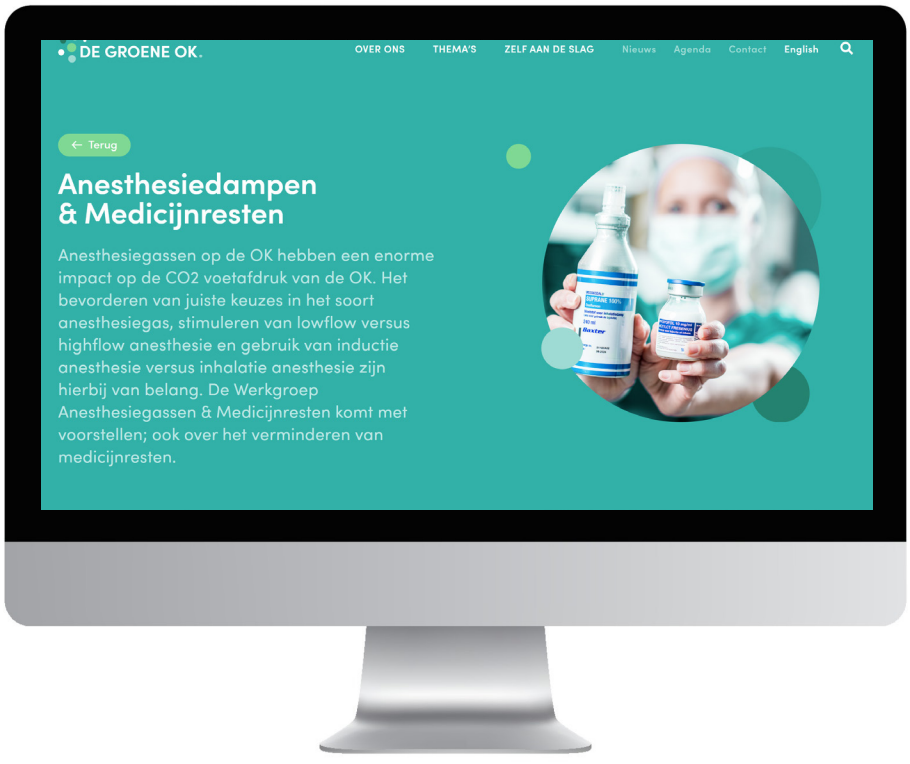
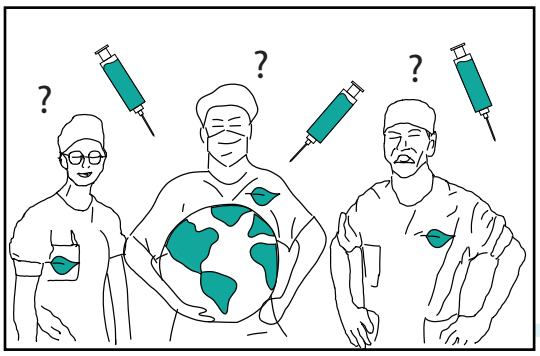


Figure 27: The "Green OR"website

Use scenario

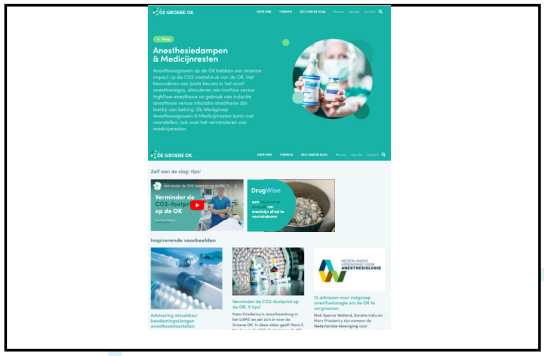
This section demonstrates a possible use scenario for the Green Team Anaesthesia using the approach.



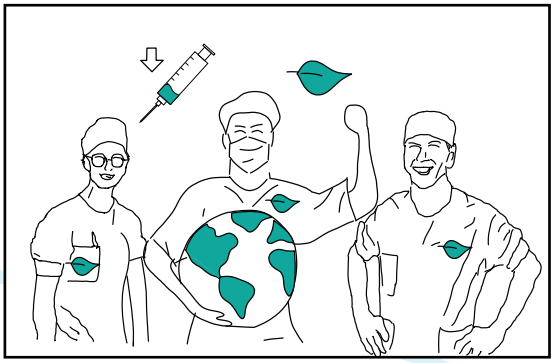
The green Team Anaesthesia is motivated to reduce medicine waste but they do not know where to start.

They go to the Green OR website and find ´DrugWise the sustainable approach towards medicine waste reduction´.

They open the appro

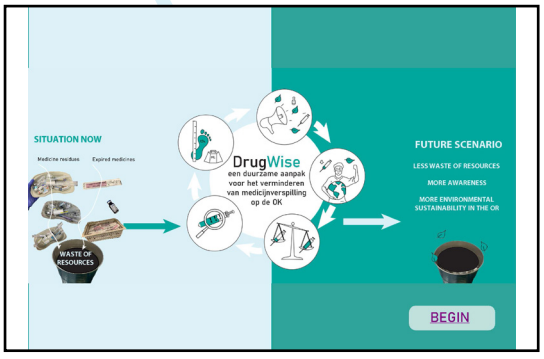


They share there learnings with the Green OR



After a few weeks of using they evaluate. They find out that their propofol waste is minimized by 53% percent!

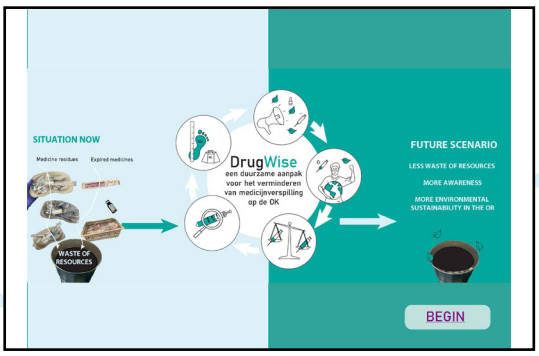
To prevent the autoc for the larger dose t **visual cues**: they print the 'visual opting for the small last dose' and add it tray.



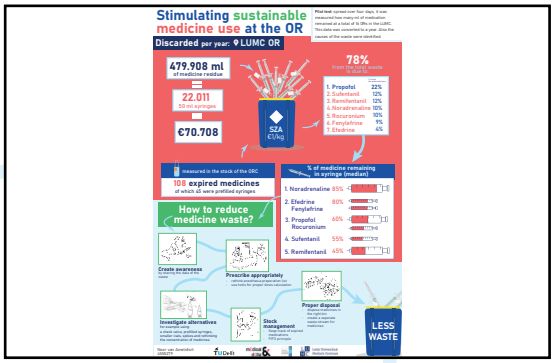
Their journey is not over yet they continue improving other environmental hotspots found using the DrugWise approach.

Figure 27: use scenario

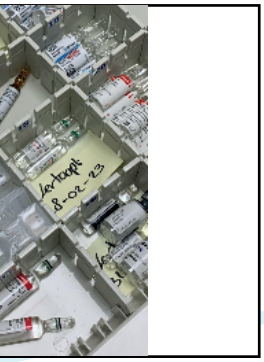
oach.



They read the introduction and follow the **5 step approach** to reduce medicine waste.



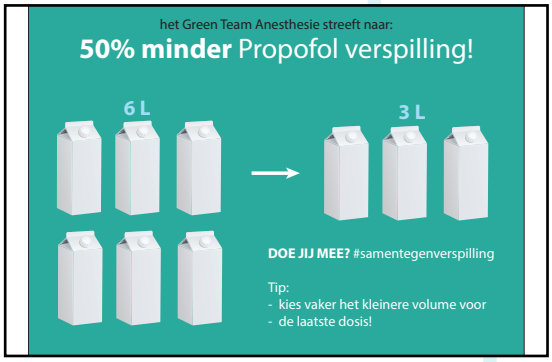
They start by **measuring the waste** and filling in the poster with the results.



cratically opting
hey make use of

l cue to stimulate
er volume for the
to the medicine

For raising awareness they spread this **poster** and add it to the day carts, prescription list and sent it in the newsletter.

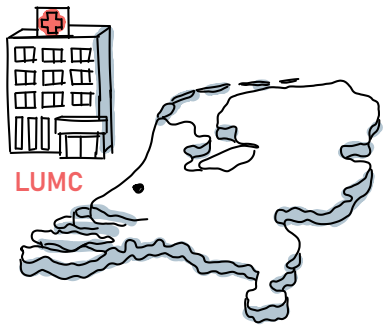


In the waste measurement they found that **6L of propofol** is wasted in a week. They find that the causes of the waste are:
1. **Lack of awareness**
2. Automatic opting for the larger volume for the last dose

So they decide to prioritize this problem.

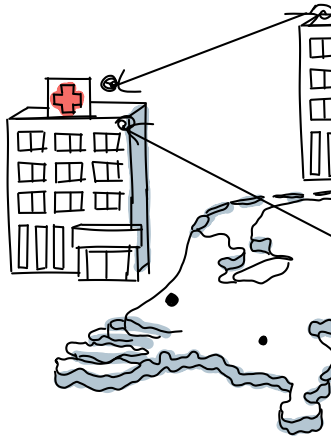
Implementation plan

While the immediate focus is on implementing and evaluating the approach within the LUMC by the Green Team Anaesthesia, there is a broader vision for its potential scalability. The aim is to extend this approach to other hospitals in the Netherlands. By sharing best practices and collaborating with different healthcare institutions, the impact of the approach can be maximized on a larger scale.



2023

- Implement the medication waste reduction guide in the **Leiden University Medical Centre (LUMC)** as a pilot project. Collaborate with the Green Team and relevant stakeholders within the LUMC to ensure smooth implementation. Present the approach to the relevant OR staff to familiarize them with the knowledge and actionable steps.
- Share the approach within the working group “anaesthesia vapour and medicine residues” of the “Nationwide Network the Green OR”
- **Monitor and evaluate the effectiveness of the guide’s implementation in the LUMC.** Gather feedback from OR staff and make necessary adjustments or improvements to the guide based on their experiences.



2024

- Expand the implementation of the m reduction approach to **other hospital** Netherlands. Identify hospitals that a in participating and establish partne “Nationwide Network the Green OR”.
- **Add the approach it to “the Green OR** accessible by all hospitals.
- Customize the guide to accommodat requirements or work flows of each maintaining its core principles and r medication waste reduction.
- Present the approach to the staff. Pr and guidance to ensure successful a practices in their ORs.

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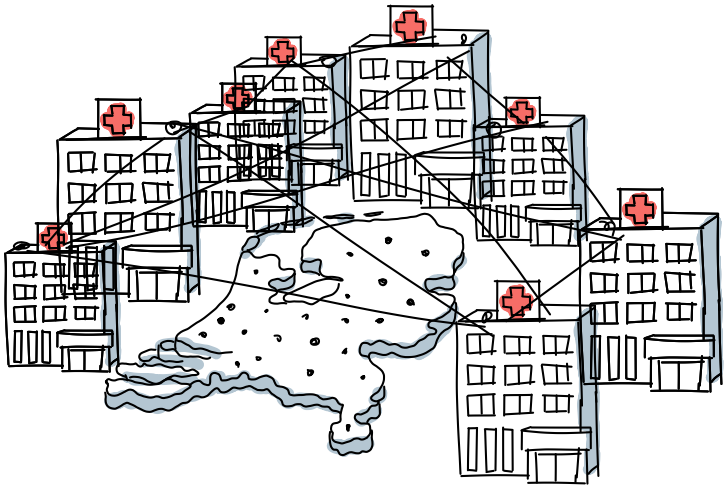

2025

- Work towards **nationwide reduction of medication waste in ORs** in hospitals throughout the Netherlands. Collaborate with relevant healthcare associations, governmental organizations, and sustainability initiatives to promote the guide's adoption as a standard practice.
- Organize conferences, seminars, or webinars to raise awareness about the importance of medication waste reduction and share success stories and best practices from hospitals that have implemented the guide.
- Continue monitoring and evaluation efforts to assess the impact of the guide on medication waste reduction in ORs across the country. Collect data and analyse the results to demonstrate the effectiveness of the implemented strategies.
- Provide ongoing support, updates, and maintenance of the guide to ensure its relevance and continuous improvement.

CONCLUSION

08

8. Conclusion

Discussion

This project sought to address the question of how to reduce medicine waste in the operating room (OR) by first understanding the problem, then quantifying the waste, identifying the causes, and finally designing interventions. This concluding chapter will critically examine each of these objectives.

Objective 1: Understand medicine waste in the OR

The initial goal was to understand medicine waste in the OR. A comprehensive understanding was achieved by conducting on-site observations, reviewing existing literature, and mapping out the critical stakeholders in the waste generation process. The study identified four key actors handling medicines in the OR - anaesthesiologists, anaesthetic nurses, OR logistics, and the hospital pharmacy. The research also uncovered four pivotal moments of waste generation: use, prescription, disposal, and stock management. By deepening the understanding of these actors and moments, the project established a solid foundation for the subsequent stages.

Objective 2: Quantification of medicine waste and identifiction of the causes

Following the understanding of the problem, the next step was to quantify medicine waste in the OR and find the causes. Real-time data was gathered manually, providing an initial measurement of the volume and types of waste. This documentation and analysis resulted in a comprehensive picture of the waste issue, with seven medications accounting for 78% of the waste. .

Concurrently, observations and data analysis uncovered a the factors contributing factors to waste such as: a lack of knowledge and awareness, inadequate resources, and suboptimal disposal practices.

Understanding these causes was of importance, as it informed the design of interventions to address the root causes of the waste problem.

Objective 3: Designed interventions

The knowledge gathered thus far enabled the formulation of targeted interventions to combat medicine waste in the OR. A sustainable approach was developed, focusing on Anaesthesia Green Teams as the primary target for intervention implementation. The interventions included five steps to reduce the medicine waste. These steps were supported by actionable actions and templates to make it the Green Teams as easy as possible to start working on reducing medicine waste in the OR.

Desirability: Green teams are currently receiving significant attention, and there is a growing demand for sustainable changes, including in the operating room. The Green Deal 3.0 initiative is evidence of this trend.

Feasibility: The proposed actions in the approach are feasible, although some may require systemic modifications, such as providing different sizes of ampoules. This necessitates adjusting protocols and requires collaboration among stakeholders.

Viability: The solutions proposed in this project consider the limited financial resources available. They can be implemented without significant initial costs. However, exploring alternatives may incur higher expenses, which should be discussed and evaluated.

Limitations

Waste measurement

Despite the significant insights gleaned from the waste tracking study, there were some limitations that need to be addressed:

Short Timeframe
The duration of the study, confined to a single week of observation, may not fully capture the total medicine waste generated in the ORs. It should be noted that the findings represent an estimated snapshot of waste generation within this timeframe rather than a comprehensive view.

Reliance on Self-Reported Data
The data collection relied on self-reporting by the researcher, which has inherent risks of subjective bias or unintentional errors. While efforts were made to maintain objectivity and accuracy, the potential for reporting bias should be considered when interpreting the findings.

Overall, these limitations represent areas for improvement in future research.

The approach

While the approach developed presents several promising strategies for waste reduction, it is important to note certain limitations that might affect its universal applicability:

Data Source Specificity
The data informing the approach was sourced solely from Leiden University Medical Centre (LUMC), reflecting the waste generation patterns, practices, and system nuances specific to this institution. Consequently, the suitability and effectiveness of the approach when applied to other hospitals could vary significantly. It's essential to understand that the approach's universality, in terms of its application to different hospital environments, remains to be fully validated in practice.

Potential Variation in Requirements
Each healthcare facility has its unique needs, resources, and challenges. Therefore, the approach, while generally applicable, might require certain adaptations or modifications to meet the specific demands of different hospitals. The assumption that the requirements identified in LUMC apply universally may not hold true in every case.

Reliance on Staff Engagement
The success of this approach heavily depends on the willingness and commitment of the hospital staff. Though the strategy incorporates lessons learned from behavioural experts and utilizes the COM-B model, driving actual behavioural change remains a significant challenge. Even with these insights, resistance or a lack of motivation to adopt new sustainable practices can limit the effectiveness of the approach. Therefore, continuous effort to engage and motivate staff is crucial for the successful implementation of these waste reduction strategies.

While these limitations do not negate the value of the approach, they do underscore the importance of testing and validation in diverse settings, alongside the potential need for customization based on the unique characteristics of each hospital.

Recommendations

Validating the effectivesness:
Effectiveness of the interventions cannot be determined conclusively within the scope of this graduation project. Long-term monitoring and follow-up measurements are necessary to assess their impact on reducing medicine waste in the OR. It is recommended that future research endeavours include a comprehensive evaluation of the implemented interventions, gathering data on waste reduction rates, cost savings, and overall sustainability outcomes.

Using kgCO2 as a measure
This thesis focused on measuring waste in terms of squandered resources and spilled medicines, rather than carbon dioxide emissions. However, future studies could benefit from including measures of carbon footprint, quantifying waste reduction in terms of kgCO2. This approach would provide a more comprehensive picture of the environmental impact of waste reduction efforts.

Collaboration with IZAAZ
In the current study, the potential to select more environmentally friendly medicines during procurement was not investigated, largely due to the scarcity of data on this subject. However, efforts are underway by the Interhospital Pharmacy of the Academic Hospitals (IZAAZ) to establish procurement criteria for more sustainable medicines by 2024. This initiative is laudable and presents a significant opportunity to make more sustainable medicine choices. Therefore, it is recommended that the collaboration with IZAAZ be strengthened and the option to procure more sustainable medicines be incorporated as a key strategy for promoting more sustainable medicine use.

Inclusion of More Stakeholders
While this project primarily focused on four actors, it would be beneficial to include other key stakeholders in future iterations. In particular, the expertise of infection prevention and OR management teams could be leveraged to provide additional insights into potential sustainability practices and solutions.

Usability Testing of the approach: While the interactive PDF format of the approach offers various advantages such as accessibility and flexibility, its usability should be tested in a real-world setting. Staff feedback can be gathered on its navigability, clarity of information, and overall usefulness. This would help identify areas for improvement and ensure that the guide serves as a truly valuable resource in promoting sustainable practices in the OR.

Approach as a decision tool:
At present, the proposed approach does not function as a primary decision-making tool, as there is still much uncertainty surrounding the alternatives presented, such as check valves and multi-dose vials. As more information becomes available on these options and their impacts, the approach has the potential to evolve into a more comprehensive decision-making tool. This progression would enable stakeholders to make informed decisions when strategising to reduce waste.

Conclusion

This project aligns with the growing desirability for sustainable practices within healthcare systems. The prominence of green teams, the increasing emphasis on environmental responsibility, and the establishment of initiatives such as the Green Deal demonstrate the urgent need for sustainable changes in healthcare settings. By addressing the issue of medicine waste in the OR, this project contributes to the broader goal of fostering environmentally conscious practices and ensuring the long-term viability of healthcare systems.

In conclusion, this project successfully understood medicine waste in the OR, identified the reasons behind its generation, and designed interventions to mitigate this issue. While the objectives were achieved, it is recognized that further research, evaluation, and collaboration are necessary to fully understand the effectiveness, feasibility, and sustainability of the proposed interventions. The recommendations and limitations highlighted in this study provide valuable directions for future research and serve as a foundation for implementing sustainable changes within the healthcare community.

Reflection

Throughout this project, I immersed myself in the field of sustainable healthcare, applying the skills and knowledge I've gained from my studies at TU Delft to address real-world challenges.

The initial months spent understanding the problem and measuring waste in the OR were super interesting. Having the opportunity to observe first-hand and interact with the professionals in their workspace was really cool!
Navigating the research synthesis phase was a bit challenging, as it wasn't easy to consolidate the extensive research into a single, cohesive direction. A useful piece of advice from my supervisors during this phase was to take a step back, to contemplate the problem, the target group, and the ultimate goal. This approach greatly assisted me in integrating my research findings and helped me regain clarity.

This project also highlighted for me the delicate balance between executing a project for an organization, such as LUMC, and meeting the academic expectations of the university. The university requires a more academically grounded approach, while the organization focuses on practical, implementable solutions. This balance became particularly evident during the synthesis stage, where it was crucial to integrate all the research into a comprehensive, academically sound format.

Reflecting on this, I recognize the importance of initially being aware of these different expectations and planning accordingly. Specifically, setting more time for the synthesis stage would be beneficial to ensure that all the research is appropriately connected and academically justified.

Besides, my learning goal was aimed to refine my communication skills, both visual and verbal, and learn to effectively manage diverse stakeholders. I am pleased with my success in engaging with stakeholders, as I was able to connect with many individuals who provided invaluable insights for the project. The picture below shows me presenting my project to the sustainability coordinator of the Alrijne hospital. I really enjoyed these kind of interactions.

However, I noticed that my verbal communication with my supervisors could be improved. At times, I found it challenging to articulate my thoughts confidently and clearly, as there were numerous elements I was simultaneously considering. This experience taught me the importance of confidence and clear communication, a lesson I will carry forward into my future opportunities.

Overall I am proud and happy of all the things I learned during this project and I look forward to the future!

Figure 28: Me at the Sustainable Hospital Lab poster presentation, presenting my findings to the sustainability coordinator of the Alrijne hospital.

Acknowledgements

Firstly I would like to thank my academic supervisors JC and Sonja. Thankyou JC for your guidance providing me with so much clearance, knowledge and enthusiasm. You provided me of advice and insights on moments where I felt stuck. It amazed that despite your busy calender you always knew what to do and make me see things more clearly. Thank you Sonja for your diligence and attention to detail that kept me grounded throughout the project. You ensured that I maintained a comprehensive approach to problem-solving and reminded me to always take a critical look at my work.

Besides,I would like to thank Medical Delta, the LDE Centre for Sustainability and Dinemarie Kweekel for providing such an interesting assignment about reducing medicine waste in the OR. Your faith in my capabilities played a significant role in the success of this project. Thank you Dinemarie for providing a work place for me at the LUMC and scheduling in time every week to discuss my process. This was really motivating and I enjoyed our discussions!

Additionally I want to thank the students and partners connected to the 'Sustainable hospitals lab'. Every two weeks the lab provided a session on a topic related to sustainability in hospitals and these session were always really interesting! I enjoyed getting involved in the field of sustainable healthcare and discussing my thesis with the other students.

Thanks to all the anaesthesiologists, anaesthetic nurses, OR logistics and the hospital pharmacy who were able to help me. Especially Hans, he founded the Green Team OR LUMC in 2016 and I was honoured that he wanted to assist me during the project. Furthermore Rixt and Raymond really help providing their expertise in sustainability and anaesthesia at the OR. Thanks for you time and commitment to make the OR more sustainable! Floris and Rob, thanks for the opportunity to experience the logistics side of the OR.

Lastly I would like to thank my family and friends who supported me throughout the project.

This project, while challenging, was an enriching experience that shaped my understanding of sustainability in healthcare, and for that, I am truly thankful!

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