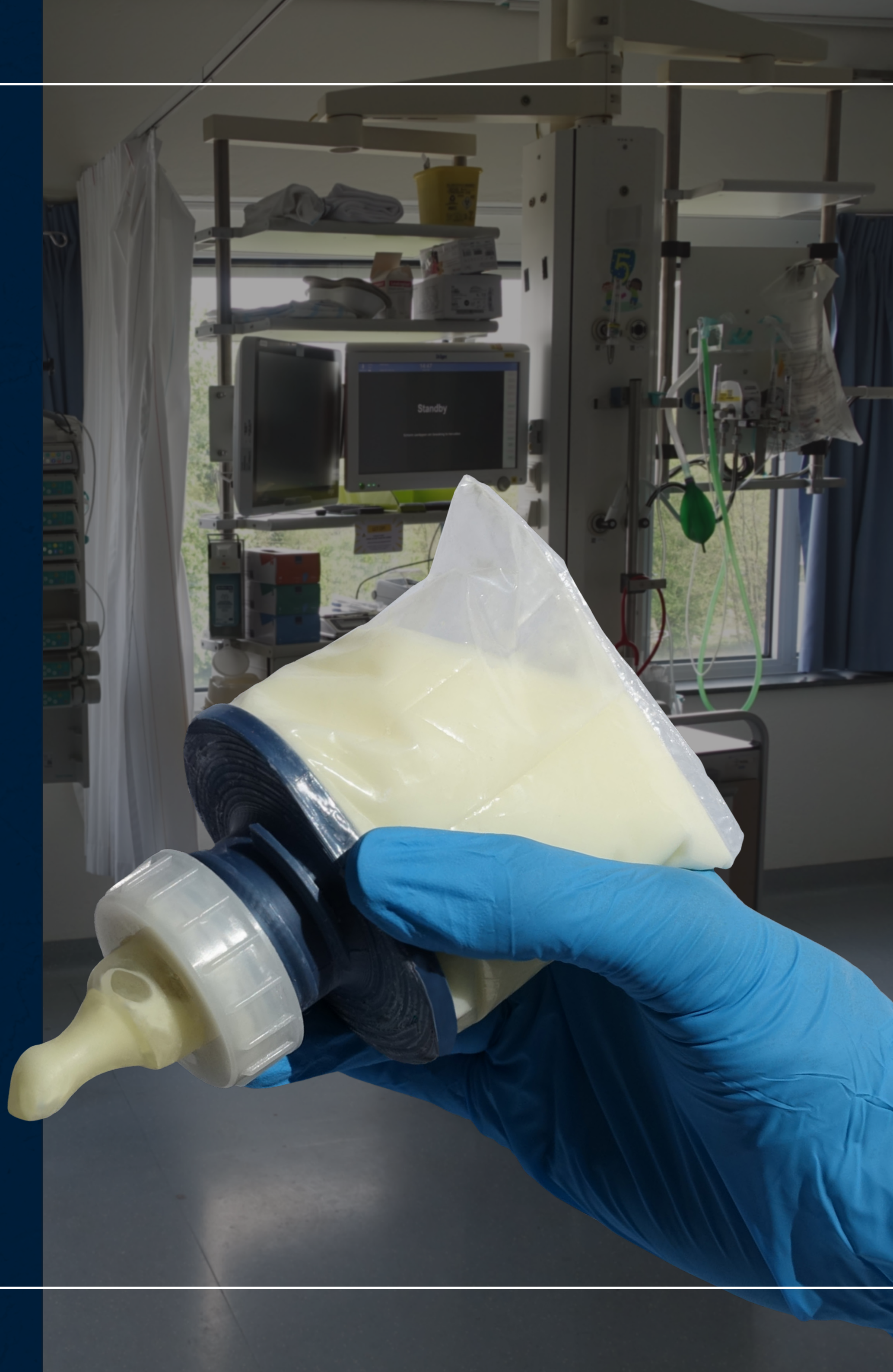
Beyond the Bottle

Design approaches to sustainable infant bottle feeding at Erasmus MC Sophia Children's Hospital



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Abstract

The use of disposable feeding bottles at the Erasmus MC Sophia Children's Hospital is a major contributor to the environmental footprint of the entire paediatric department. Reusable feeding bottles are commercially available, but their introduction into the hospital is hindered by concerns about safety, hygiene, limitations in physical infrastructure and financial constraints.

This project combines a qualitative study investigating the journey of a feeding bottle from arriving as an empty product to its disposal as waste in the paediatric intensive care unit (PICU), with a quantitative waste audit. This audit revealed that annually, a minimum of 555 kilograms of feeding bottles are discarded from the PICU alone. The consistent use of accessory products, such as feeding teats or enteral feeding sets, further adds to this material waste. Based on this in-depth investigation of the current feeding practices and waste flows, ten sustainability hotspots were determined, leading to the development of eight explorative interventions to reduce the environmental footprint.

The designed mono-material feeding pouch reduces the material weight required to transport an equivalent amount of formula milk by 60% compared with conventional bottles. This saves more than 329 kilograms of plastic waste from the PICU annually. The smaller size of the feeding pouch decreases the generated volume of waste by two-thirds and requires 40% less transportation capacity to deliver.

Integration into the existing infrastructure of the hospital is ensured with the developed stackable preparation and transportation tray and the bedside pole holder, which supports both teat-based and enteral feeding for the proposed next generation of feeding containers.

The project also highlights the current use of sterile water, which more than doubles the disposed mass associated with feeding bottles, while being supported by potentially outdated guidelines. This topic is suggested as a key opportunity for immediate changes by the Sophia Children's Hospital.

Introducing any new medical device is a complex challenge, and the development of this next generation of feeding containers and the necessary accessory products must be supported by a questioning of the established practices surrounding infant feeding. Reducing the environmental footprint of infant feeding at the Sophia Children's Hospital, therefore, requires looking beyond the bottle to the wider system of feeding practices and hospital-wide processes and infrastructure.

Abbreviations

Frequently used terms are abbreviated.

As the research has been performed in a Dutch hospital and context, many Dutch phrases are relevant. This work is in English, and it has been chosen to translate the original phrases for a uniform language structure. The translations into English are provided here for clarity and are given according to alphabetical order of the abbreviation.

Abbreviation	English	Dutch
EMC	*Erasmus Medical Centre*	*Erasmus Medisch Centrum*
PICU	*Paediatric intensive care unit*	*Intensive Care Kinderen*
PD	*Plastics and drinks cartons*	*Plastic verpakkingen en drankenkartons*
PP	*Polypropylene*	*Polypropeen*
CO2e	*Carbon dioxide equivalent*	*Koolstofdioxide-equivalent*

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1. Project introduction

Chapter Content

This project aims to reduce the resource footprint of disposable feeding bottles used in the Erasmus MC Sophia Children's Hospital.

The chapter outlines the Dutch climate and healthcare context. The specific focus of this project on the paediatric intensive care unit is described, as well as the challenges faced in this environment. The employed methods of divergence and convergence, as well as the project's goals, are framed.

Note: Image by Erasmus MC (n.d.)

1.1 The impact of healthcare

Healthcare influences lives on many levels. On an individual scale, this can translate to the treatment of a disease, the healing of injuries, paediatric care and even the fostering of new, healthier habits. On a national level, hospitals can provide complex medical care for a variety of patients and conditions, as well as facilitate research to promote long-term health and well-being. However, despite these positive contributions, the healthcare sector also contributes to a growing climate crisis, as noted in Karliner et al. (2019).

A national study by Steenmeijer et al. (2022) calculates that the Dutch healthcare sector is responsible for 7.3% of the country's national equivalent greenhouse gas emissions. The prolific use of disposable medical products is a major contributor to the overall resource consumption of the healthcare sector. The Green Deal 3.0, a set of agreements and guidelines aimed at increasing the sustainability of the Dutch healthcare sector, identifies the need for changes in the current use of disposable medical products. The goal of reducing primary raw material consumption by 50% by 2030, compared to 2016, has been set by the Green Deal Duurzame Zorg (2022).

1.2 Disposable feeding bottles in the focus area

The Sophia Children's Hospital currently uses a single-use system for patient feeding. This system is primarily based on formula milk. Every time a patient is fed, a feeding bottle is discarded. Investigating six Dutch university medical centres, Noort et al. (2024) determined that feeding bottles ranked fifth in terms of climate impact among 50 other medical disposables. Approximately 430,000 kg CO2e can be traced to disposable feeding bottles in 2022 alone.

Disposable feeding bottles are furthermore the only product in the top 15, seen in Figure 1.1, which are exclusively used in only one process or procedure. This showcases the outsized contribution of feeding bottles to the ecological impact, relative to their distribution of use.

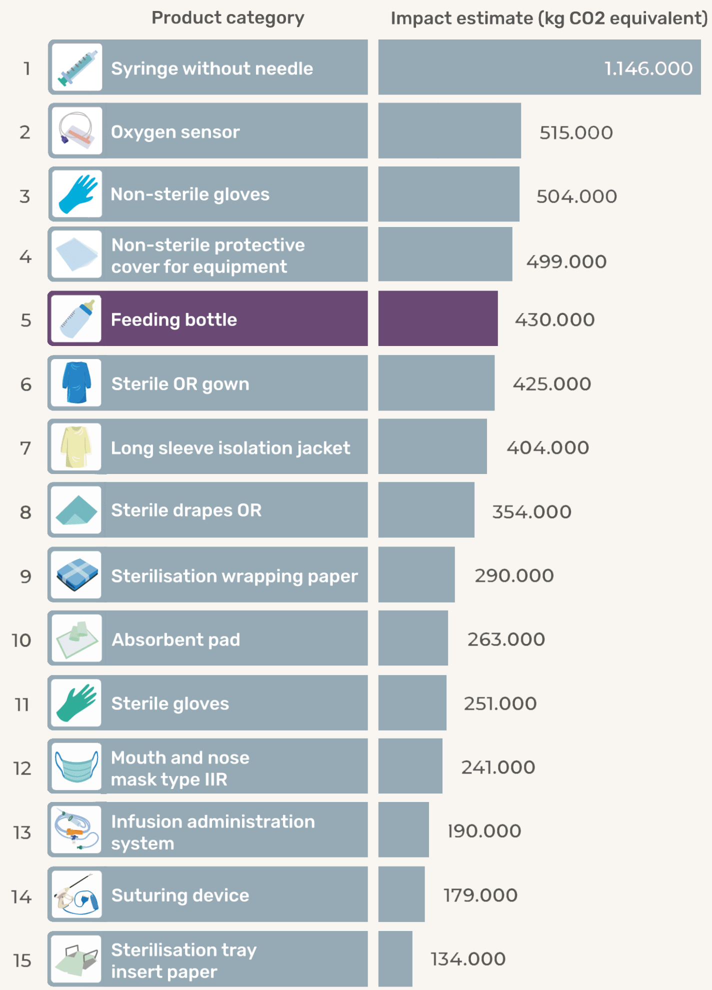


Figure 1.1 - Top 15 disposable medical products by kg CO2e

Note: Adapted from Landelijke Inventarisatie Medische Disposables UMC's by Noort et al. (2024)

Focus area: paediatric intensive care unit

In the Sophia Children's Hospital, it is the paediatric intensive care unit that constitutes the focus area of this project. This is primarily due to this department initiating the project as well as facilitating access. The need to improve food systems of medical nutrition has also been emphasised from within the unit itself, in Verbruggen et al. (2024). The PICU Green Team, developing sustainability at the grassroots level, is a further partner in developing this project. While not the only department where disposable feeding bottles are used, the PICU is a priority environment due to the high numbers of patients generating a large amount of waste. This high number of patients also allows sustainable changes to have a noticeable impact on the overall hospital situation.

Current state of focus area

A need exists to reduce the resource consumption of the disposable feeding bottles, yet the current system in the Sophia Children's Hospital cannot accommodate reusable bottles in any of the involved departments due to concerns about safety, hygiene, limited infrastructure and restricted financial resources.

Additionally, the various collaborating departments are not effectively linked and are not aware of the challenges and limitations faced by each separate department. Lastly, there exists no information on the specific amount, condition or distribution by care unit of disposed feeding bottles. In Figure 1.2, a small portion of the total amount of the disposable feeding bottles used daily is shown.

Improving the sustainability of the current system of patient feeding requires addressing all these identified existing shortcomings. The Sophia Children's Hospital is interested in tangible and actionable outcomes that can improve the existing feeding system, yet is also open to long-term, sustainable solutions to develop the feeding system.

Figure 1.2 - A portion of the total amount of disposable feeding bottles used daily

1.3 Project approach

This project is structured on a research phase, and a design with two cycles of divergence and convergence was used. As shown in Figure 1.3, while the phases of divergence and convergence follow each other, they themselves are processes of iteration and fuzziness.

Divergence 1: Exploring the current use of feeding bottles in the Sophia Children's Hospital

The initial divergence explores the existing feeding process and the challenges that the hospital departments face with regard to patient feeding. This exploration is supported by a waste audit, quantifying the amount of disposed feeding bottles as well as the material composition of the involved waste stream.

Convergence 1: Mapping sustainability hotspots in the feeding process

The subsequent convergence combines the findings from the exploration of the feeding process as well as the results of the waste audit to create a map of hotspots. The hotspots mark critical moments which most contribute to the environmental footprint of disposable feeding bottles in the Sophia Children's Hospital.

Divergence 2: Developing interventions to address identified hotspots

A second divergence develops initial interventions. These interventions serve to explore ways of addressing the identified hotspots. The developed interventions are then used to gauge the feasibility as well as desirability of the proposed direction by collaboratively validating the proposals together with the project stakeholders.

Convergence 2: Moving beyond the bottle for the next generation of feeding containers

In the second convergence, a design concept based on collaborative validation was developed. The proposed next generation of feeding containers for formula milk used in enteral or oral feeding in a hospital context, and a supporting low-risk, high-yield proposed adjustment to the use of sterile water in the feeding process, provides a tangible and actionable outcome desired by the Sophia Children's Hospital. Aside from the tangible proposal, the move beyond the bottle is also a challenge to existing practices and mindsets on the fundamental requirements for infant feeding.

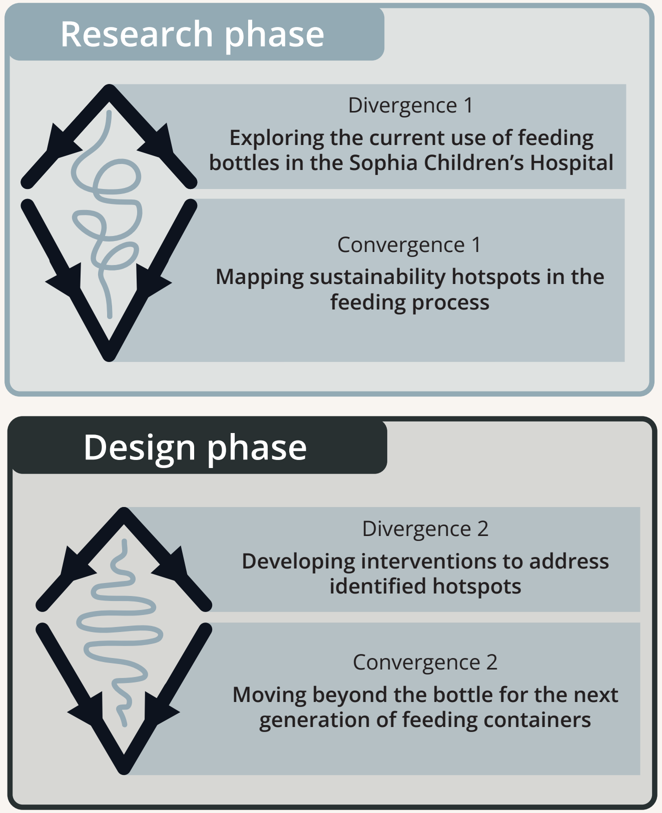


Figure 1.3 - Diamonds of divergence and convergence constitute the structure of this project

1.4 Project goals

The main goal of the project is to reduce the environmental footprint of disposable feeding bottles used in the PICU of the Erasmus MC Sophia Children's Hospital. To achieve this goal, a research phase and a design with two cycles of divergence and convergence were used. As shown in Figure 1.4, both phases have specific goals.

Reduce the environmental footprint of disposable feeding bottles used in the PICU of the Erasmus MC Sophia Children's Hospital

Research phase

- To **explore and map** the existing feeding process to identify hotspots of environmental impact in the Sophia Children's Hospital related to disposable feeding bottles.
- To determine the quantity and mass of feeding bottles and the material composition of the associated waste stream, originating in the PICU of the Sophia Children's Hospital.

Design phase

- To **develop** a t**angible prototype** for a feeding container with a reduced environmental impact suitable for the context of the Sophia Children's Hospital
- To **challenge** to existing **practices and mindsets** shaping the requirements for patient feeding in a hospital context
- To **build** project stakeholder **awareness** on the identified challenges and limitations in the departments related to the feeding process

Figure 1.4 - The main goal of this project and the supporting goals of the research and design phase

2. Impact of healthcare on climate change

Chapter Content

This chapter examines how healthcare contributes to climate change due to emissions of greenhouse gases and how these emissions increase the pressure placed on the healthcare system.

The impact of healthcare is first examined as a global footprint, by the contributed emissions and the large consumption of natural resources. The footprint of healthcare in the Netherlands and the institutional footprint of the Erasmus MC are subsequently presented.

Note: Image by Senna (2021) via Getty Images

2.1 Global footprint: the role of healthcare in climate change

It has been established that human activities can lead to changes in the climate system of Earth (Intergovernmental Panel on Climate Change [IPCC], 2023). While a variety of human activities can result in changes to the climate system, it has been further determined by the IPCC that an increase in global temperature is directly related to the emissions of greenhouse gases. The scale of the contribution to climate change from the healthcare sector can be determined by comparing the net greenhouse gas emissions to global emissions.

This climate footprint of the healthcare sector has been determined to be equivalent to 4.4% of global net emissions (Karliner et al., 2019). Placing this into context, if the healthcare sector were a country, it would be the fifth-largest emitter on the planet. When considering this total footprint, 71% consists of emissions classified as scope 3, defined as Other indirect GHG emissions in the Greenhouse Gas Protocol (Ranganathan et al., 2004). This scope includes emissions from the production, transport, use, and disposal of goods and services, making the supply chain the main contributor to the sector's total emissions. Figure 2.1 shows the three scopes and their contributing elements across the value chain for a company.

The measured rise of global temperatures due to climate change and inaction, as described in Romanello et al. (2024), has already resulted in direct threats such as extreme heatwaves, droughts, storms, and flooding. Related consequences, such as mass migration of climate refugees and increased transmission of infectious diseases due to temperature changes, have also been identified by Romanello et al. (2024) and are similarly predicted to increase. As a result, healthcare systems face growing patient loads and more complex care needs.

A sector under pressure

Healthcare is a major contributor to climate change, but it also experiences some of the most direct consequences. A rising number of patients with increasing complexity of required care exerts pressure on the healthcare sector. With the majority of the sector's emissions being able to be traced to the supply chain, when this increase in patients is met through greater use of resources, a feedback loop arises.

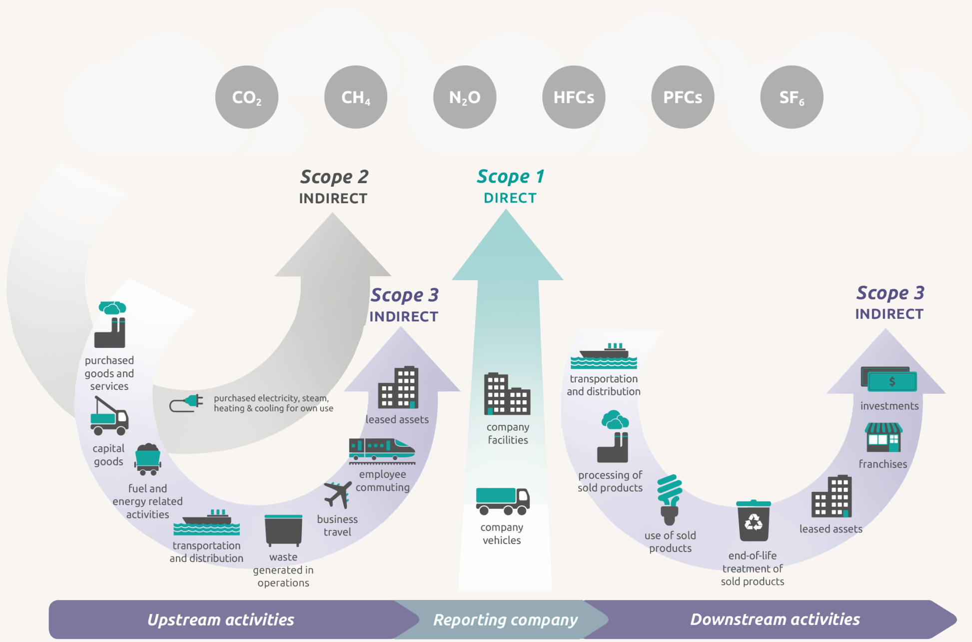


Figure 2.1 - Scopes and emissions across the value chain according to the Greenhouse Gas Protocol

Note: Adapted from Technical Guidance for Calculating Scope 3 Emissions by Barrow et al. (2013)

2.2 National footprint: the case of the Netherlands

It has been established that on a global level, healthcare is not only a major contributor to climate change but also increasingly experiences the direct consequences caused by shifting global conditions. While low- and middle-income countries are predicted to experience the greatest impact (Karliner et al., 2019, p. 9), high-income nations are also affected. A country such as the Netherlands, ranked eighth on the Human Development Index (United Nations, 2025), might appear to be well-positioned to withstand pressure from climate change, yet two factors complicate this expectation. The Netherlands is examined in greater detail because this project focuses on a specific Dutch hospital

National emissions profile of the Dutch healthcare sector

Emissions of greenhouse gases result in a global climate shift regardless of origin (Althor et al., 2016); thus, the impact of much larger emitters, such as the United States of America or the People's Republic of China, contributes to the risk faced by the Netherlands (Karliner et al., 2019). Second, the Netherlands' healthcare system is responsible for a large amount of emissions disproportionate to the size of the national population. According to Karliner et al., the Netherlands has an emission of 0.79 tCO2e per capita, which places it eighth out of the 43 countries studied. Also, according to Karliner et al., the climate footprint of the healthcare sector for the Netherlands is 5.9% of the national total. Compared to the 43 investigated countries, this ranks the Netherlands as sixth globally, as shown in Figure 2.2, when the footprint of the healthcare sector is related to the national total.

A national study by Steenmeijer et al. (2022) calculates that the Dutch healthcare sector is responsible for 7.3% of the national equivalent emissions of greenhouse gases. The study stresses that due to differences in various factors, such as selected environmental stressors, definitions and estimates, it is difficult to directly compare results. However, in the same work, several other models are examined, including the model used in Karliner et al. (2019), and it is suggested that a range of 6-8% is accurate for the Dutch healthcare sector's contribution to the national emission footprint.

Beyond greenhouse gases, Karliner et al. report that the sector accounts for 7.5% of blue water consumption, 7.2% of land use and 4.2% of waste production compared to the national total, while in Steenmeijer et al., the use of abiotic raw materials is identified as 13% of national consumption.

These various figures demonstrate that the Dutch healthcare sector holds a large share of the country's overall environmental footprint. Placing these contributions into context, the Centraal Bureau voor de Statistiek (2025) identifies at least 93 distinct types of industry, including healthcare. While the environmental footprint of industries varies, the proportion attributed to a single sector in terms of national emissions and resource use is strikingly high.

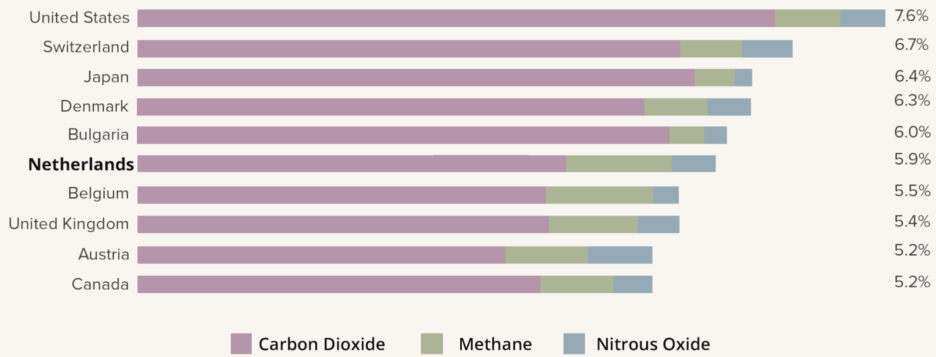


Figure 2.2 - The top ten nations, when comparing the footprint of healthcare as a percentage of national emissions

Note: Adapted from Health Care's Climate Footprint: How the health sector contributes to the global climate crisis and opportunities for action by Karliner et al. (2019)

2.3 Institutional footprint: the Erasmus Medical Centre

It has been established that on a global level, as well as for the Netherlands in particular, the healthcare sector is not only a major contributor to climate change but can also be expected to experience some of the most direct consequences caused by shifting conditions. This work is focused on a specific Dutch hospital, the Erasmus University Medical Centre, located in the city of Rotterdam. As a teaching hospital, as well as being the largest of the eight university medical centres in the Netherlands (Vennekens & Vogelezang, 2025), the Erasmus MC combines extensive patient care, medical education, research and innovation.

Mission statement of the Erasmus Medical Centre

The primary mission statement published by the Erasmus MC in the Strategy28 report (Erasmus MC, 2024b) is a commitment to stand for a healthy population and excellent care through research and education. The published report notes the many challenges facing the healthcare sector, threatening to disrupt the stated objective. Ongoing developments such as population ageing, migration and the decline in the relative number of young people are seen as fundamental challenges. Additionally, growing socio-economic inequality coupled with ever-increasing financial costs associated with medicines, treatment and innovative technologies are predicted to add further pressure to an already strained system. Lastly, the report addresses the ecological footprint of healthcare, describing it as enormous. In particular, this last element is identified as a feedback loop, as the negative effects of rapid climate change (Romanello et al., 2024) caused by the ecological footprint contribute to ever greater demand for healthcare, which is described by Steenmeijer et al. (2022) as leading to an increasing footprint to maintain standards.

A culture of disposing

As noted in the annual report (Erasmus MC, 2024a), as an academic medical centre, Erasmus MC focuses primarily on tertiary care, providing complex medical procedures as well as the associated academic education and research. This focus on providing care requires constant adherence to high medical standards and careful management of direct and potential risks to patients.

Figure 2.3 - Single-use products associated with the use of disposable feeding bottles

This standard of care forms the main pillar against which any change is tested. Reducing patient safety or care quality through direct risk, potential infection, lack of expertise, or staff availability is not permissible. It is through this lens that the high prevalence of single-use medical products can be understood. Single-use medical products are prolific in healthcare due to a wide range of factors, with the perception of being safer than reusable products identified as the foremost reason (Hoveling et al., 2024; MacNeill et al., 2020). This safety is expressed in the reduction of infection and related improved health outcomes, as noted in Kane et al. (2018). Examples of the various single-use products relevant to the use of disposable feeding bottles are shown in Figure 2.3.

However, it is raised (Greene et al., 2022; Hoveling et al., 2024; Kane et al., 2018; MacNeill et al., 2020) that in many cases, the use of disposables might not strictly be one of medical need, but rather of lower cost, convenience and concerns about liability. This "disposables culture" (Steenmeijer et al.,2022, p.48) is named a potential contributor to the large material extraction footprint of healthcare.
The environmental annual report for 2024 by the Erasmus MC (2025) identified 32,000 kg of plastic waste as being disposed of for the year. Compared to 16,000 kg of plastic waste counted in 2019, according to the annual report for 2023 (Erasmus MC, 2024c), an effective doubling in weight has occurred in five years. While a high point of 36,000 kg of plastic waste was counted in 2020, this was likely related to COVID-19 efforts. The waste audit performed in this project identified that the paediatric intensive care unit of the Erasmus MC discards a minimum of 547.5 kg of plastic in feeding bottles alone per year. This single department accounts for 1.7% of the plastic waste mass of the total hospital. When examining beyond the intensive care department to look at other departments, which may have a larger number of patients, the amount of waste continues to increase.

Agreements, such as the Green Deal 3.0 (Green Deal Duurzame Zorg, 2022), which establishes guidelines and objectives, recognise the amount of discarded material. The Erasmus MC, which has signed this agreement, is committing itself to accelerating the transition to sustainable healthcare while maintaining the required standard of care, based on five pillars.

The five pillars of the Green Deal Zorg 3.0 are health promotion, knowledge and awareness, CO2 reduction, circularity and medicines. The pillar of CO2 reduction and circularity of particular importance, as it has been identified that 71% of emissions traceable to healthcare can be classified as scope 3 or related to the supply chain of medical products (Honkoop et al., 2024; Karliner et al., 2019). Key guidelines aimed at reducing the amount of material are to increase the percentage of gathered waste which is recycled to 75% and a reduction of 50% in the consumption of primary raw materials by 2030.

A mission under pressure

The Erasmus MC looks forward to a changing future with a commitment to stand for a healthy population and excellent care. This objective is challenged by a range of issues, including ensuring and growing the sustainability of a wide range of healthcare-related facets, identified as a key issue. External programs, such as the Green Deal, establish guidelines and objectives to facilitate the move towards sustainable healthcare. Growing internal understanding and ongoing improvements, as described in environmental annual reports (Erasmus MC, 2024c , 2025), highlight the environmental performance of the Erasmus MC.

However, the prevailing use of single-use medical products continues to add further emissions and material footprint to the healthcare sector. A perception of these products providing added safety despite little compelling evidence supporting this viewpoint (MacNeill et al., 2020, p. 2091), complicates reducing the high use of disposable products.

2.4 Key points chapter 2

This chapter establishes that climate change is both a product of healthcare activity and a growing source of pressure on health systems. Healthcare contributes 4.4% of global net emissions, and the resultant rise in temperatures, extreme weather, and shifting disease patterns increases demand for care.

In the Netherlands, the healthcare footprint is large relative to the country's size. The sector is responsible for 6 to 8% of national greenhouse gas emissions, with further large shares of blue water use, land use, waste generation, and raw material consumption. As 71% of healthcare's emissions can be traced to scope 3 emissions, the use of single-use disposable medical products is responsible for a large amount of the consumption of the raw material and energy, as well as the generated waste.

At the institutional level, the Erasmus MC must balance its mission to deliver excellent care while the prevailing medical culture of disposable products leads to a high material footprint.

3. Project research approach

Chapter Content

This chapter introduces the two main phases of the project: the research phase and the design phase.

The research phase is presented in the following chapters, which detail the feeding process, the waste audit and the resulting map of hotspots.

The design phase is presented by the initial intervention proposals, which are further developed into the final design concept and accompanied by recommendations for future development.

The project is divided into two main phases. A research phase and a design phase, consisting of several related elements, as shown in Figure 3.1.

3.1 Research phase

In the first phase, the current system of infant bottle feeding at the Erasmus MC Sophia Children's Hospital was investigated. Qualitative insights from the process study are supported with quantitative data from the waste audit, as shown in Figure 3.1. Literature research on sustainability, circularity, environmental impact, infant feeding, medical devices and material development provided a theoretical foundation .

The process research was conducted primarily through user observation and informal interviews with staff members of various departments in the Erasmus MC. Due to the demanding environment of the hospital, staff members were generally not able to participate in formal interviews. Job shadowing during full working days and informal conversations, which were anonymously written down, allowed observation of real practices in context. Photography was used to capture situations as well as environments relevant to the feeding process. These real practices were situated within a broader context by incorporating national (Werkgroep Infectie Preventie [WIP], 2014a, 2014b) as well as Erasmus MC-specific guidelines.

In parallel, a structured waste audit was also performed, targeting waste bags containing feeding bottles leaving the PICU. Best practices from publications describing waste audits performed in other hospitals or departments at the Erasmus MC (Hsu et al., 2020, 2021; Hunfeld et al., 2023; Slutzman et al., 2023) were determined. Waste bags from specific periods were collected and weighed, and their contents counted. Alongside direct use of this data, an extrapolation to estimate annual quantities of disposed bottles was also performed.

The data from both research elements were used to develop a map of sustainability hotspots in the process of disposable bottle feeding at the Erasmus MC.

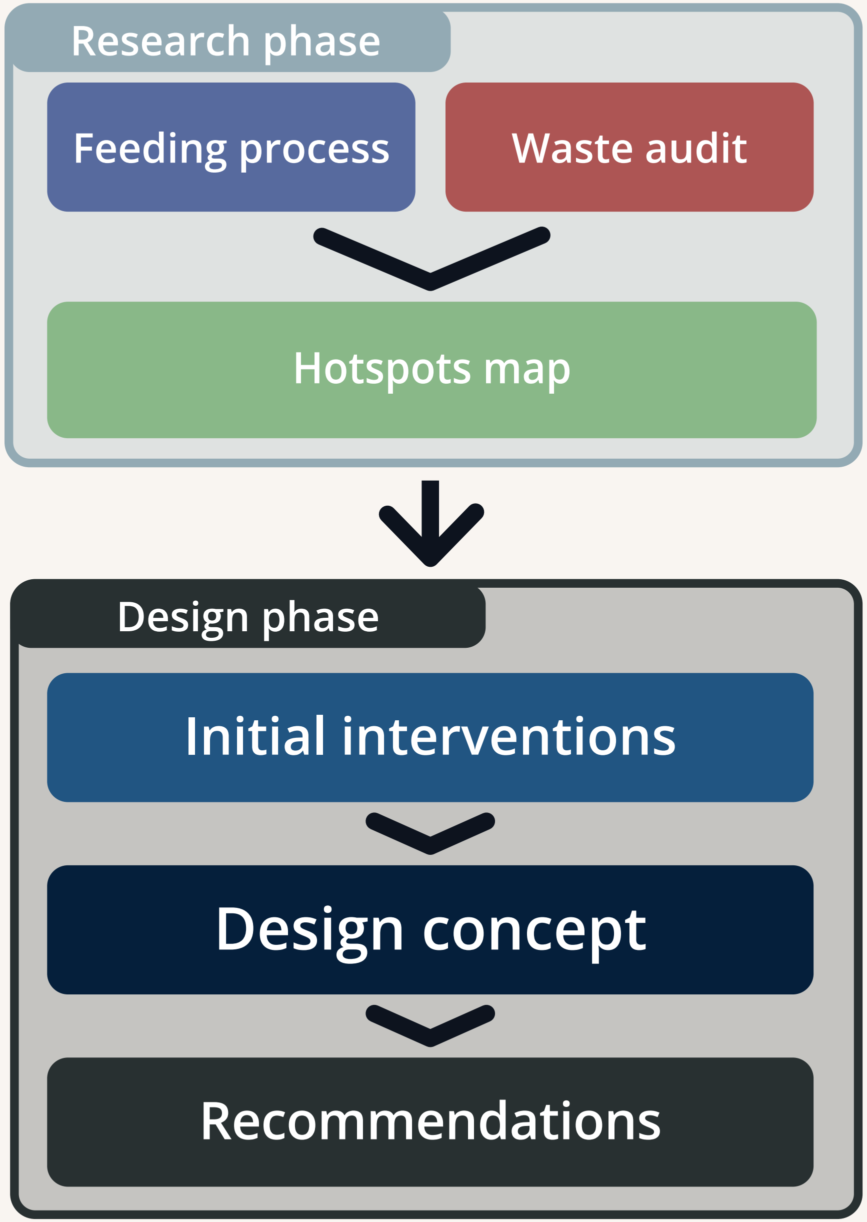


Figure 3.1 - The connection between the research and design phases in this project

3.2 Design phase

In the second phase, the developed map of hotspots was used as the foundation to iteratively develop a design concept that lowers the resource footprint of disposable feeding bottles at the Erasmus MC Sophia Children's Hospital. An initial explorative range of interventions was developed to determine stakeholders' ambitions and align further project outcomes. This development included collaborative brainstorming sessions as part of the DesHealth project, as well as a role in a new cooperation between the Erasmus MC and Danone, the current supplier of many products related to infant feeding.

Based on the stakeholder feedback, the design was concentrated on three connected tangible products. The three design concepts were developed from physical sketches, low-fidelity prototypes and additive manufacturing.

Physical validation, a session of which is shown in Figure 3.2, with staff members, was used to determine that the concept not only reduced the resource footprint but was also functional in the PICU context. This qualitative validation is supported by quantitative evaluations comparing the design concept against the current disposable feeding bottles in terms of reduced material mass, required waste bags and transportation. Recommendations on addressing hotspots not covered by the three design concepts, in particular the current use of sterile water, are a part of the overall project outcome.

Figure 3.2 - Introducing prototypes of the design concept to staff members in the hospital

4. Feeding method and bottles

Chapter Content

This chapter introduces the difference between infant feeding in a hospital context and a typical home environment. The prevalence of enteral feeding and the importance of viewing it as a medical method of feeding are introduced.

The four relevant types of disposable feeding bottles currently used in the Sophia Children's Hospital are introduced. The reasons that reusable feeding bottles cannot be adopted in the Erasmus MC are presented. Based on this, the R-strategies of Refuse, Rethink and Reduce are identified as offering the most potential in reducing the environmental impact of feeding bottles.

4.1 Infant feeding in the hospital

The hospital and especially the paediatric intensive care unit, which forms the context of this project, are very different to a typical home environment with regard to infant feeding methods.

It has been identified that more than 80% of the PICU patients in the Sophia Children's Hospital are fed using an enteral method. Enteral feeding bypasses a patient's mouth to deliver nutrition directly to the gastrointestinal tract by passing fluid through a feeding tube, as shown in Figure 4.1. This method of feeding is aimed at reaching the nutritional goals for a patient as soon as possible, which has been found to improve outcomes (Gunst et al., 2025). While Gunst et al. go on to conclude that practices appear to be changing to a more restrictive feeding for critical patients, enteral feeding currently remains the main method by which nutrition is delivered to patients in the PICU.

During enteral feeding, the patient does not control the volume of or the duration during which nutritional fluid is delivered. This is controlled with an enteral feeding set, which acts as the intermediate connecting element between the patient and a feeding bottle. An enteral feeding set is coupled with a feeding bottle. The feeding is initiated and monitored by a paediatric nurse.

While around 80% of the patients are fed using an enteral method delivering formula milk, the remaining 20% are split between a conventional feeding bottle method and rare cases of direct breastfeeding. The feeding bottle method is similar to a typical home environment and is performed with a feeding bottle with a mounted feeding teat. A typical example of this method of feeding is shown in Figure 4.2. In the feeding bottle method, either expressed milk or formula milk may be used, depending on availability.

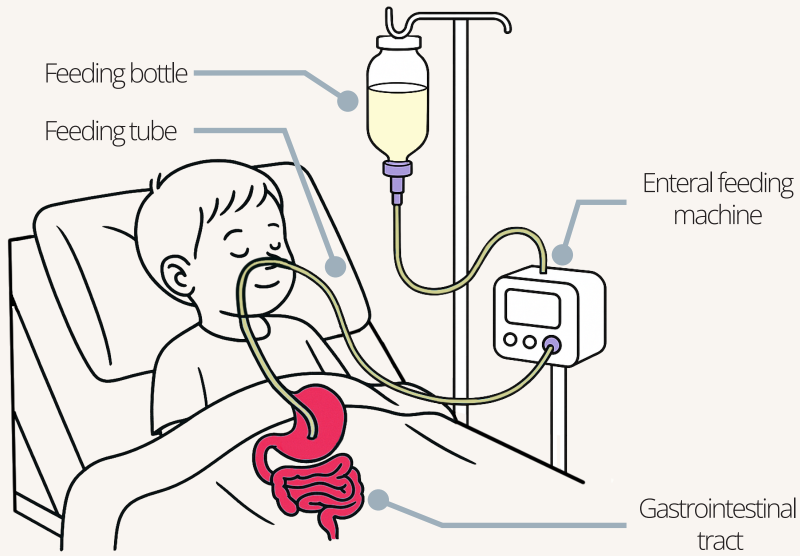


Figure 4.1 - Enteral feeding

Figure 4.2 - Conventional bottle feeding of an infant

It should be noted that the widespread use of commercial formula milk has been identified with both positive and negative outcomes. The marketed convenience as well as other stated benefits of formula milk have been called into question (Rollins et al., 2023). The widespread marketing claims made by manufacturers have been challenged by the World Health Organization and the United Nations Children's Fund (2022). While breastfeeding is greatly beneficial for both mother and child (Victora et al., 2016), it is not always feasible for the mother or caregivers. Thus, while further investigation of this topic is beyond the scope of this work, due to the prevalent use of formula milk in enteral feeding, it is considered the primary fluid used.

These differences between the hospital and home environment are important to consider, as they greatly affect the requirements of the container used to deliver nutrition to a patient. In Figure 4.3, a typical case of enteral feeding in the Sophia Children's Hospital is shown. An inverted feeding bottle is connected to a volume-regulating enteral set with a tube. The enteral feeding machine dispenses a set volume of formula milk over a period of time to a patient through the connected feeding tube.

Figure 4.3 - A feeding bottle used to deliver nutrition in an enteral method to a patient

4.2 Relevant disposable feeding bottles

Currently, in the Sophia Children's Hospital, four types of disposable feeding bottles are in use, shown in Figure 4.4. The extra-large variety is demonstrated in an inverted position, which highlights the integrated suspension element. No other bottle incorporates this element. Each bottle is described in greater detail in *Appendix A*.

All four types can be used interchangeably, the primary difference is in the volume of each bottle. The small bottle has a capacity of 50 mL, the medium bottle a capacity of 130 mL, the large bottle a volume of 250 mL and finally the extra-large bottle can hold up to 500 mL. Each bottle incorporates the same thread on the neck. This thread, shown in Figure 4.5, allows attachment of the cap and feeding teat as well as enabling connection to an enteral feeding set.

Figure 4.6 presents the mass of each bottle and the corresponding volume-to-mass ratio (mL/g). A linear increase in both weight and volume-to-mass is consistent with the similar construction and wall thickness of each bottle.

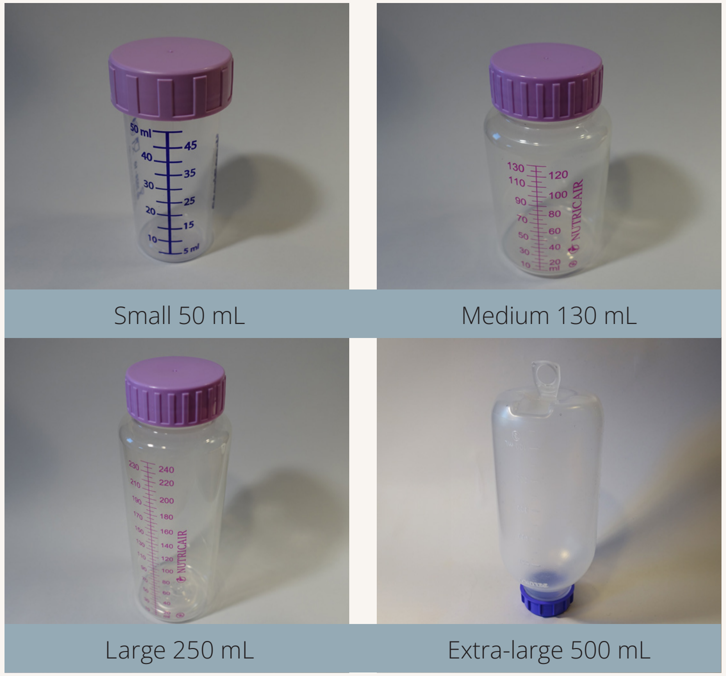


Figure 4.5 - The four types of disposable feeding bottles: small, medium, large and extra-large

Figure 4.4 - The thread shared by all feeding bottles

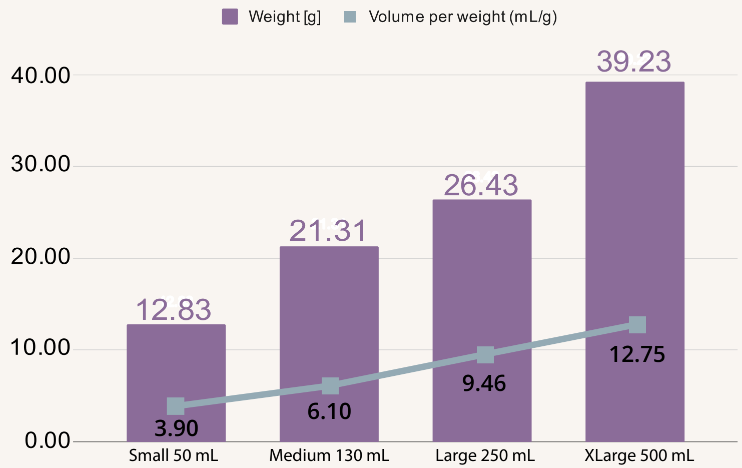


Figure 4.6 - Mass and volume-to-mass ratio for four types of disposable feeding bottle

4.3 Reusable feeding bottles and R-strategies

Currently, only disposable feeding bottles are used in the Sophia Children's Hospital. While reusable polypropylene or glass feeding bottles, examples of which are shown in Figure 4.7, are commercially available, their introduction into the intensive care unit, as well as the general hospital context, is hindered by concerns about safety and hygiene, as well as limitations in physical infrastructure and financial resources. There is a current lack of cleaning, sterilisation and bottle retrieval equipment, as well as insufficient staff availability to perform the added workload associated with the cleaning, storing and categorising of the daily volume of feeding bottles. In addition, a high upfront financial investment is needed to acquire this new equipment. Lastly, the introduction of glass bottles brings concerns of potential breakage, while reusable polypropylene introduces potential infection risk with inadequate processing.

While all these concerns can potentially be addressed, due to their extent, introducing reusable feeding bottles as a method to reduce the environmental impact of patient feeding was determined to be neither feasible nor currently desirable for the Erasmus MC. An in-depth investigation into the specific concerns was determined to be beyond the scope of this project.

Instead, the recognition that disposable bottles cannot be phased out quickly, yet a need exists to reduce the associated environmental impact, formed a key starting point for this project.

Figure 4.7 - Commercially available reusable polypropylene and glass feeding bottles

Note: Image by MediCare Colgate. (n.d.)

R-strategies for raw material

Due to the extent of the identified concerns associated with introducing reusable feeding bottles as a method to reduce the environmental impact of patient feeding, it is necessary to examine the required move to economic circularity as solely applicable to disposable feeding bottles. R-strategies, as described in Mast et al. (2022), aimed directly at the use of raw materials, such as Recycle or Recover, are already practised, yet these are hindered in their effectiveness by existing national Dutch regulations on the handling of waste originating in hospitals (Ministerie van Infrastructuur en Waterstaat, 2024), as well as providing the lowest impact in reducing environmental impact.

R-strategies for product service life

R-strategies, which aim to increase a product's service life, such as *Reuse*, *Repair*, *Refurbish*, *Remanufacture* and *Repurpose*, are similarly hindered in their application to disposable feeding bottles. While a seemingly simple product, consisting of an extremely limited amount of components and materials with low value, feeding bottles come in direct contact with patients and are thus medical devices with high criticality, as designated by Kane et al. (2018). These types of devices are named the most *"difficult subset...since they combine a high cost of recovery with a low cost of disposal and replacement."* (Kane et al., 2018, p. 44). Many of the systemic barriers to the circular transition of medical devices, as identified in Hoveling et al. (2024), in particular those related to safety and regulations, present a challenge to introducing these R-strategies.

R-strategies at the top of the value hill

As stated in Hoveling et al. (2024), the strategy of *Refuse* allows for the greatest impact and can be achieved in a device by "*abandoning its function or by offering the same function in a radically different, more sustainable device."* (Hoveling et al., 2024, p.2). Naturally, abandoning the feeding of patients is not a viable proposal for the Sophia Children's Hospital. The strategies of *Rethink* and *Reduce* can also offer high impact, being located high, as shown in Figure 4.8, on the value hill (Achterberg et al., 2016) of a circular economy.

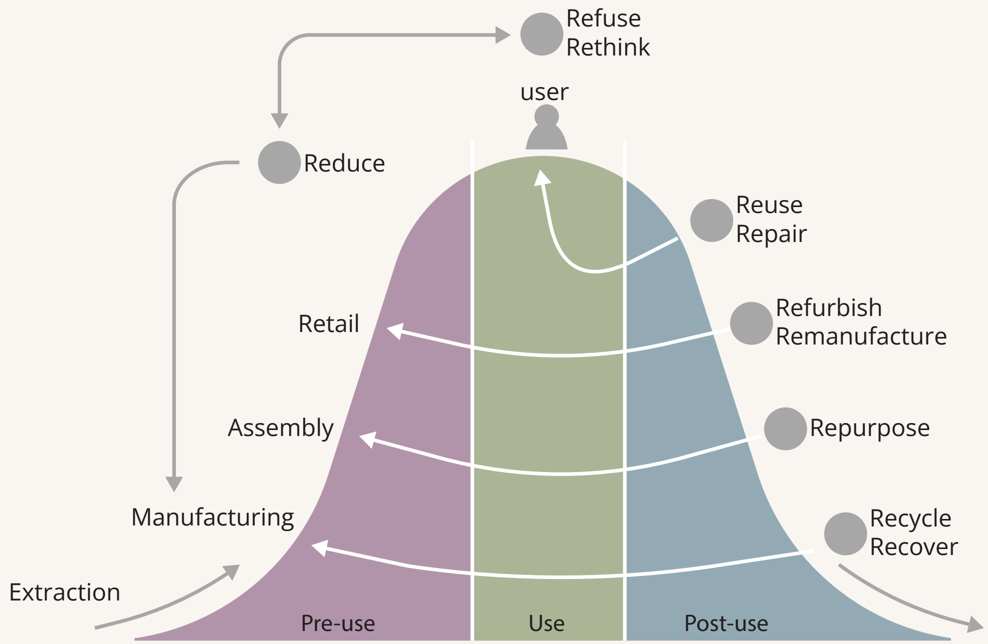


Figure 4.8 - R-strategies applied to the value hill of a circular economy

4.4 Key points chapter 4

This chapter sets the clinical context for infant feeding and the difference between a home environment and a hospital. In the PICU at the Sophia Children's Hospital, enteral feeding is the predominant method, used for more than 80% of patients. Feeding in this setting serves clear medical goals and is initiated and monitored by paediatric nursing staff.

Four disposable bottle types are used, sharing a common neck thread and differing mainly by volume. While reusable feeding bottles are commercially available, due to infection-control requirements, missing cleaning, sterilisation and bottle retrieval equipment factors, their adoption at the Erasmus MC is currently not feasible. While a change towards more circular medical products is necessary to reduce the high environmental impact. R-strategies such as Reuse, Repair, Refurbish, Remanufacture, and Repurpose cannot effectively be applied to this product with low value yet high-criticality. However, continued use of disposable feeding bottles brings a high environmental impact.

This project, therefore, considers the R-strategies of Refuse, Rethink and Reduce as offering the most potential to be applied in the development of a design concept that lowers the environmental impact of disposable feeding bottles while acknowledging the necessity of patient feeding.

5. Bottle feeding process at the Sophia

Chapter Content

This chapter traces the complex journey a disposable feeding bottle undergoes through the Sophia Children's Hospital, from arriving as an empty product, to its use in feeding patients and finally leaving as a waste item. This journey has been divided into six key stages: Storage, Preparation, Delivery, Use, Disposal and Collection.

The findings are one of the foundational elements used to determine the hotspots impacting the sustainability of bottle feeding at the Erasmus MC.

5.1 Condensed journey map

At the Sophia Children's Hospital, disposable feeding bottles pass through multiple staff members and departments, from storage to eventual disposal as hospital waste in a complex journey. Examining each of the various phases in the journey of a feeding bottle, in combination with a more detailed inspection of key elements used in these phases, makes it possible to identify hotspots which currently impact the sustainability and usability of feeding bottles. Due to the complexity and connected nature of the journey, it is first introduced as a condensed map, showing only the phases and their internal relationships.

It is possible to identify six distinct phases in the current journey that a feeding bottle passes through, from storage to waste. All six phases and their connections to each other are shown in a condensed manner in Figure 5.1. This process starts at the *Storage* phase, moves through *Preparation* and then *Delivery* and *Use*. Both of these last two phases can lead to *Disposal,* from which bottles either exit as general hospital waste and eventually incineration or proceed to the last phase. The last phase, *Collection*, concludes the journey with bottles ending as PD waste with eventual recycling.

The current journey of a feeding bottle is a linear one. As shown in Figure 5.1, most phases directly lead to a subsequent one. The only divergence from this is that both the *Delivery* and *Use* phases lead to the *Disposal* phase. Examining the current journey from the perspective of a circular economy, by adoption of R-strategies (Mast et al., 2022), shows that only two out of nine strategies are being met, these being recover and recycle, as based on the definitions in Hoveling et al. (2024). The two strategies of recovery and recycling are the two lowest steps in the transition between the linear and a circular economy.

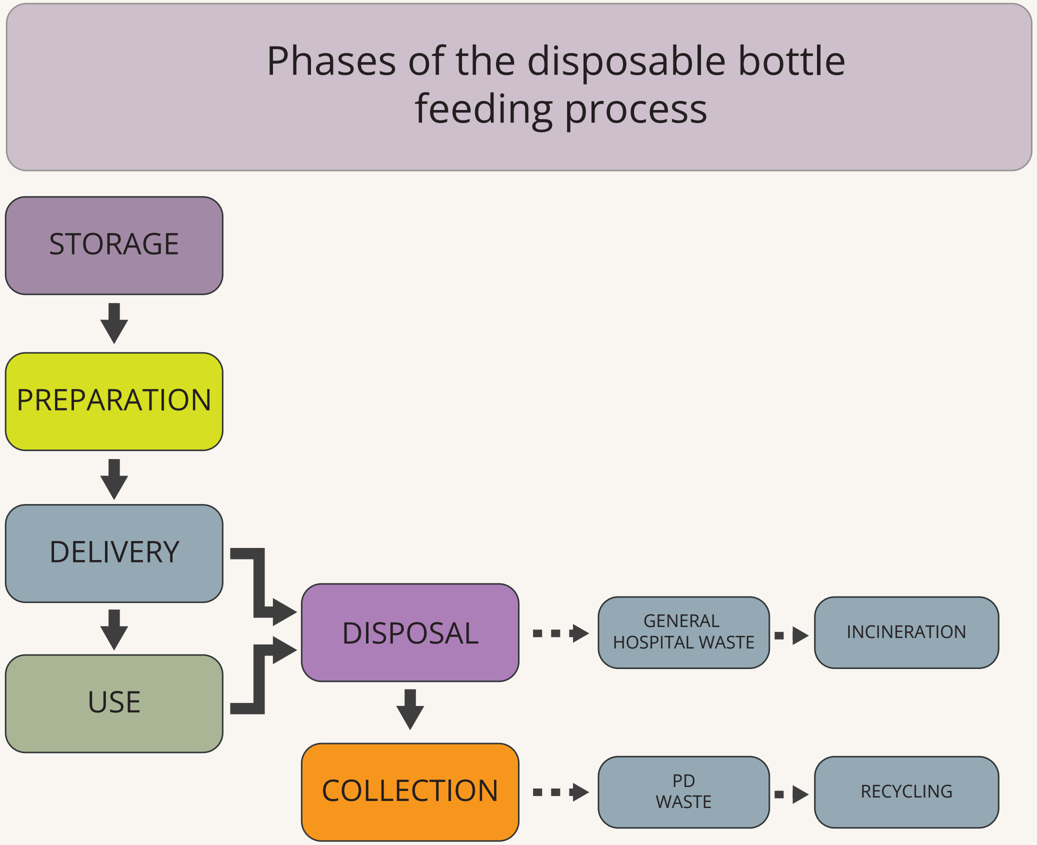


Figure 5.1 - The six phases that a feeding bottle passes through, from storage to waste

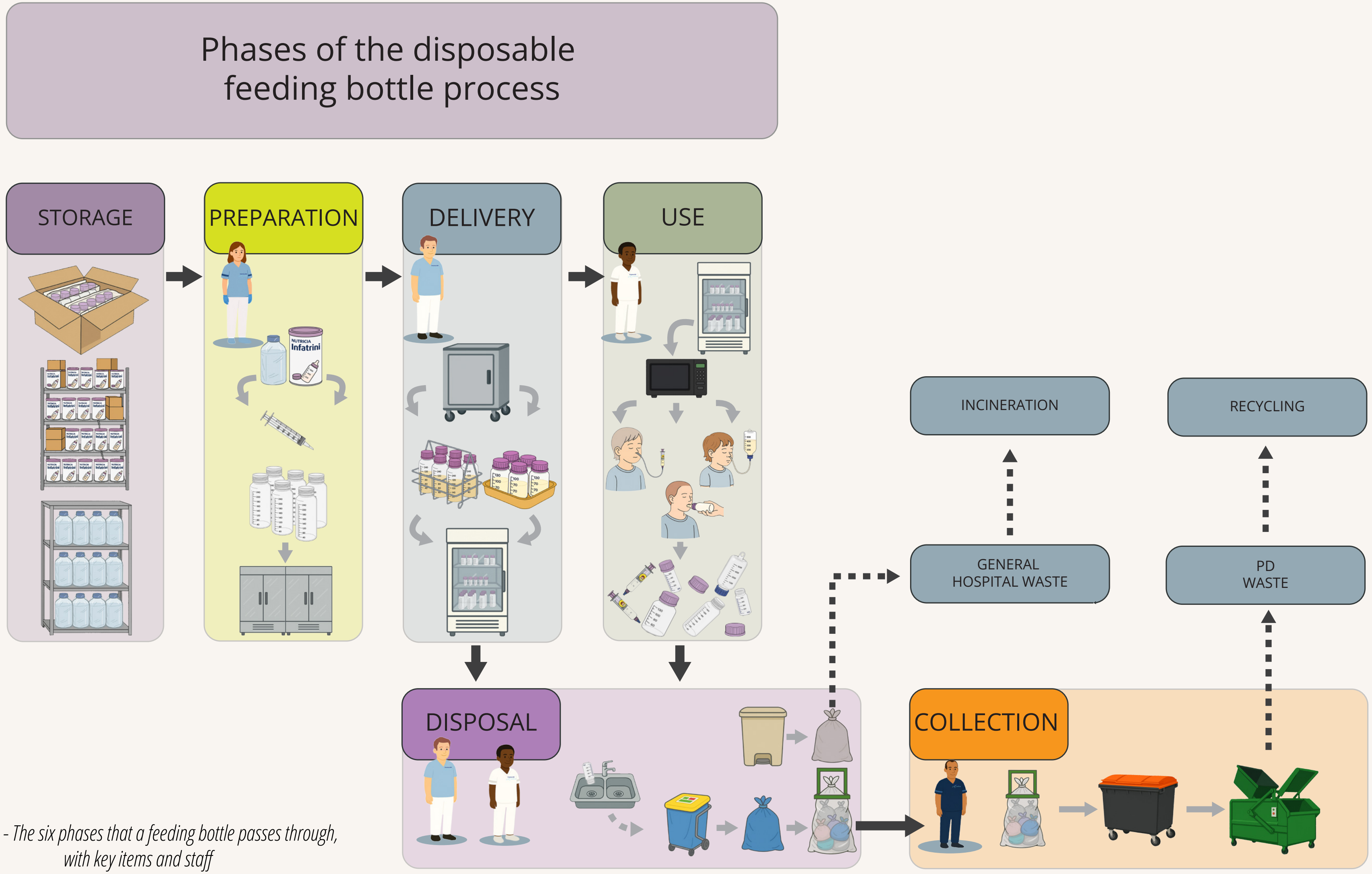


Figure 5.2 - The six phases that a feeding bottle passes through, with key items and staff

5.2 Expanded map

The initial condensed examination can be expanded by including greater detail on the various key moments in each phase. The expanded map, shown in Figure 5.2, contains items and staff members involved in each stage. The six distinct phases in the current journey of a feeding bottle each contain various key moments, items and staff members. By superimposing these elements on the established phases, a more in-depth understanding of the entire process, as well as specific moments of friction and items or moments that influence sustainability and usability, can be identified.

5.3 Key staff

Four staff groups are of specific importance to the six phases of the feeding-bottle journey. While their actions are described in greater detail in subsequent sections, they are briefly introduced here.

The *kitchen staff*, represented in Figure 5.3, are involved in the storage and preparation phases. They retrieve bottles, formula powder, and sterile water from storage. Using these materials, they prepare formula milk, then fill, cap, and label bottles according to daily orders.

The *feeding assistants*, represented in Figure 5.4, are involved in both the delivery and disposal phases. They transport prepared bottles from the kitchen to the PICU using insulated trolleys and trays. Following this delivery, they dispose of unused or unnecessarily prepared bottles.

Paediatric nurses, represented in Figure 5.5, organise feeding moments for each patient. They heat bottles, manage enteral or oral feeding, and then remove patient labels and discard the bottles.

Finally, *logistics staff,* represented in Figure 5.6, handle the collection phase. They remove waste bags from the wing bin and move the collected material to the hospital waste management area for eventual external processing.

5.4 Detailed phases

The overall journey of the feeding bottle is presented through a condensed and an expanded map, and a more detailed examination of each of the six identified phases and the constituent subphases now follows. Most phases are viewed through the lens of the feeding bottle as a physical container and potential waste item. This is the case for the phases of *Storage*, *Preparation*, *Delivery*, *Disposal* and *Collection*. In the *Use* phase, it is rather the transported milk formula and its delivery to the patient which is examined more closely. This distinction makes it possible to separate the primary end goal of feeding bottles, the actual feeding of a patient, from the required physical materials.

Figure 5.3 - Representation of a kitchen staff member

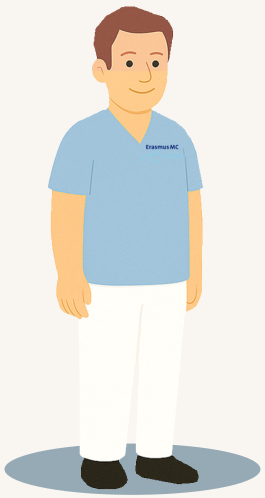


Figure 5.4 - Representation of a feeding assistant

Figure 5.5 - Representation of a paediatric nurse

Figure 5.6 - Representation of a logistics staff member

5.4.1 Storage Phase

This phase covers the various materials necessary to prepare infant formula in the Erasmus MC kitchen. Due to the daily preparation of feeding bottles, a large amount of consumable material is used daily. A storage room adjacent to the preparation kitchen holds several types of packaged bottles, several types of infant formula, as well as a large supply of sterile water in plastic jugs. The materials from the storage phase are used in the subsequent preparation phase, as shown in Figure 5.7.

Material 1 : Packaged bottles

Four types of feeding bottles are used, depending on the volume of formula milk requested to be supplied to a patient. All types of bottles arrive in sterile packaging, either as single items or in a multi-pack. A set of feeding bottles in multi-packs is shown in Figure 5.8. All bottles are unpacked, with a significant amount of resulting packaging material being disposed of, with an example shown in Figure 5.9.

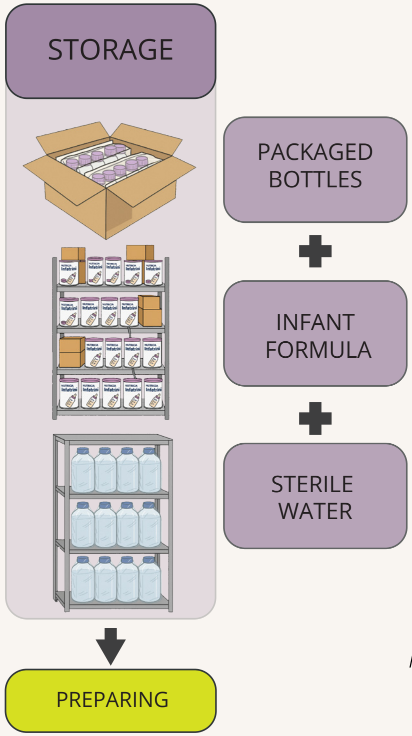


Figure 5.7 - The storage phase, with its relation to other stages and the most critical materials

Figure 5.8 - Feeding bottles arrive packaged

Figure 5.9 - All bottles come sealed and are manually unpacked

Material 2: Infant formula

Due to the various nutritional as well as medical requirements of patients, different types of infant formula are used. The vast majority takes the shape of formula powder, which must be dissolved in a liquid to create formula milk. Figure 5.10 shows a storage rack with several formula powders.

Some types of ready-made liquid infant formula are also used. Due to these liquids both being significantly less used compared to powders, as well as differing little in required procedures, this work does not investigate these liquids further.

Material 3: Sterile water

The national Dutch guidelines on the preparation of food for infants, as well as enterally delivered food (Werkgroep Infectie Preventie [WIP], 2014a, 2014b), prescribe the use of either freshly boiled and cooled tap water or sterile water. The Erasmus MC uses packaged sterile water stored in plastic jugs, of which examples are shown in Figure 5.11.

Erasmus MC guidelines further mandate that opened water jugs must be discarded after twenty-four hours, regardless of the amount of water used. This leads to frequent disposal of only partially emptied jugs, which adds a significant amount of plastic as well as transported water weight to the entire bottle journey.

Figure 5.10 - Several types of formula powder are used, depending on the patient's nutritional needs

Figure 5.11 - Sterile water is used to mix the formula powder, stored in plastic jugs

5.4.2 Preparation Phase

This phase covers the preparation of formula milk, which is dispensed into feeding bottles for delivery to patients. In this stage, the kitchen staff fulfil orders and prepare a specific amount of formula milk and feeding bottles for each patient. This is done according to Erasmus MC and other external guidelines (Werkgroep Infectie Preventie [WIP], 2014a, 2014b), to minimise contamination and the patient risk. As shown in Figure 5.12, this phase can be divided into three subphases: ordering, mixing and storing.

Subphase 1: Ordering

The ordering process involves individual daily orders, shown in Figure 5.13, that specify the type and volume amount of formula milk and potential additives for every patient. Kitchen staff processes these orders to prepare feeding bottles, shown in Figure 5.14. The required tools, materials and formula powder are also prepared. Due to the large number of patients and the associated amount of preparation, all the orders for feeding bottles must be submitted up to several hours before the daily pickup at 14:00.

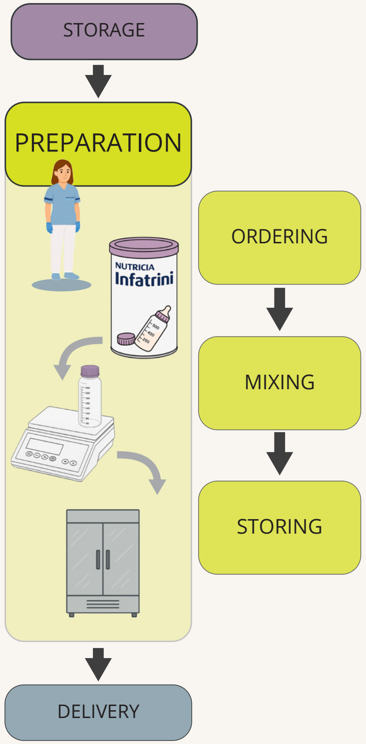


Figure 5.12 - The preparation phase, with its relation to other stages and its constituent subphases

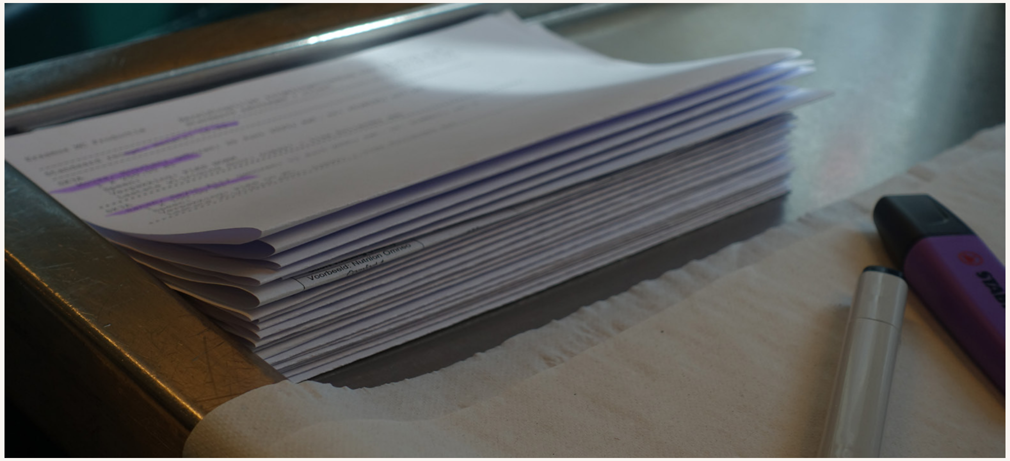


Figure 5.13 - Orders detailing the requested nutrition for the next day for every patient

Figure 5.14 - Different types of bottles are in use, with the large bottle being the most common

Subphase 2: Mixing

All feeding orders are based on specific methods and ingredient ratios of formula powders and are prepared according to recipe books. This process requires many additional products, such as disposable syringes shown in Figure 5.15.

The main steps of this process are shown in Figure 5.16. Every dose of formula powder is manually weighed by kitchen staff. The powder is mixed and dissolved in sterile water to form formula milk. A mixing vat is used to prepare the volume of several feeding bottles simultaneously. A disposable syringe is used to withdraw and dispense precise amounts of formula milk into feeding bottles. A separate syringe is used for each particular patient to avoid contamination. Finally, every feeding bottle is capped and labelled with a sticker containing information on the content and the associated patient.

Figure 5.15 - A range of additional products, such as syringes, is used during preparation

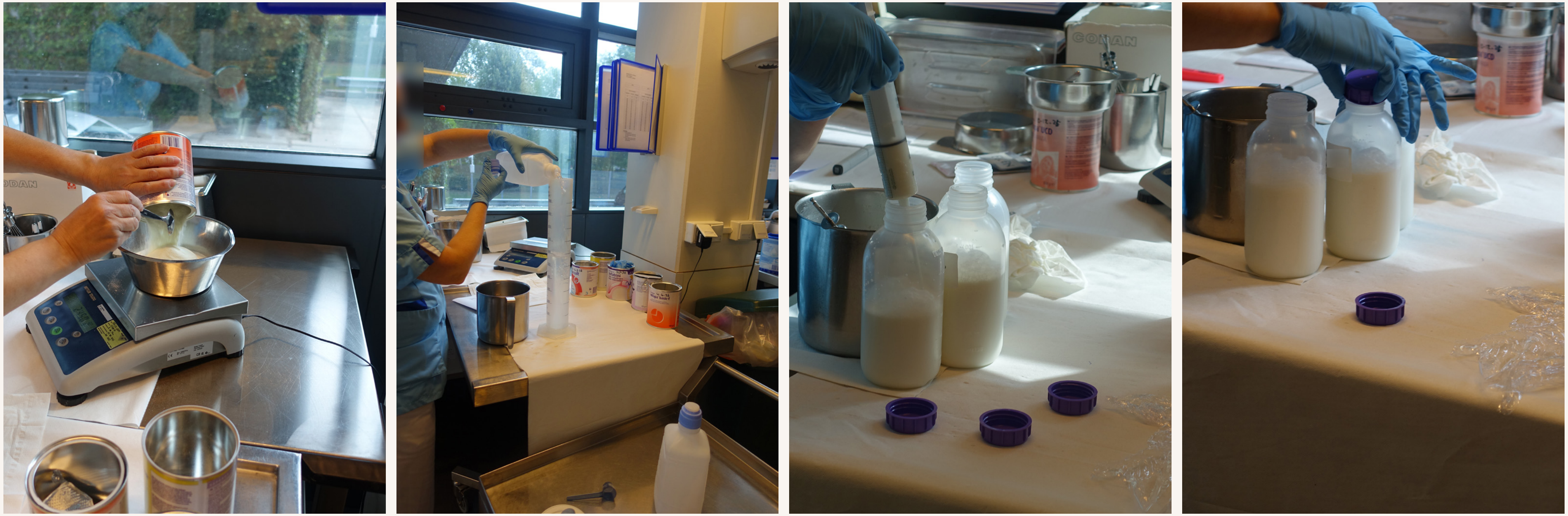


Figure 5.16 - The main steps in manually preparing formula milk and filling feeding bottles

Subphase 3: Storing

On completion of the mixing, the kitchen staff stores the prepared bottles in the kitchen double-entry fridge, shown in Figure 5.17, which allows later retrieval by feeding assistants.

It has been found that sometimes a small number of syringes filled with formula milk are prefilled for the neonatal department, shown in Figure 5.18. As was also identified in Honkoop et al. (2024), several other products are needed to prepare syringes, which further adds to the resources necessary for the feeding process. Due to the small quantity prepared, as well as being specific to the neonatal as compared to the intensive care department, this work does not consider the preparation of these syringes further.

Figure 5.17 - Bottles are stored before pickup for delivery

Figure 5.18 - Small syringes may be prepared for the neonatal department

5.4.3 Delivery Phase

This phase covers the delivery of a feeding bottle. In this stage, the feeding bottle leaves the preparation kitchen, is moved through the hospital to end in an ICU. Each phase involves a feeding assistant transporting the feeding bottles through the hospital to allow paediatric nurses to feed patients. Depending on the encountered situation, a feeding assistant might also need to dispose of unused or unneeded bottles. As shown in Figure 5.19 this section can be divided into three subphases: loading, movement and unloading.

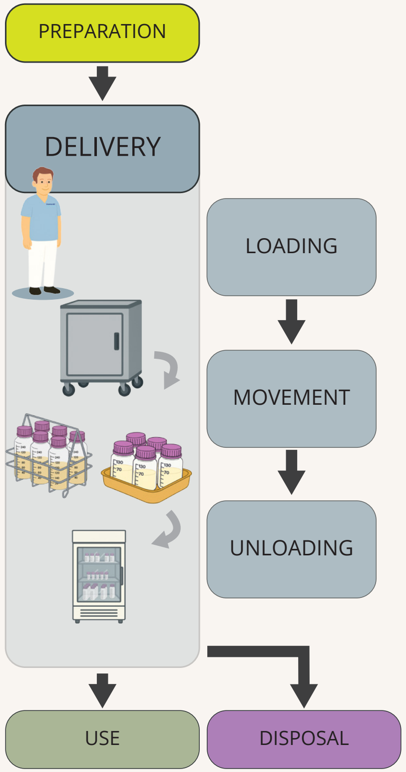


Figure 5.19 - The delivery phase, with its relation to other stages and its constituent subphases

Subphase 1: Loading

Feeding assistants gather and deliver the daily order of feeding bottles. The feeding bottles are collected from the kitchen fridge, loaded into insulated trolleys, which keep the bottles at a low temperature, and are moved to the PICU. Bottles are stored in designated carrying racks, but only one of the four types of bottles fits these racks, as shown in Figure 5.20. The three other types are either stored loosely in the trolley or in disposable trays, shown in Figure 5.21.

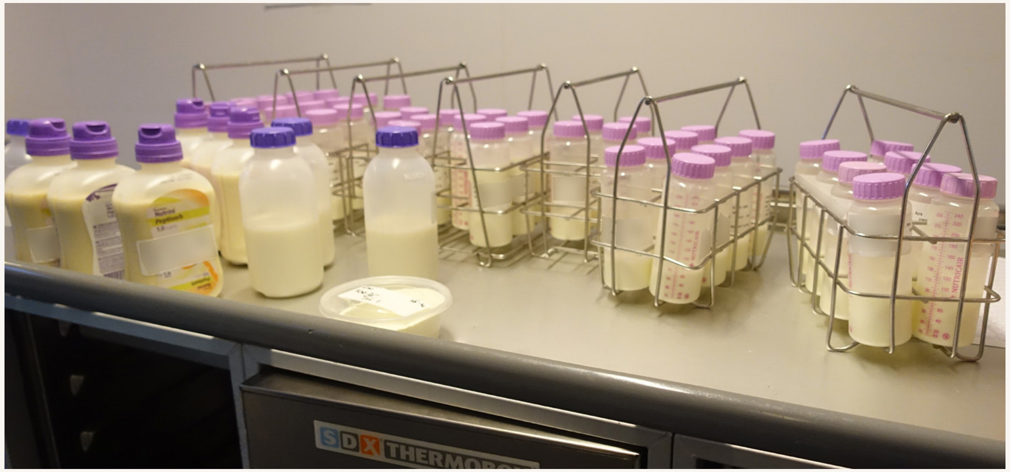


Figure 5.20 - Only one out of four types of bottles fits in the carrying racks

Figure 5.21 - Bottles haphazardly stored in disposable trays

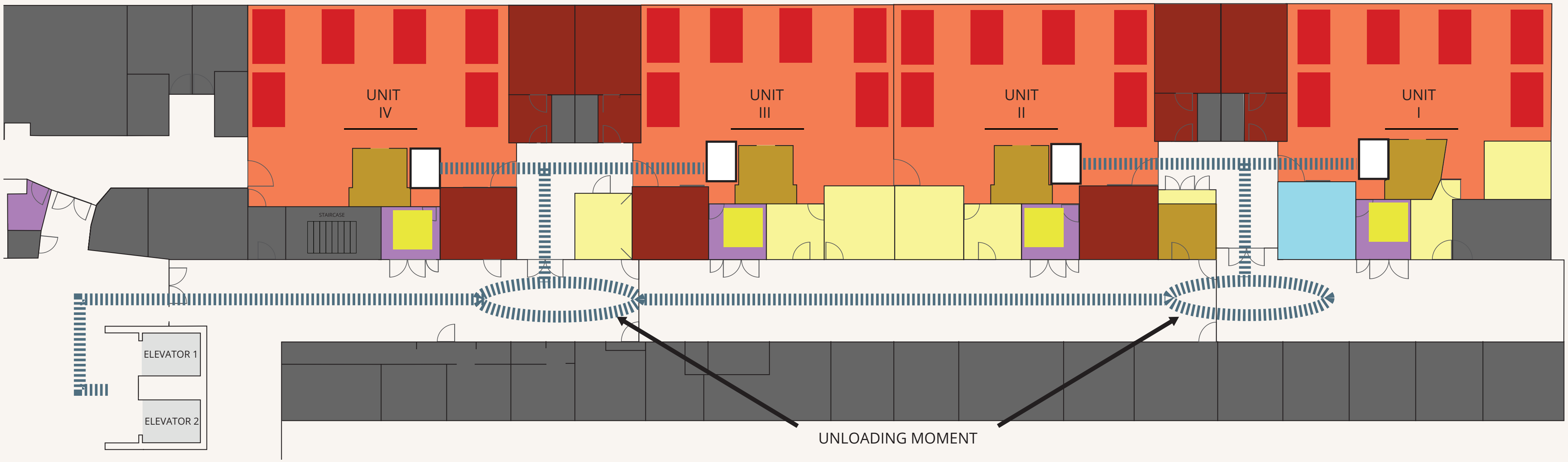
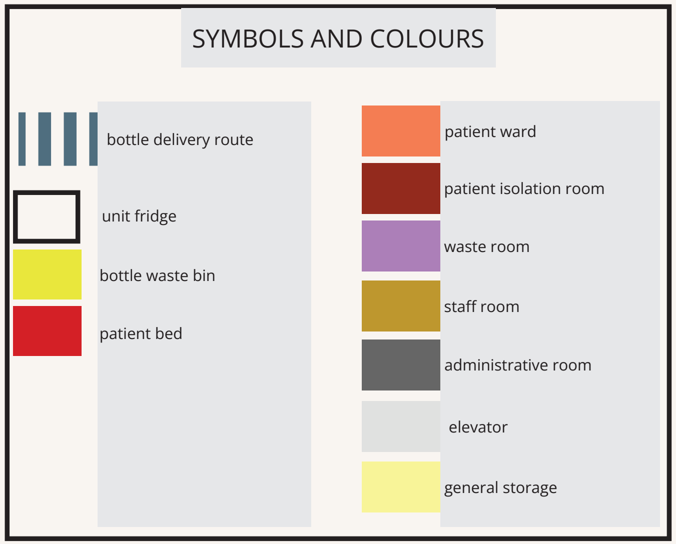


Figure 5.22 - Floor plan of the PICU, with relevant elements to the delivery phase marked



Delivery to the PICU

The delivery phase is distributed over the entire hospital, starting at the preparation kitchen and ending at each specific intensive care unit. The floor plan in Figure 5.22 shows relevant elements to the delivery phase.

The paediatric care wing is located on the third floor of the Sophia Children's Hospital, and the transportation of the insulated trolley requires the use of the elevators to reach it. A central hallway runs the length of the entire wing.

The overall wing is divided into four units: IV, III, II, and I. Units IV and III, as well as units II and I, are connected by the same entrance. Each unit has its own fridge as well as an associated waste room.

Subphase 2: Movement

Feeding assistants move the trolley through various corridors and elevators to reach their assigned unit, this is shown in Figure 5.23. Due to the layout of the wing, where each two intensive care units share a main entrance to the wing, shown in Figure 5.24, the trolley and assistant will make two stops.

Figure 5.23 - The insulated trolley is moved through the corridors of the hospital

Figure 5.24 - Two intensive care units share a main entrance to the wing

Subphase 3: Unloading

The feeding assistant makes two stops in the PICU corridor, near either units IV and III or units II and I, where they will unload the trolley to proceed to the unit fridge. The feeding assistant will fill the fridge with the prepared new bottles, shown in Figure 5.25.

Sometimes patients will have left the wing, while their feeding order has still been prepared. These prepared bottles can no longer be used and are emptied and disposed of. This can include entire batches of bottles at the same time, as shown in Figure 5.26.

Patients may also have left the ward earlier than expected or have had some difficulty during the feeding moment, which means that not all previously delivered bottles have been used. These unused bottles are also discarded as waste.

Figure 5.25 - A feeding assistant delivers feeding bottles to a unit fridge

Figure 5.26 - Entire batches of prepared bottles might need to be discarded

5.4.4 Use Phase

This phase covers the use stage of a feeding bottle. After being delivered to the PICU by a feeding assistant, the bottles are used to feed a patient. Bottles are stored in the unit fridge and are heated prior to feeding. In most cases, bottles are connected to an enteral feeding set, which delivers the container formula milk to a patient. Only rarely is the bottle used with a feeding teat to directly feed a patient. As shown in Figure 5.27, this phase can be divided into three subphases: retrieving, heating and feeding.

Subphase 1: Retrieving

Each patient in the PICU has an assigned nursing staff member, who is responsible for the various feeding moments that a patient might have. Depending on the age, medical condition and established dietary plan, a patient might have a feeding moment up to every two hours. Feeding bottles are stored in fridges located in each ward. A fridge of this type is shown in Figure 5.28. Feeding bottles may be stored in carrying racks, as shown in Figure 5.29, or loosely, depending on the type of bottle.

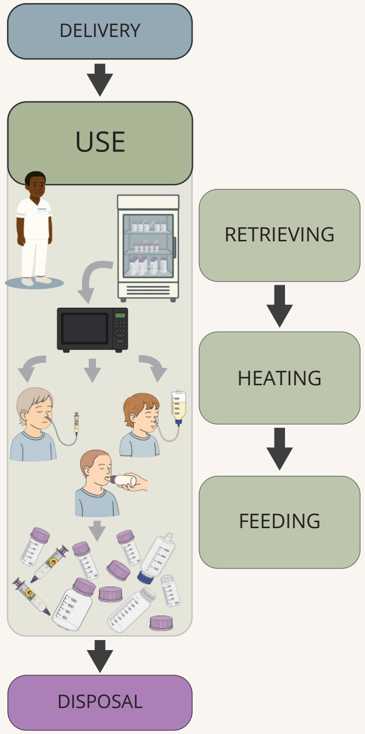


Figure 5.27 - The use stage, with its relation to other stages and its constituent subphases

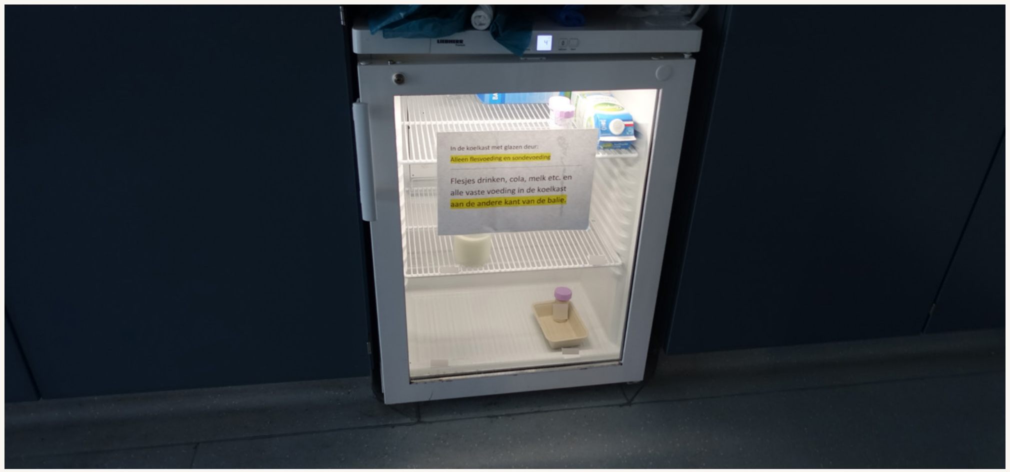


Figure 5.28 - A specific fridge for feeding bottles is present on each unit

Figure 5.29 - Bottles stored in carrying racks in the unit fridge

Subphase 2: Heating

Before being used to feed a patient, the formula milk contained in the feeding bottle is heated in a microwave, as shown in Figure 5.30. The unit fridge normally keeps the milk at 5 °C. Due to the microwave not providing an accurate temperature, the paediatric nurse must thoroughly mix the bottle before feeding to eliminate hot or cold spots and reduce the risk of giving overheated milk to the patient.

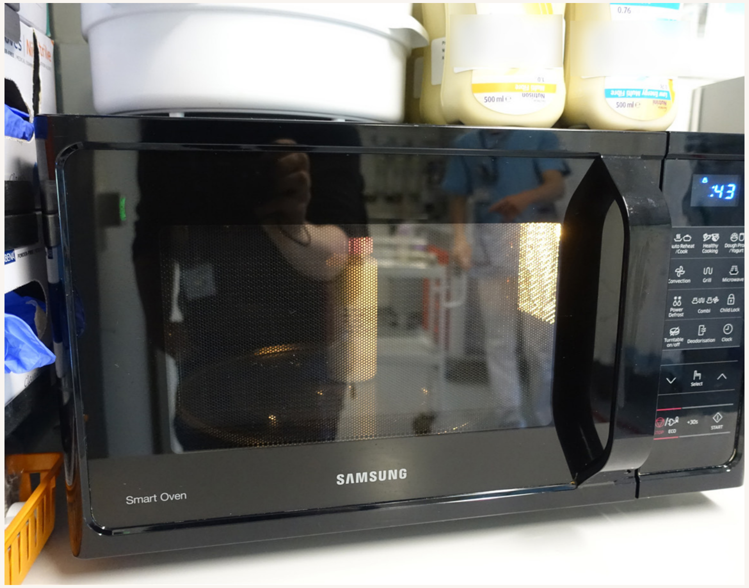


Figure 5.30 - Bottles are heated in a microwave

Subphase 3: Feeding

Depending on the patient, feeding is done either orally, by attaching a disposable drinking teat to the bottle, or enterally with a feeding set, as shown in Figure 5.31. It has been identified that more than 80% of patients are fed enterally. The entire volume of a bottle can be delivered to a patient and distributed over a period of time by the feeding set.

The frequent use of these additional products to which the feeding bottle is attached or where the bottle is only used as a vessel to withdraw milk from means that the bottle is rarely used as a bottle itself. Direct bottle feeding done either by a nurse or by the patient caregiver, such as a parent, is thus the minority of all cases.

In some cases, only a small amount of the milk from a feeding bottle is given to a patient. In this case, a disposable syringe is used to draw up a volume of milk, and this syringe is connected to the enteral feeding set. This syringe is another disposable product used during the feeding process, and its use is shown in Figure 5.32.

Figure 5.31 - An enteral feeding set is used to feed patients

Figure 5.32 - Disposable syringes can be used to deliver formula milk

5.4.5 Disposal Phase

This phase covers the disposal stage of a feeding bottle. Both feeding assistants and nursing staff dispose of bottles in various states and at different times. Depending on the disposal location, either by feeding assistants, who dispose of bottles during the delivery process, or nursing staff, who dispose of bottles after they have been used during the feeding of a patient, bottles enter different waste streams. As shown in Figure 5.33, this section can be divided into four subphases: pre-disposal handling, unit waste, wing waste and general waste.

Subphase 1: Pre-Disposal Handling

Feeding assistant disposes of bottles during the delivery process which were unneeded or bottles which have remained unused during an entire day. Entire batches of prepared bottles are often discarded due to this. The bottle might be emptied or rinsed in a sink, shown in Figure 5.34, and is disposed of both with and without the attached cap, as shown in Figure 5.35. A sticker is present on all feeding bottles, which contains information on the content, but also confidential patient information. Due to this, this sticker should be removed before disposal, but this is often not the case.

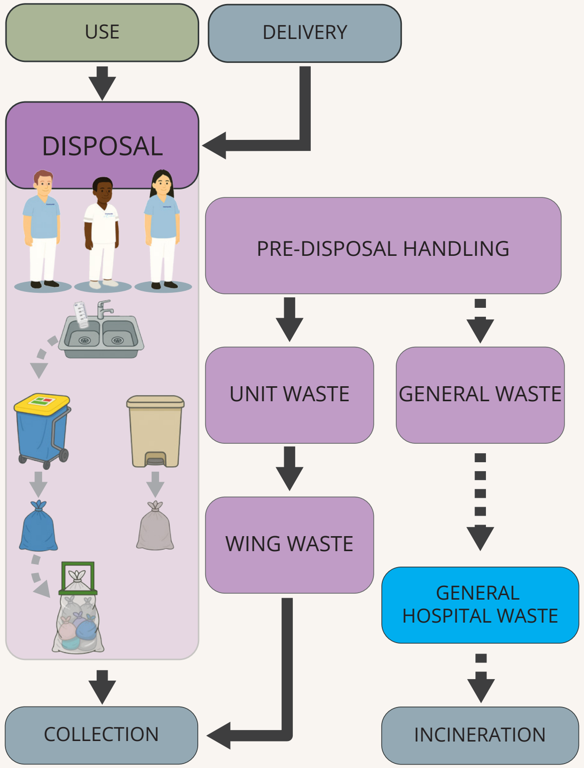


Figure 5.33 - The disposal stage, with its relation to other stages and its constituent subphases

Figure 5.34 - Bottles are emptied in the sink before disposal

Figure 5.35 - Bottles are found to be disposed of both with and without an attached cap

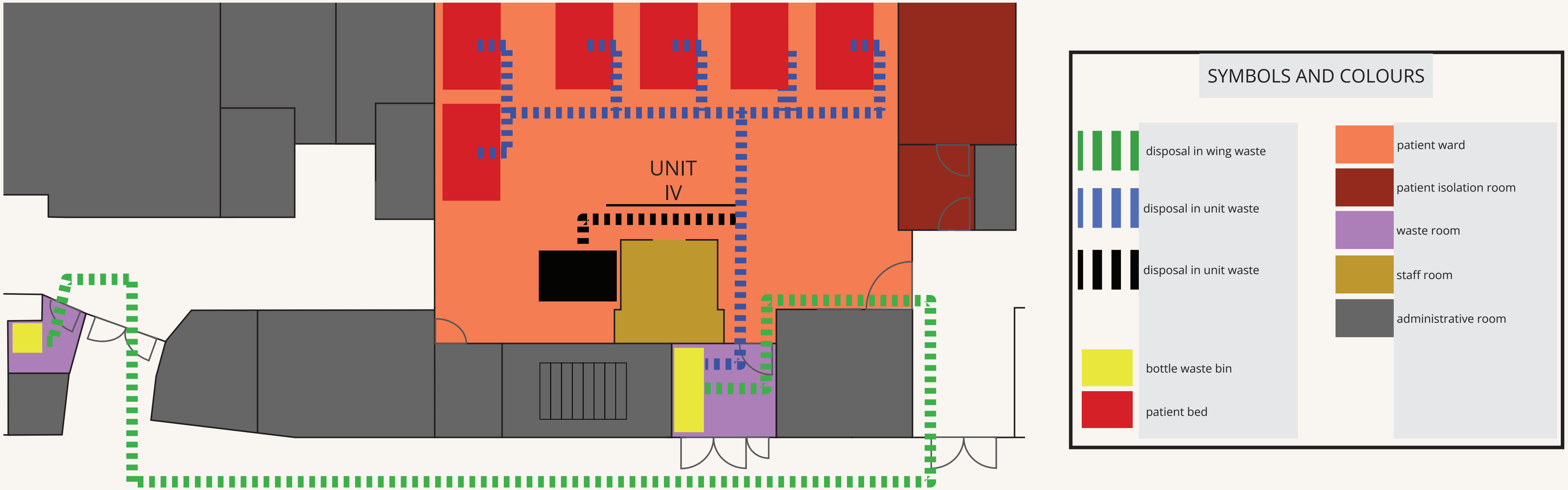


Figure 5.36 - Floor plan of Unit IV in the PICU, with relevant elements to the disposal phase marked

Disposal detail: Locations in the PICU

Disposal of feeding bottles happens in various locations of the PICU. The specific locations and travel paths for Unit IV are showcased in greater detail in the floor plan shown in Figure 5.36.

Feeding bottles used in isolation rooms are not discarded in the same waste stream as all other bottles. All materials entering an isolation room are treated as hazardous waste and are disposed of in specific waste bins. Due to this difference, this room is not investigated further in this project.

Subphase 2: Unit waste

Each care unit has an associated unit waste room, with a specific PD waste bin, shown in Figure 5.37. This is the designated location for PD waste and ensures the separation of recyclable plastics from other materials. Specific orange waste bags are prescribed to distinguish PD waste from other waste streams. However, this type of bag is frequently not used or even available.

Subphase 3: Wing waste

The PD waste bags from the unit waste room are collected daily and transferred to the unit waste bin, shown in Figure 5.38. Care assistants perform this collection and transfer. The wing waste bin allows for several days' worth of unit waste to be stored. This primary waste stream continues its movement through the hospital and to eventual recycling.

Alternate path: General waste

The PICU also contains several general waste bins, an example is shown in Figure 5.39, used for a variety of other waste items not requiring specific containers or procedures. Due to their central location compared to the unit waste room, which leads to a reduced amount of required time for disposal, feeding bottles are sometimes disposed of in these general bins. General waste bags are not transferred to the unit waste bin, instead being classified as non-specific hospital waste.

This secondary waste stream leaves the hospital and is incinerated (Zavin, 2025) due to Dutch guidelines on waste management of non-specific hospital waste.

Disposal detail: Waste bags

Seven types of bags have been observed in various uses throughout the PICU. The variety, shown in Figure 5.40, comes from the number of distinct waste bins requiring distinct bags. However, waste bags have been observed to be used interchangeably, either due to low supplies and accompanying time pressure or lack of awareness of the impact that different types of bags have to the resulting waste stream. Specific orange waste bags are prescribed to distinguish PD waste from other waste streams. However, this type of bag is frequently not used or even available.

Figure 5.37 - A unit waste bin

Figure 5.38 - The wing waste bin

Figure 5.39 - A general waste bin

Figure 5.40 - A selection of waste bags, without the prescribed PD waste bag

5.4.6 Collection Phase

This phase covers the collection stage of a feeding bottle. After bottles are disposed of by either feeding assistants or nursing staff, the waste bags are collected by logistics staff and moved to the Erasmus MC main waste management location. When disposed of by either feeding assistants or paediatric nurses in the designated PD waste bins, the bottles are separated from other waste materials and can potentially be recycled. As shown in Figure 5.41, this section can be divided into three subphases: retrieving, transporting and compacting.

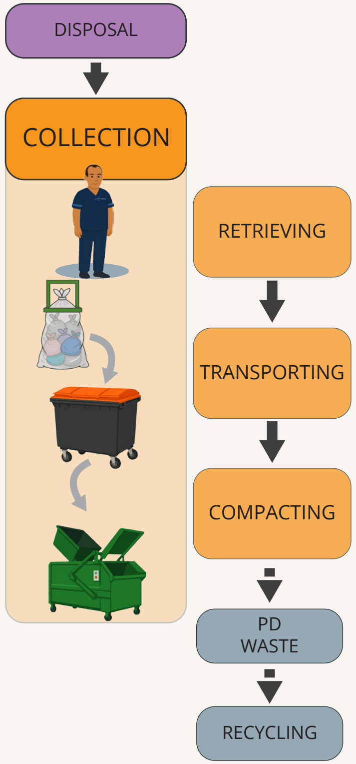


Figure 5.41 - The collection stage, with its relation to other stages and its constituent subphases

Subphase 1: Retrieving

Feeding bottles that have been disposed of in the PD waste bags and subsequently moved to the unit waste room are collected twice a week and transported to the waste handling facility of the EMC. The Sophia Children's Hospital has a waste room where all PD waste bags from the different floors of the hospital are stored, shown in Figure 5.42, before being transported by facility workers to the Erasmus MC main waste management location. An expanded outline of the waste management location, as well as its connection to the Sophia Children's Hospital can be found in Appendix B.

Figure 5.42 - The waste room of the Sophia Children's Hospital

Subphase 2: Transporting

Due to the size and weight of the waste wing bag, which contains bags from all four units over several days, facility workers are unable to carry the bag to subsequent locations. Instead, a container, shown in Figure 5.43, is brought from the Sophia Children's Hospital waste room to the wing waste room using the nearby elevators. The wing waste bag for each floor is lifted over, and a new empty wing bag is installed. Facility workers move the container from the waste room to the EMC waste management location using a drivable towing vehicle.

Subphase 3: Compacting

As the final step before feeding bottles leave the hospital, the comparatively loosely filled waste bags are compacted into a more space-efficient and dense format. This is done with the use of a waste compactor, shown in Figure 5.44. PreZero collects containers filled with the compacted PD waste and transports them to a facility for separation and recycling.

Figure 5.43 - A waste container holds the waste bags gathered from the entire hospital

Figure 5.44 - A drivable towing vehicle transports the waste container

5.5 Key points chapter 5

This chapter maps the journey of disposable feeding bottles across six phases. Kitchen staff, feeding assistants, nurses, and facility workers all contribute at specific moments in this mostly linear process. The resulting map, shown in Figure 5.45, is a clear baseline of the current process, showcasing the various main moments of the disposable bottle feeding process.

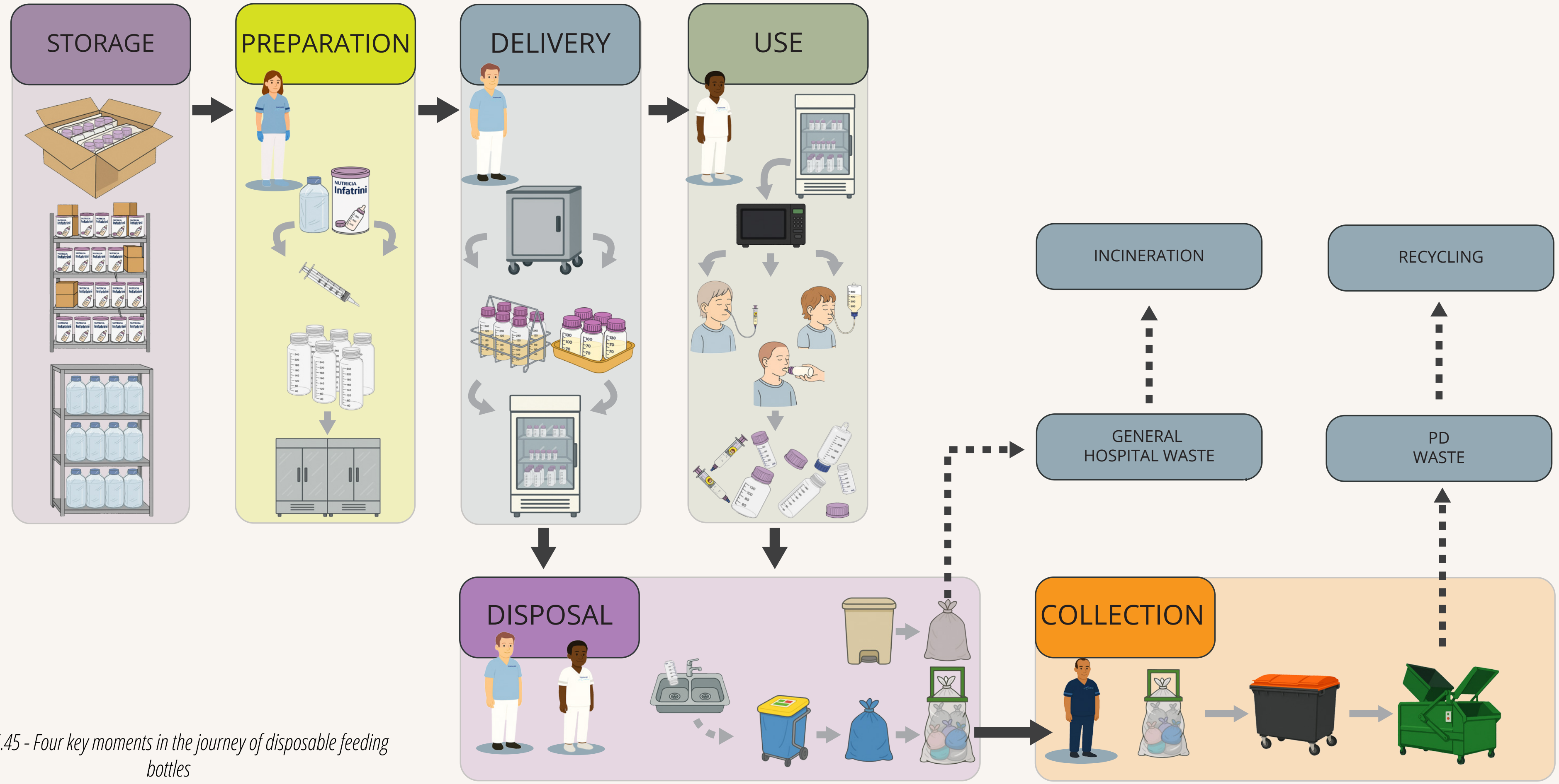


Figure 5.45 - Four key moments in the journey of disposable feeding bottles

Key points chapter 5

In Figure 5.46, key moments of the preparation, delivery, use and disposal phases are shown.

From the *storage phase,* disposable feeding bottles, formula powder, and sterile water are materials used in the subsequent phases.

In the *preparation phase*, kitchen staff manually weigh and mix formula powder with sterile water, dispense formula milk by syringe and finally cap and label feeding bottles. Daily orders dictate the number of feeding bottles that are prepared.

During the *delivery phase*, feeding assistants transport bottles from the kitchen to the ICU in an insulated trolley. The carrying trays only fit one of the four types of bottles. Due to changes that occur between orders placed and bottles being delivered, entire batches of prepared bottles are frequently discarded.

In the *use phase*, paediatric nurses feed patients with the contents of feeding bottles. In 80% of cases, bottles are not used to directly feed a patient but rather as a reservoir for an enteral feeding set.

The *disposal phase* contains the discarding of feeding bottles. The intended unit waste bin separates the plastic feeding bottles from other materials. Bottles are also frequently disposed of in general waste, which results in incineration. The patient label on each bottle is not consistently removed before disposal.

The *collection phase* is the final step, where waste bags with feeding bottles are collected and transported to the Erasmus MC waste management location. These waste bags are compacted and finally leave the hospital for external processing.

Figure 5.46 - The six phases of the disposable feeding bottle process

6. Waste Audit

Chapter Content

This chapter presents the results of the waste audit performed on the waste stream leaving the paediatric intensive care unit of the Erasmus MC Sophia Children's Hospital.

The results provide insight into the quantity and mass of disposed feeding bottles, from which the annual mass of discarded feeding bottles is extrapolated. These findings are supplemented by an analysis of the necessary sterile water jugs, which have an outsized contribution to the overall mass.

In addition, the discrepancy between the loose and screwed on caps, as well as findings on non-bottle waste, is presented.

These findings complement the findings from the investigation of the bottle feeding process in determining hotspots impacting the sustainability of bottle feeding at the Erasmus MC.

6.1 The feeding bottle waste stream

Feeding bottles are frequently disposed of in Sophia Children's Hospital's four paediatric intensive care units. This waste flow is investigated to determine the specific amount of disposed bottles and thus quantify the environmental footprint of disposable feeding bottles in average use. This contributes to defining the hotspots impacting the sustainability of the current feeding process.

Primary and secondary waste streams

The waste flow has been identified as consisting of a primary waste stream and a secondary waste stream. The primary waste stream separates the plastic feeding bottles into a specific stream, ending with compacting and shipment from the EMC to a specialised location for incineration. The secondary stream contributes to the general waste stream and moves from the EMC to a more general waste management location.

The investigation consists of a combined waste audit, merging the results of three separate audits that have examined the primary waste stream over several days. Three collection windows and three measurement moments were performed.

Due to limitations in project resources, the secondary waste stream was not investigated during this audit. An overview of the audit structure is given in Figure 6.1.

Collection window

Each collection window covers three weekdays, with waste collected from Tuesday afternoons to Friday morning. The distribution of these collection windows is shown in Figure 6.2. Each PICU generates and disposes of its waste in its associated waste bin. The waste bags from each separate unit waste bin are regularly collected and collectively disposed of in a plastic waste bin serving the entire wing. This wing bin was analysed during each measurement window.

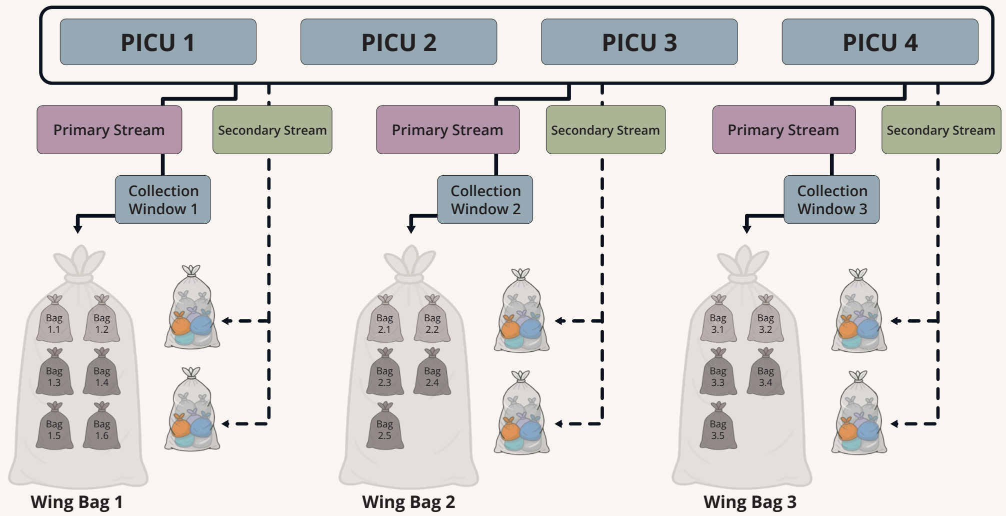


Figure 6.1 - Process of PICU waste disposal linked to waste audit

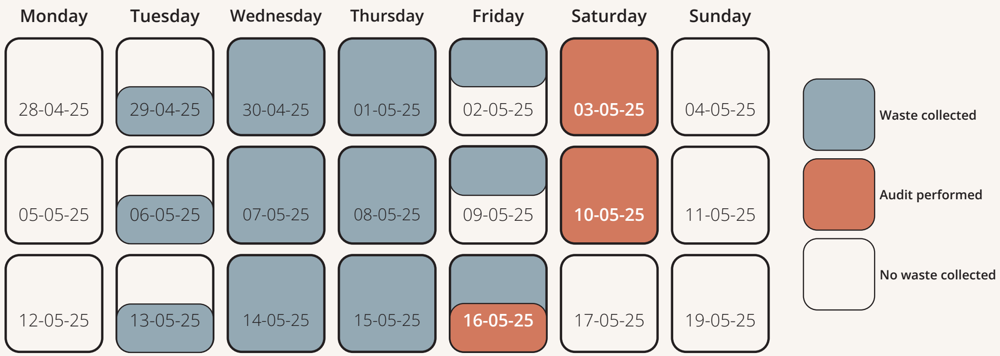


Figure 6.2 - Calendar overview of waste audit collection windows and measurement moments

Traceability

Due to a lack of traceability present on any of the items investigated in the waste audit, it is impossible to determine from which specific unit or during which time of the collection window a specific item originates.

Measurements

Each measurement moment involved identifying, categorising, and counting every item found in each waste bag. This was performed manually to ensure accuracy, with reference photographs taken to cross-check the count. An example of the categorisation can be seen in Figure 6.3. A complete overview of all the audited waste bags can be found in *Appendix C*.

The collection of garbage over several days reduces the influence of a single potential outlying day or event and increases the reliability of the overall information.

Figure 6.3 - Example of a counted and categorised waste bag

6.2 Waste items types

Specific items were counted in the waste audit, shown in Figure 6.4. These consisted of the four types of feeding bottles as well as the two types of associated caps. Bottles are distinguished between a capped and an uncapped state. Caps are distinguished between capped, as attached to a bottle, or uncapped if found loosely in the waste bag. The small, medium, and large bottles all have the same cap, but the extra-large bottle has a distinctly different cap, both in appearance and weight.

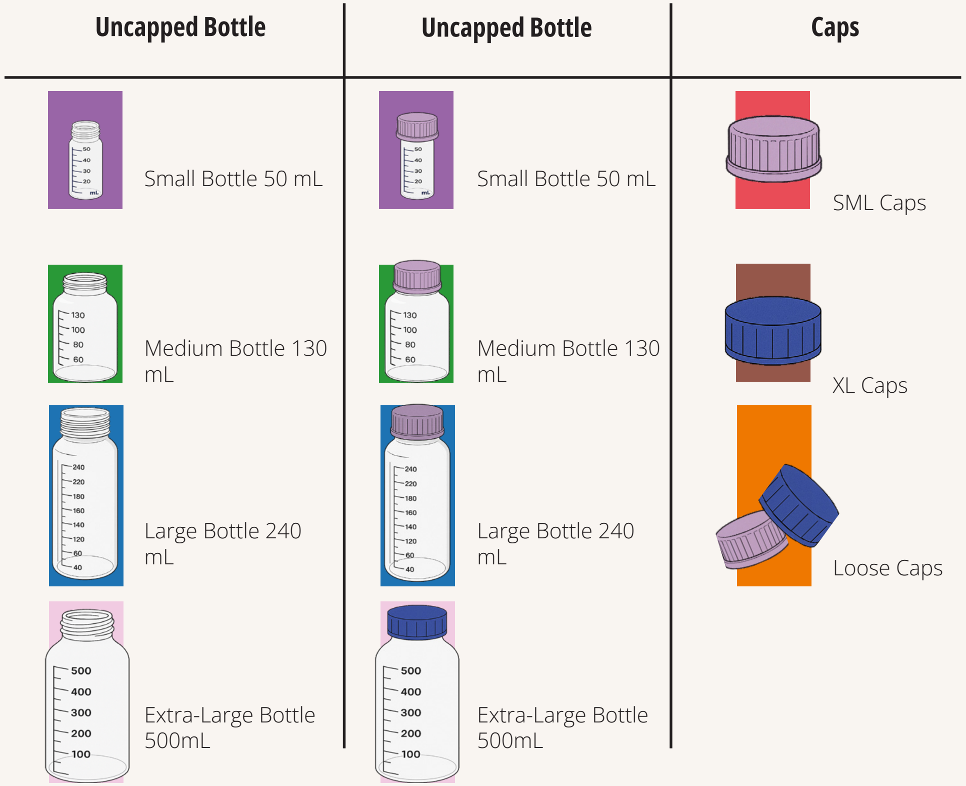


Figure 6.4. The specific waste items counted during the waste audit

6.3 Waste item states

The various bottles were also categorised based on the amount of formula milk they were still filled with. Due to the nature of the waste items, it is not possible to determine if the formula milk was used in patient feeding or disposed of in another manner, such as being poured down a sink.

Additionally, the initially filled volume cannot reliably be identified for each bottle. The initial volume was identified with either attached information labels or residue lines. Some bottles had removed labels or unclear residue lines, making identification impossible. Thus, each category, as shown in Table 6.1, represents the minimum number of bottles matching these criteria.

Empty

This category constitutes all bottles that were not found to have any formula milk. This is considered the default state.

Full

This category constitutes all bottles that were found to still hold all the formula milk, according to the attached information label. This allows for determining the number of bottles which were disposed of without any formula milk used to feed a patient.

Filled

This category constitutes all bottles that were found to still hold some of the formula milk, according to the attached information label. This allows for determining the number of bottles which were disposed of without all the formula milk being used to feed a patient yet the remaining milk was not disposed of.

Underfilled

This category constitutes all bottles that were found to still hold some of the formula milk, according to the attached information label. This allows for determining the number of bottles used for a volume of milk for which a smaller bottle could have been used. The possibilities of this category are shown in Table 6.1.

This category consists of bottles filled with *less than 50 mL* or filled with l*ess than 130 mL.*

Small bottles cannot be *filled less than 50 mL* due to no smaller bottle being available. This bottle cannot be *filled less than 130 mL* due to its volume.

Medium bottles that are *filled less than 130 mL* are not counted. Subtracting the number of medium bottles that are *filled less than 50 mL* from the total number of this bottle type provides this number.

Bottle State	Full milk	Underfilled <50 mL	Underfilled <130 mL
Small Bottle 50 mL	Possible	Not relevant	Not possible
Medium Bottle 130 mL	Possible	Possible	Not Counted
Large Bottle 240 mL	Possible	Possible	Possible
XLarge Bottle 500mL	Possible	Possible	Possible

Table 6.1 - Possible underfilled bottle states

6.4 Total quantity of items

The combined waste audit counted a total number of 1330 discarded feeding bottles and caps, shown in relation to each other in Figure 6.5.

A total of 257 small bottles, 95 medium bottles, 279 large bottles, and 30 extra-large bottles were counted for a total of 661 bottles. Additionally, 567 caps were attached to small, medium, or large bottles, 28 caps to extra-large bottles, and 74 caps were loose in the waste bags, for a total of 661 caps.

Percentual distribution of waste items

The percentage distribution shows that 49.7% of the counted items are various bottles, while 50.3% are the two types of caps. Large bottles are most frequently used, with 42.2% of the total bottles, seen in Figure 6.6. Small bottles follow second with 38.9% of the total. Both extra-large and medium bottles trail, even combined, do not match the quantity of other bottle types, as shown in Figure 6.7.

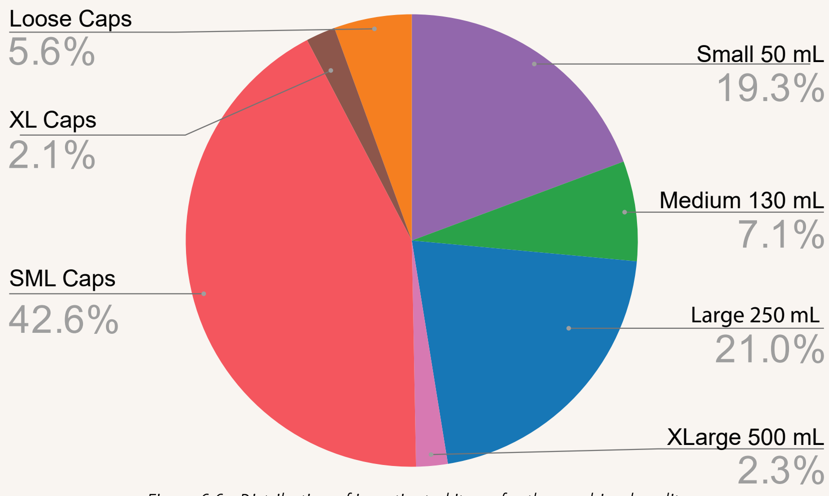


Figure 6.6 - Distribution of investigated items for the combined audit

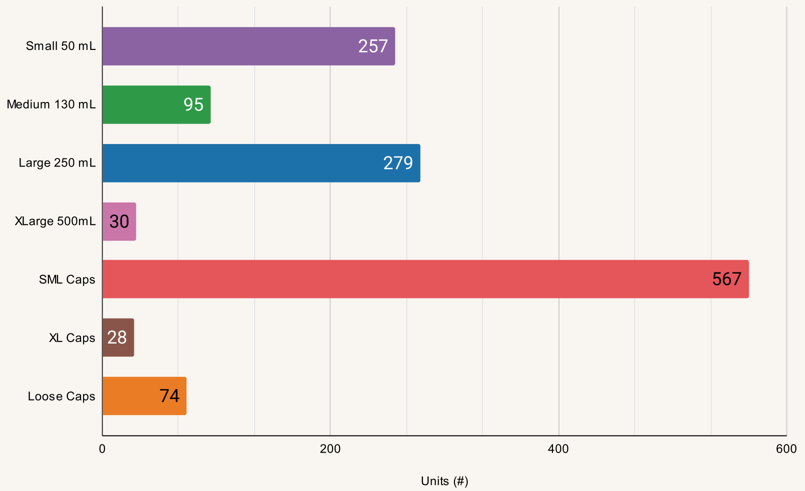


Figure 6.5 - Total amount of each item category counted in the waste audit

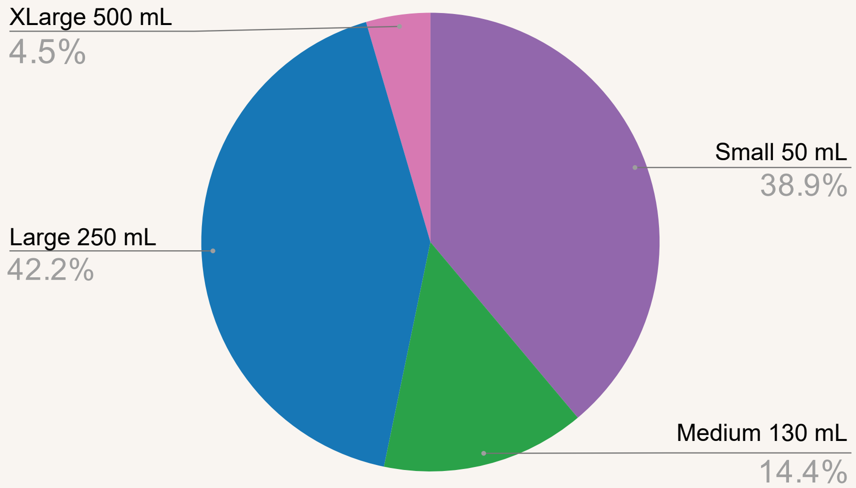


Figure 6.7 - Narrowed distribution of bottles

6.5 Distribution of mass between items

The combined waste audit counted the number of discarded feeding bottles and caps, totalling 1330 items. Applying the weighed mass of each item category, this results in 2197.35 grams of small bottles, 1406 grams of medium bottles, 6179.85 grams of large bottles, and 1030.5 grams of extra-large bottles. The weight is increased by 2426.76 caps attached to small, medium, or large bottles, 136.64 caps attached to extra-large bottles, and 316.72 grams of loose caps. This is shown in Figure 6.8.

This results in 10813.7 grams, or 10.80 kilograms, of bottles and 2880.12 grams, or 2.88 kilograms, of caps, or 13693.82 grams, or 13.69 kilograms, of total feeding bottle waste. The percentual distribution of weight for each item category counted in the waste audit is shown in Figure 6.9, while Figure 6.10 shows the percentual distribution of weight when only bottles are considered.

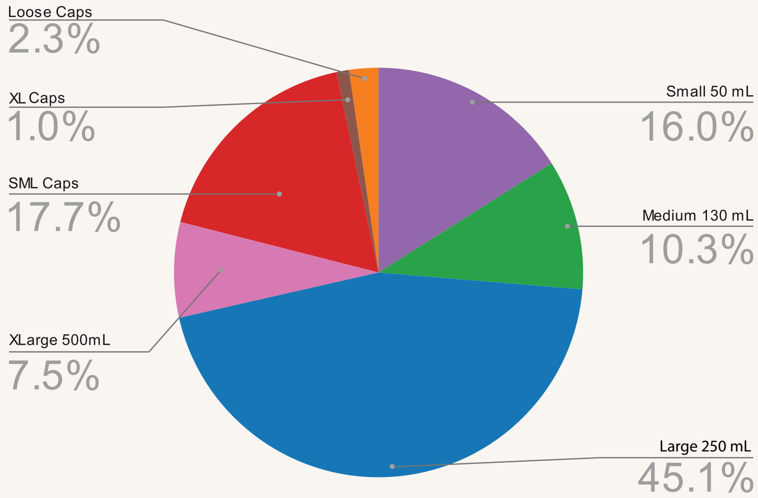


Figure 6.9 - Distribution of weight for each item category counted in the waste audit

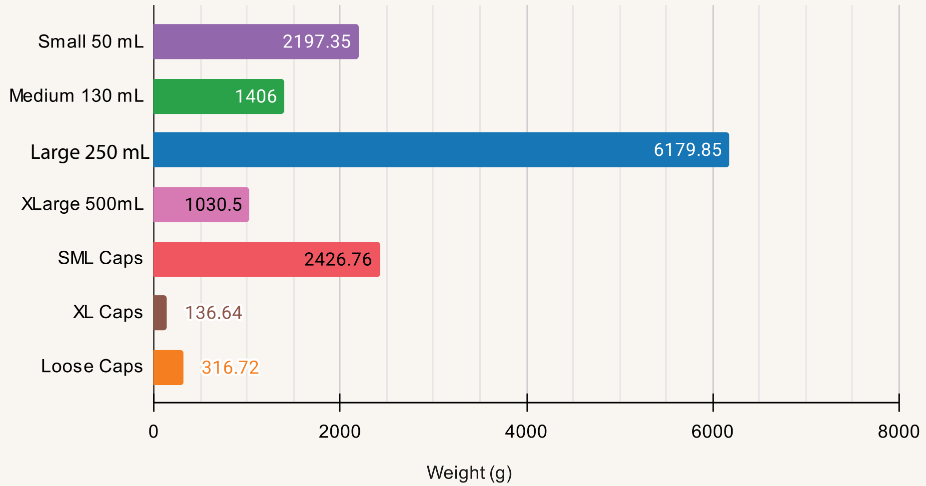


Figure 6.8 - Total weight of each item category counted in the waste audit

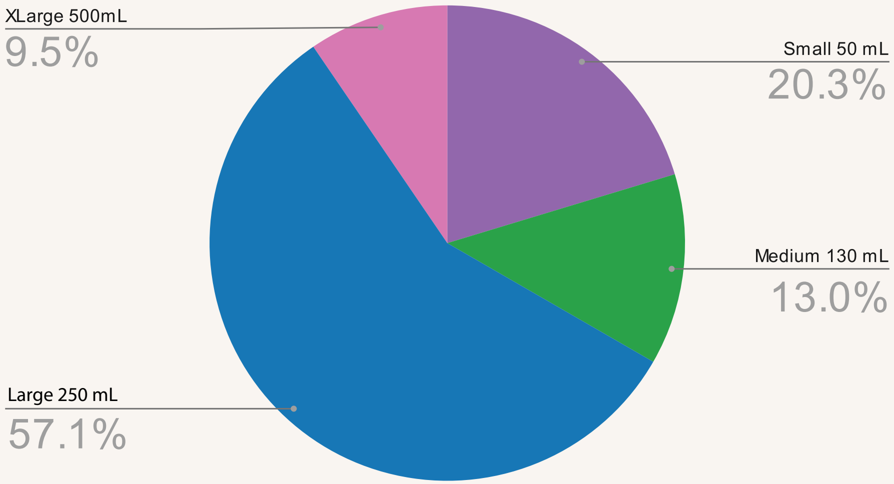


Figure 6.10 - Distribution of weight for bottles counted in the waste audit

6.6 Comparison of item mass to item quantity

Figure 6.11 shows that large bottles form the majority of the contributing counted mass, both when looking at total items and compared directly to other bottles.

Figure 6.12 shows that while caps are roughly equal in quantity to bottles, they contribute 21.0% of the total weight.

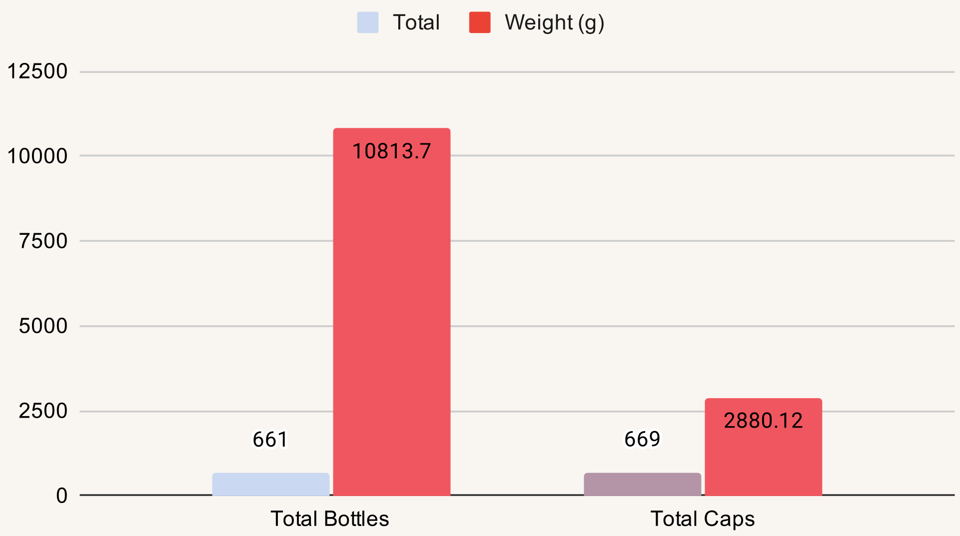


Figure 6.11 - Unit quantity of bottles and caps compared to their weight

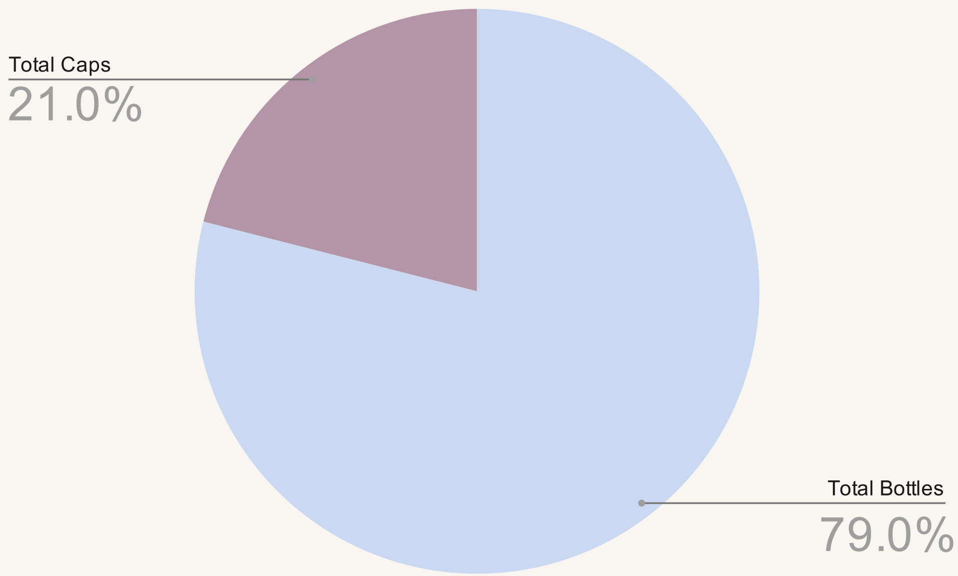


Figure 6.12 - Weight of all caps percentually compared to all bottles counted in the waste audit

6.7 Extrapolation of daily and annual disposal of feeding bottles

Considering the nine waste collection days, it is possible to make an estimate of daily feeding bottle use. Based on this daily number, a further extrapolation to the annual amount of feeding bottles disposed of in the PICU can be made. It is important to note that this extrapolation cannot account for many external factors, which might influence the amount of disposed bottles. Factors such as variation in length of patient stay, errors in preparation of feeding bottles, changes in patients' diet, distribution of patient ages, and disposal practices all impact the amount of disposed feeding bottles. However, the annual extrapolation still provides a valuable baseline against which any reduction in the mass of disposed feeding bottles can be measured.

The daily amount of disposed feeding bottles is calculated as 1/9th of all counted items, and the annual amount is extrapolated based on the resulting amounts.

Annual disposal by mass

As the waste audit determined 13.69 kilograms of total feeding bottle waste over nine days, this yields 1.52 kilograms of feeding bottles disposed of by the PICU daily. This is extrapolated to 555.36 kilograms or more than half a tonne of feeding bottles every year. It should be stressed that while PICU waste is the subject of this waste audit, it is not the only department in the Sophia Children's Hospital where feeding bottles are disposed.

Disposal by quantity

The waste audit determined that 661 feeding bottles were disposed of over nine days, which would mean an average of 73.4 feeding bottles were disposed of in the PICU daily. Extrapolating this to an annual figure supplies that of 26,807 feeding bottles disposed of from the PICU.

6.8 Required sterile water jugs based on the annual disposal of feeding bottles

The mixing of formula milk is currently done with sterile water, delivered in 1-litre water jugs. A single jug has a mass of 167 grams. Based on the distribution of the four types of feeding bottles in the audit findings, an average bottle can be defined. This bottle has a mass of 21 grams and a volume of 162 mL.

Therefore, approximately 6.2 average feeding bottles can be filled with the content of a single sterile water jug, resulting in an additional 27 grams of plastic mass associated with each disposed feeding bottle. The annual disposal of 555.36 kilograms in feeding bottles is supplemented with 725.8 kilograms of disposed sterile water jugs. Thus, as shown in Figure 6.13, sterile water jugs add roughly 1.3 times as much material mass as feeding bottles themselves.

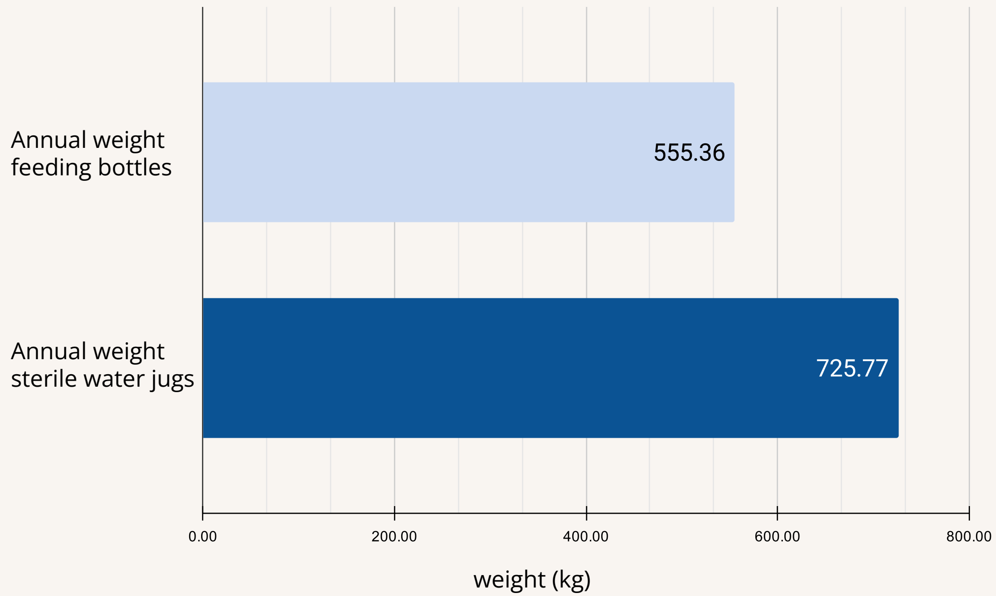


Figure 6.13 - Extrapolated annual weight of disposed feeding bottles and required water jugs for PICU, based on waste audit findings

6.9 Discrepancy in bottle caps

The waste material flow from the PICU is entirely linear. However, several items change from their original pre-disposal state. One of the main changes is that feeding bottles are losing their associated caps. This is seen not only in the consistent amount of bottles of various sizes found without attached caps but also in an inconsistency between the number of bottles without caps and the number of loose caps.

The diagram in Figure 6.14 shows the change occurring to each accounted item in the audit to its eventual end state.

A total of 661 caps were counted. 567 caps were attached to small, medium, or large bottles, 28 caps to extra-large bottles, and 74 caps were loose in the waste bags. A total of 70 uncapped bottles were counted. This combines for a total of 669 caps. Thus, as shown in Figure 6.15, four more loose caps were found than uncapped bottles.

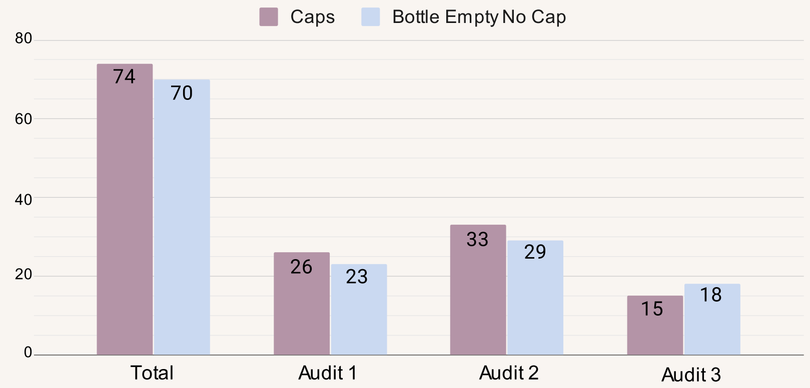


Figure 6.15 - Discrepancy of loose caps compared to uncapped bottles in combined audit and separate audit measurement moments

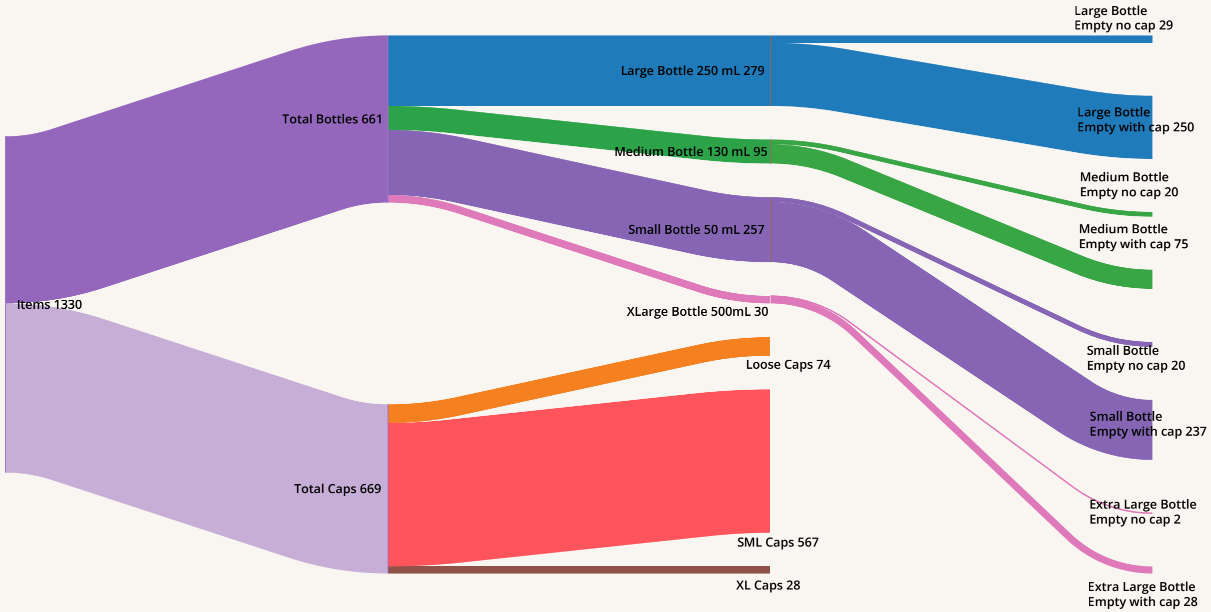


Figure 6.14 - Changes of items from their original state

6.10 Supplemental findings

While the waste audit investigated the specific amount of disposed bottles to quantify the environmental footprint of disposable feeding bottles, several other noteworthy findings were made. In particular, it was found that items not belonging in the plastic stream, such as gloves, paper, cardboard, plaster, and metal components, were consistently found in the audited waste bags. Examples of these items are shown in Figure 6.18.

The total weight of non-bottle waste was 12.60 kilograms, which is 47.9% of the overall audited weight, shown in Figure 6.16. However, only 18.2% of all audited items are non-bottle waste as shown in Figure 6.17. Non-bottle waste thus constitutes a small numerical part of the overall waste, yet it contributes significantly to the overall disposed mass.

Further identification of the non-bottle waste has not been performed due to the scope of the audit and this project.

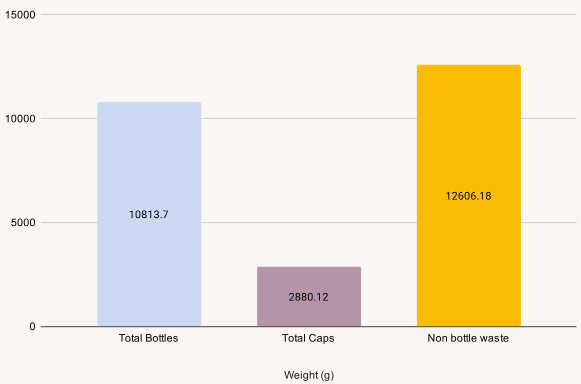


Figure 6.16 - Total weight of non-bottle waste compared to bottle waste

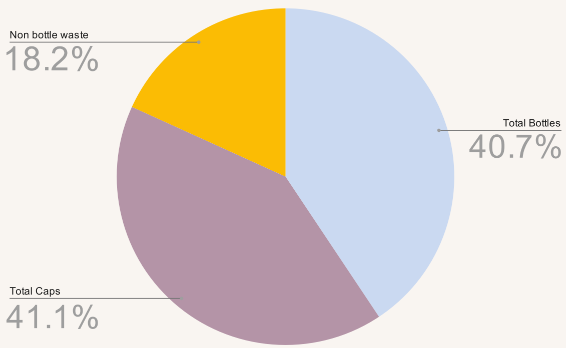


Figure 6.17- Total quantity of non-bottle waste compared to bottle and cap quantity

Figure 6.18 - Examples of non-bottle waste items

Milk remnants contribute to dirty bags

Even a single uncapped bottle or a bottle with a cap only loosely screwed on almost always leads to leakage of these drops into the waste bag. In an uncooled environment, such as a waste bin, the milk quickly spoils, creating an unpleasant smell and sticky residue. An example of encountered residue is shown in Figure 6.19.

Figure 6.19 - Example milk residue in disposed feeding bottles

Patient sticker on bottles

The labels containing confidential patient information were consistently found to still be attached to various bottles, shown in Figure 6.20.

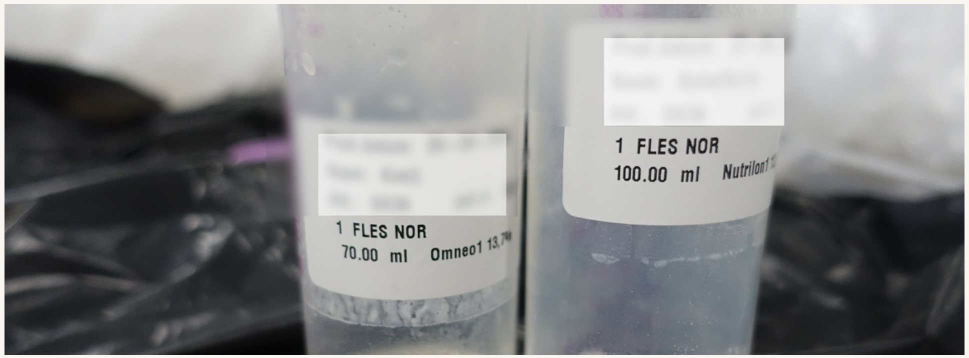


Figure 6.20 - Example of labels still attached to disposed bottles

Bags do not adhere to internal colour coding practices

According to internal Erasmus MC practices, PD waste is colour-coded as bright orange when applied to waste bins and the associated logistics infrastructure. During the audit, no orange bags were found to be used for feeding bottle waste, as shown in Figure 6.21.

Figure 6.21 - Left: audited waste bags, and on the right, PD colour-coded waste bags

6.11 Key points chapter 6

This chapter reports the results of a waste audit performed on waste bags from the PICU of the Erasmus MC Sophia Children's Hospital, with a focus on disposable feeding bottles. This audit was conducted across three collection windows and nine weekdays with manual counting and categorisation of a total of sixteen waste bags. In total, 1,330 items were counted, with 49.7% being bottles and 50.3% being caps for a total of 13.69 kilograms of polypropylene waste. As shown in Figure 6.22, 10.80 kilograms of feeding bottles was identified and 2.88 kilograms of screw caps. Thus, 21.0% of the total mass, consists of screw caps. Large bottles made up the greatest share, 42.2%, of total items.

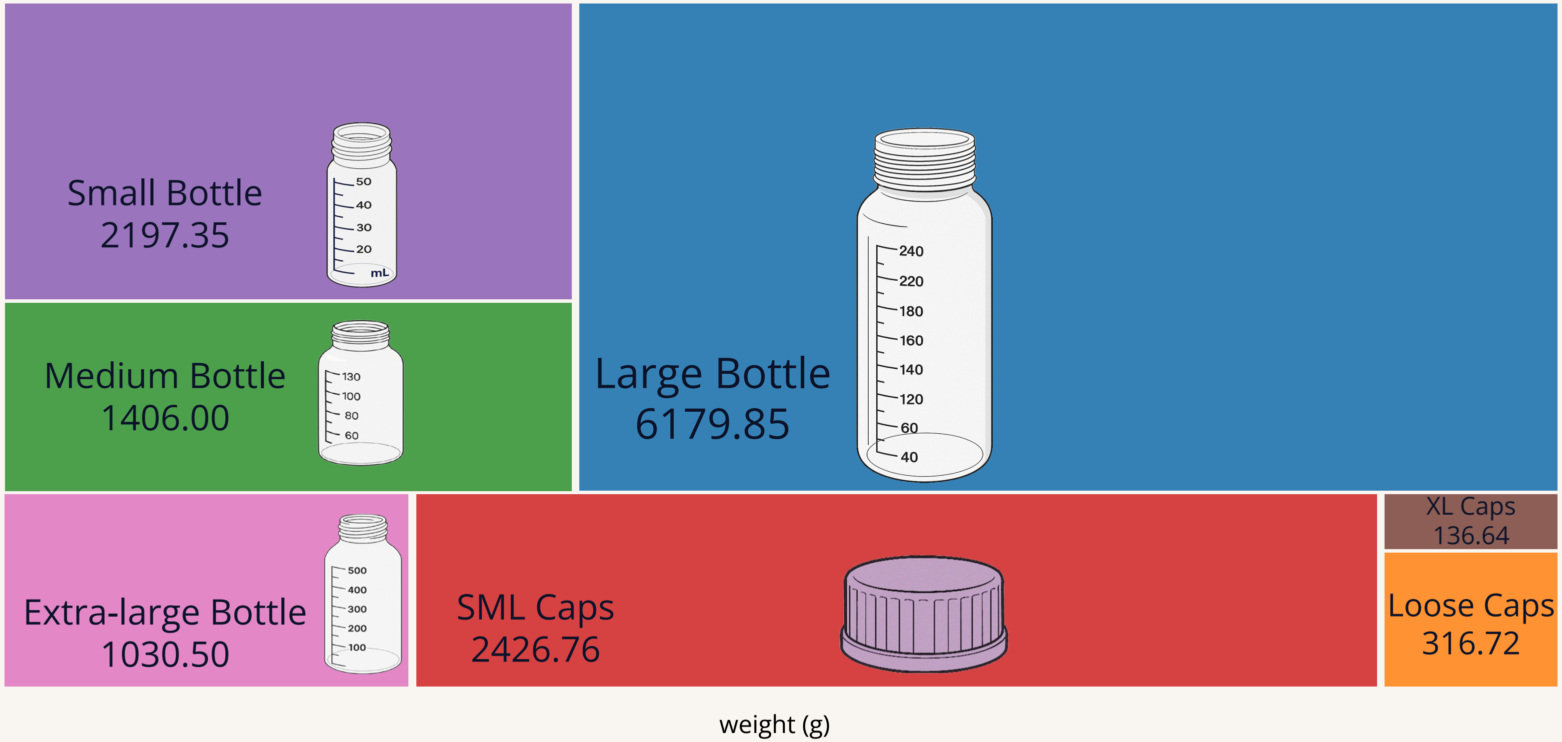


Figure 6.22 - Total weight of each item category counted in the waste audit

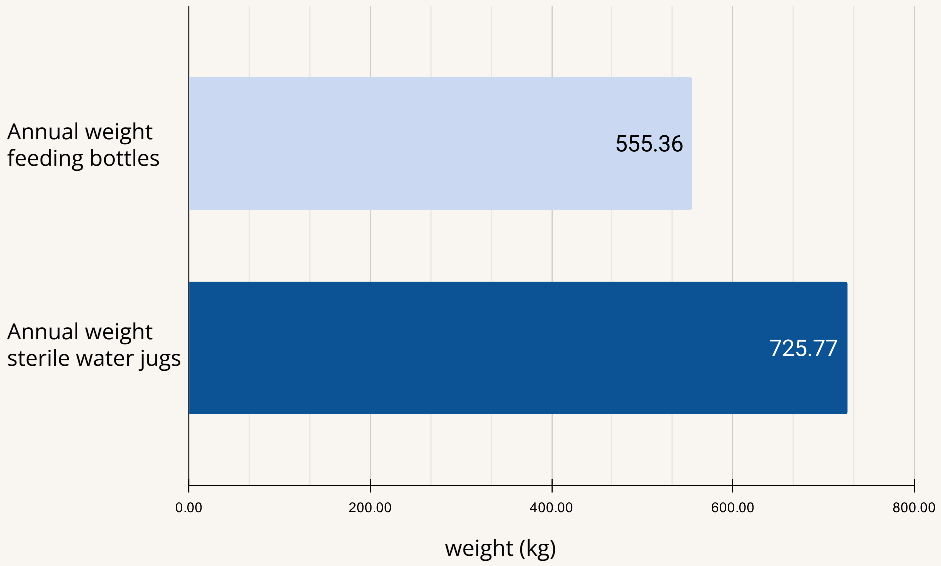


Figure 6.23 - Extrapolated annual weight of disposed feeding bottles and required water jugs for PICU, based on waste audit findings

Figure 6.24 - Examples of non-bottle waste identified in waste bags

Key points chapter 6

Annually, at least 555.36 kilograms of feeding bottles are estimated to be disposed of from the PICU. This is supplemented by at least 725.8 kilograms of disposed sterile water jugs, effectively more than doubling the overall disposed mass, as shown in Figure 6.23.

A discrepancy between the counted amount of uncapped bottles and caps exists. This suggests differences in staff disposal technique. Bottles were found not to be consistently emptied of milk, and also not rinsed before disposal. This results in uncapped bottles leaking milk residue, leading to dirty waste bags and odour development. Confidential patient labels were often found to still be attached to feeding bottles. None of the sixteen audited waste bags followed established internal colour coding.

Lastly, non-bottle materials were frequently present, shown in Figure 6.24, and contributed 47.9% of the audited mass, despite being only 18.2% of the items. This shows a considerable lack of effective separation, considering that many of the non-bottle materials are not plastic-based.

Traceability limits meant that items could not be linked to specific units or times, and only feeding bottles disposed of in the designated PD waste bins were audited. Together, these findings provide a quantitative as well as qualitative view of PICU feeding bottle waste, as well as quantifying the additional material mass disposed of in sterile water jugs

7. Identified hotspots

Chapter Content

This chapter builds upon the identified findings from both the current feeding process and the performed waste audit to identify sustainability hotspots in the use of disposable feeding bottles.

The ten identified hotspots are overlaid on the expanded journey map to show where impacts concentrate and how they propagate across storage, preparation, delivery, use, disposal, and collection.

7.1 Hotspots overlaid on the feeding process map

At Sophia Children's Hospital, disposable feeding bottles pass through multiple staff members and departments, from storage to eventual disposal as hospital waste, on a complex journey.

Based on the key insights from the process context and the waste audit, ten hotspots have been identified. These hotspots are overlaid on the feeding process map, as shown in Figure 7.1. Subsequent sections cover each of the ten identified hotspots in greater detail.

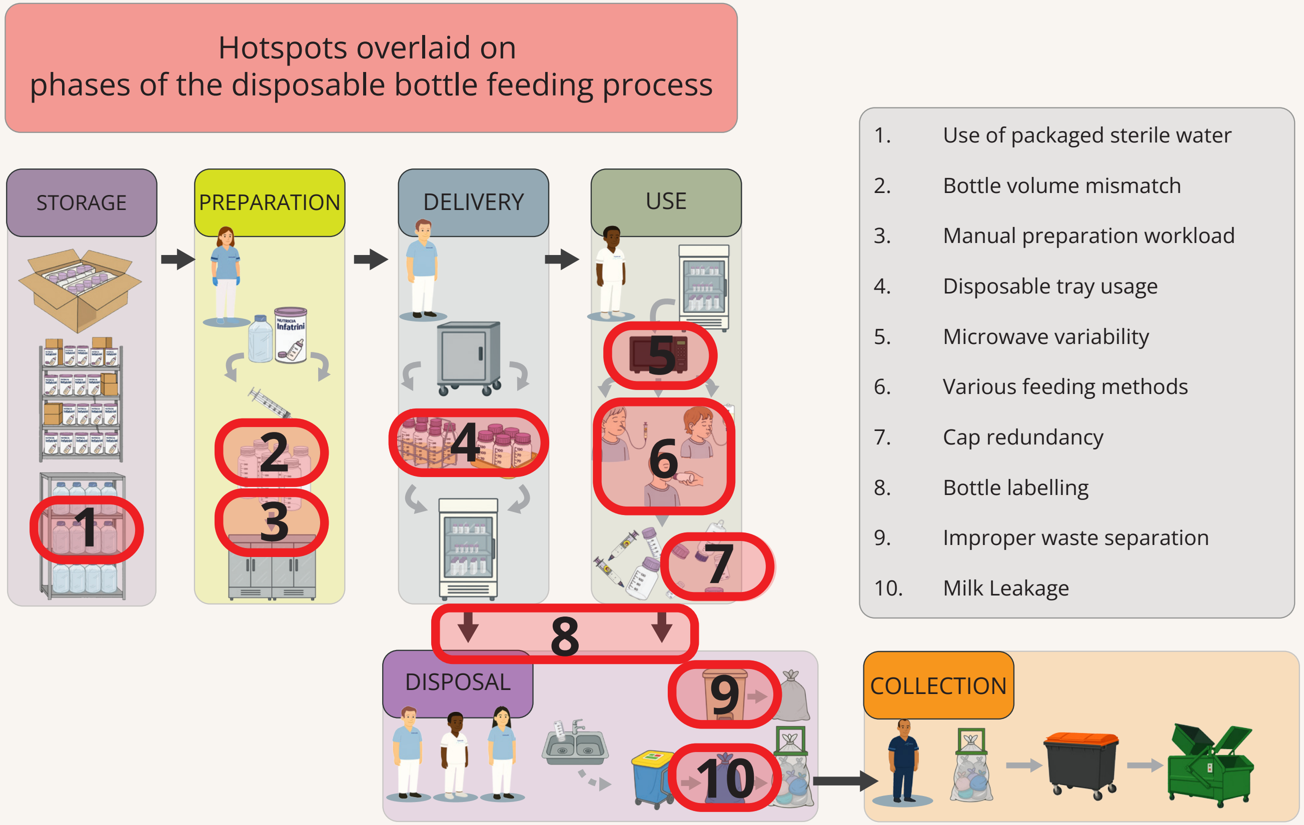


Figure 7.1 - Identified hotspots overlaid on the feeding process map

7.2 Hotspot 1: Use of packaged sterile water

The mixing of formula milk is currently prescribed in national Dutch guidelines to be done using either freshly boiled and cooled tap water or sterile water (Werkgroep Infectie Preventie [WIP], 2014a, 2014b). The Erasmus MC uses packaged sterile water stored in plastic jugs, shown in Figure 7.2. These plastic jugs are a considerable added use of resources.

Based on the waste audit findings, it is extrapolated that while annually 555.36 kilograms of feeding bottles are discarded from the PICU alone, this is supplemented with 725.8 kilograms of disposed sterile water jugs. In addition, the resources associated with transportation, as well as the sterilisation of water, should be accounted for.

Figure 7.2 - Sterile water stored in 1-litre jugs

7.3 Hotspot 2: Bottle volume mismatch

As shown in Figure 7.3, bottles with a potential volume of 250 mL have been found during the waste audit marked with less than half of their potential volume. This mismatch not only results in material waste generated by underfilled bottles but also increases the amount of staff handling, as well as increasing the chance of improper separation and disposal of the bottle.

Accommodating the frequent feeding moments with four types of bottles is a definite cause of this mismatch. The manual preparation involved in each bottle, as well as the availability of the large bottles compared to other types, must also be considered.

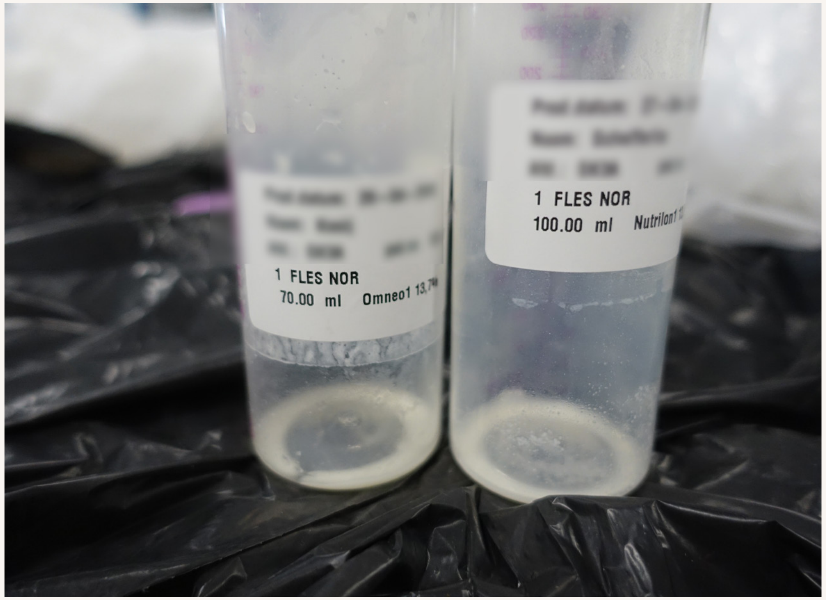


Figure 7.3 - Bottles with a potential volume of 250 mL are often filled with significantly less fluid

7.4 Hotspot 3: Manual preparation workload

Every bottle is prepared daily in the kitchen. This high workload requires careful and precise measuring and dosing of large quantities of formula powder. As shown in Figure 7.4, disposable syringes are used to withdraw precise amounts of mixed formula milk.

This manual preparation is not only time and labour-intensive but also limits the ability to quickly respond to changes in ordered patients' nutrition. This often leads to entire batches of prepared bottles being disposed of. This results in both plastic and a waste of formula powder and sterile water being disposed of without contributing to the key task of feeding patients.

Figure 7.4 - Dispensing prepared formula milk manually by syringe

7.5 Hotspot 4: Disposable tray usage

Every bottle must be transported from the kitchen to every PICU. Only one of the four bottles properly fits the carrying tray, and various disposable trays are used for the three other bottle types, as shown in Figure 7.5.

This complicates organised delivery batches of bottles and introduces a consistently disposed tray. In the case of a paper-based tray, this adds a new material to an otherwise plastic-exclusive waste stream. These paper-based trays were not found in the bags investigated in the waste audit, suggesting effective separation, yet they still contribute to the overall waste mass of the Erasmus MC.

Figure 7.5 - Only large bottles fit carrying racks, with disposable trays used for other sizes

7.6 Hotspot 5: Microwave variability

Bottles are stored in fridges and heated to a comfortable temperature for the patient to consume, with a microwave shown in Figure 7.6. This microwave cannot achieve a consistent temperature, and bottles must be mixed before feeding to eliminate hot or cold spots. This not only requires the experience of a feeding assistant but also runs counter to the manufacturer's recommendation for disposable feeding bottles, based on potential

However, national Dutch guidelines from the Werkgroep Infectie Preventie (2014a, 2014b) on the preparation of infant and enteral food note that a microwave is permissible. However, these guidelines reference an unavailable publication from 1998, which raises questions about its current validity.

Figure 7.6 - A microwave is used to heat formula milk

7.7 Hotspot 6: Various feeding methods

A key point identified in the feeding process is that in at least 80% of cases, bottles are not used to directly feed a patient but rather act as a reservoir for an enteral feeding set, as shown in Figure 7.7. This enteral set introduces several other items, such as syringes and feeding tubes, to the feeding process. When feeding bottles are used to directly feed a patient, a disposable drinking teat is attached.

Thus, in every feeding situation, a feeding bottle must be augmented with accessory items, which are subsequently also disposed which further adds to the material waste.

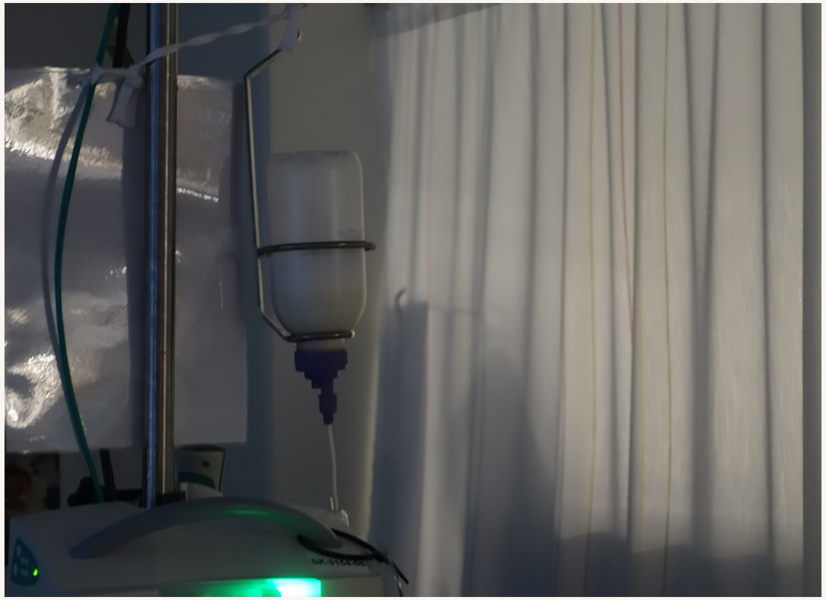


Figure 7.7 - A feeding bottle is coupled to an enteral feeding set

7.8 Hotspot 7: Cap redundancy

Every bottle comes packaged uncapped. It is then capped upon being filled with milk, uncapped for feeding, and ideally recapped before disposal. The cap only functions temporarily to seal the bottle during transport due to various other products being used to transfer formula milk to a patient.

The waste audit identified that 21.0% of the disposed mass consisted of caps. Thus, a considerable amount of the overall disposed mass comes from a supporting item with only a temporary function. In addition to the waste, preparation of the bottles involves a large amount of manual labour, as shown in Figure 7.8.

Figure 7.8 - In the preparation kitchen, caps are screwed on manually

7.9 Hotspot 8: Bottle labelling

Bottles are currently labelled with a sticker containing information on both the content as well as confidential patient information. This sticker should be removed before disposal, which has been found not to consistently happen, as shown in Figure 7.9.

The effect of the sticker in diluting potential recycling is low, as the sticker contributes only a small amount of material to the waste stream. However, the distribution of confidential information is a relevant concern.

Figure 7.9 - Bottle labels contain information on the content as well as confidential patient data

7.10 Hotspot 9: Improper waste separation

Although bottles are intended for PD waste, they are often discarded in general waste bins, making recycling impossible. Bottles discarded in general waste are incinerated and are responsible for an increased ecological footprint. In addition, the designated PD waste bins are used to dispose of other material types, as shown in the audited waste bag in Figure 7.10.

This lack of effective separation complicates the effective recycling of waste. While the R-strategies of recovering or recycling raw material provide the lowest potential impact in reducing environmental impact, an improperly sorted and incomplete waste stream further degrades this.

Figure 7.10 - Different material types have been found mixed with designated PD waste

7.11 Hotspot 10: Milk leakage

Bottles are frequently disposed of with milk drops or residue still inside. If not drained before disposal, as shown in Figure 7.11. Milk quickly spoils, and an unpleasant smell necessitates more frequent disposal of waste bags, as well as the potential for bacterial growth.

While the presence of milk residue is not anticipated to degrade the recycling potential of gathered material, it does contribute to environmental impact in other ways. The more frequent disposal of waste bags directly adds disposed material, as well as additional processing. The increased cleaning required to mitigate the potential for bacterial growth increases the use of cleaning chemicals. Lastly, the unnecessary disposal of dairy-based formula milk and the sterile water used to prepare it must be accounted for.

Figure 7.11 - Milk residue remains in many bottles if not drained

8. Initial explorative interventions

Chapter Content

This chapter presents the eight explorative interventions developed from the identified hotspots. Three of these interventions form the base of the subsequently developed design concept.

Due to the interdepartmental complexity of the use of sterile water, developing an explorative intervention for the use of packaged sterile water was beyond the scope of this project. However, due to the outsized environmental impact of this topic, it is covered in greater detail.

8.1 Range of explorative interventions

The ten identified hotspots in the environmental footprint of disposable feeding bottles have been used to create eight interventions, as shown in Figure 8.1.

Due to the outsized impact that the use of sterile water has on the resource footprint, this hotspot is stressed in greater detail. However, due to the interdepartmental complexity of this issue, as well as it being beyond the project's direct focus on the feeding bottle, no specific intervention proposal is given. It is suggested that this topic receive further specific study.

Hotspot 10, milk leakage, was determined not to have a considerable impact on the resource footprint of disposable feeding bottles and was not developed further.

The interventions of a bottle form redesign, bottle sealing foil and bottle tray were identified as offering the greatest reduction in the resource footprint while also being most aligned with stakeholders' ambition. These interventions were further developed into the proposed design concept.

Figure 8.1 - The eight initial interventions, along with the outsized impact of the use of sterile water

8.2 Current use of sterile water

Using 1-litre sterile water jugs, add an average of 38.8 grams of plastic waste for each prepared feeding bottle, which themselves only weigh 20.9 grams on average. Based on the waste audit findings, it is extrapolated that while annually 555.36 kilograms of feeding bottles are discarded from the PICU, an additional 725.8 kilograms of sterile water jugs are disposed of. As shown in Figure 8.2, this results in an effective doubling of the plastic waste disposed of.

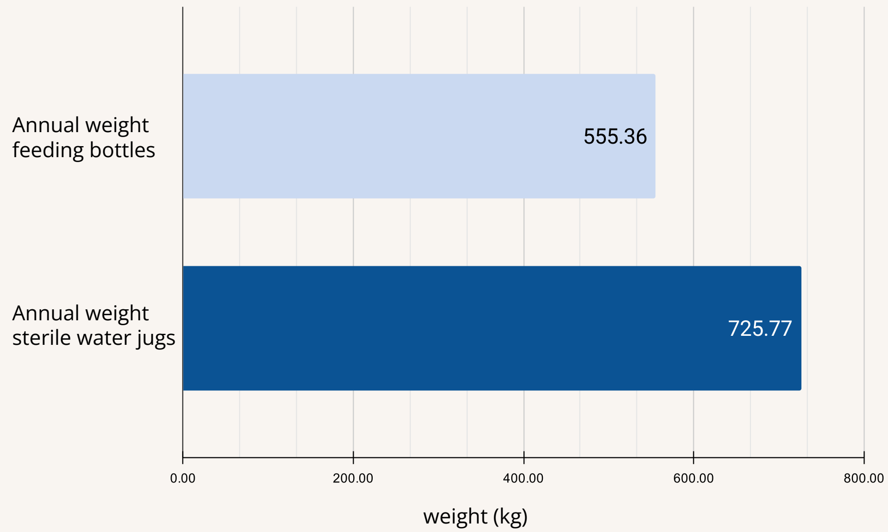


Figure 8.2 - Extrapolated annual weight of disposed feeding bottles and required water jugs for PICU, based on waste audit findings

Potentially superseded backing

The mixing of formula milk is currently prescribed in national Dutch guidelines to be done using either freshly boiled and cooled tap water or sterile water (Werkgroep Infectie Preventie [WIP], 2014a, 2014b). However, no research or publications are provided in these guidelines to support either the medical or practical necessity of this claim. The studies which are cited in the guidelines are dated, with no publication newer than 27 years at the time of this project, as shown in Figure 9.3. These studies might no longer reflect contemporary best practices.

1. Weenk, G.H. and G.V.M. Koopmans-Zwanenburg, Veilig voeden per sonde.Tijdschr Hyg Inf Prev. 95(2): p. 47-50.

2. Rombeau, J.L. and A. Durelli, Parenteral and Enteral Nutrition. In: Saunders Infection Control Reference Service. Infection Control, ***1998.*** *30: p. 383-87.*

3. Vermande, K., Produkten voor bijzondere voeding. Warenwetbesluit, ***1992.*** *Besluit van 16 april.*

4. Graham, S., Percutaneous Feeding Tube Changes in Long-Term-Care Facility Patiënts. Inf Contr Epidem, ***1996.*** *17: p. 732-36.*

5. Pingleton, S.K., Enteral nutrition as a risk factor for nosocomial pneumonia (editorial). Eur J Clin Microbiol Infect Dis, ***1989.*** *8: p. 51-5.*

Figure 8.3 - None of the cited studies in the guidelines are newer than 27 years at the time of this project writing

Financial cost of sterile water

The use of consumables such as packaged sterile water also adds further financial costs. Based on several suppliers (Brosch Direct, 2025; Premier Healthcare & Hygiene Ltd, 2025; Safety Direct, 2025; The Vet Store, 2025), a cost of €3.00 is assumed per jug. Assuming an average filling of 162 mL and 26,807 annual feeding bottles, based on the extrapolations from the conducted waste audit, an annual financial cost associated with packaged sterile water can be determined. This calculation shows that an annual expenditure of at least €80,421 is necessary to purchase sterile water jugs. Any sterile water jugs which are not fully used, which have been demonstrated to frequently occur, will naturally further increase this expense.

The current use of packaged water is significant in terms of material use, financial cost and appears to lack substantial contemporary backing. Addressing this directly is beyond the scope of this project, but it is criticalv to reducing the environmental footprint of infant feeding in the Sophia Children’s Hospital.

8.3 Bottle size use optimisation

Currently, a great deal of unnecessary bottle volume is used. Large 240 mL bottles hold volumes of milk half or less than half their capacity.

Collaborating with the doctors to decide nutritional volume, nutritional assistants placing the orders, and staff in the preparation kitchen mixing various powders, a more fitting bottle size for different types of patients and milk orders could be identified. Greater use of smaller bottles in the preparation kitchen could help reduce volume waste.

Creating or purchasing this optimised size, as shown in Figure 8.4, could reduce the overall amount of products in inventory. This streamlining has benefits for logistics, transportation and waste disposal.

Figure 8.4 - Possible bottle size intervention

8.4 Bottle preparation

The kitchen prepares all feeding bottles for the entire Sophia Children's Hospital daily. This involves a large workload of carefully and precisely measuring and dosing powders and liquids.

Trained healthcare professionals perform minute manual labour, which can largely be automated. Related fields, such as laboratories or commercial food preparation, have a range of automated methods, a suggestion is shown in Figure 8.5, for filling test tubes or other containers. It is important to note that an automated preparation introduced into the existing process without adjustment to either the method of ordering or the utilised bottles will not result in a considerable reduction in the resource footprint.

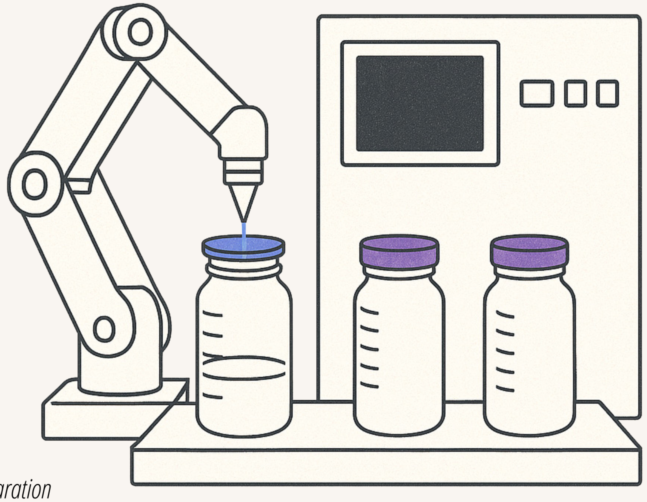


Figure 8.5 - Possible bottle preparation

8.5 Bottle trays

The current carrying rack can hold six bottles total, yet only one of the four types of bottles fits. Disposable trays are used, adding to the generated waste.

A transportation tray, a suggestion is shown in Figure 8.6, suitable for all four types of bottles currently in use, would reduce the resources necessary to deliver feeding bottles, as well as eliminate potential unmarked deliveries. Material choice depends on the footprint produced material is suitable for the required cleaning and sterilisation.

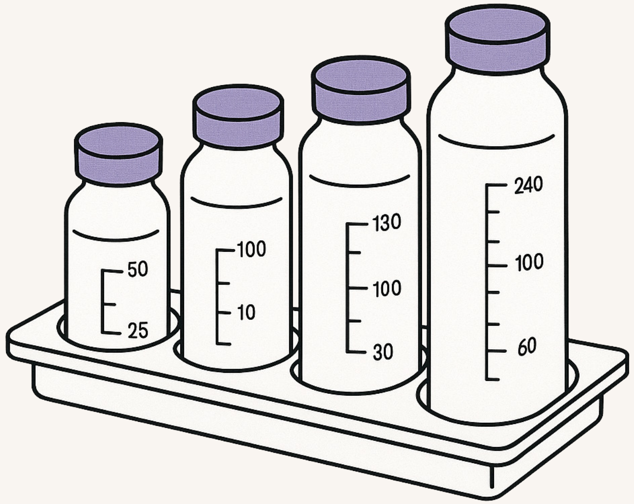


Figure 8.6 - Possible bottle tray

8.6 Bottle heating

Bottles are stored in fridges and microwaved to a temperature comfortable for patients. The microwave provides the fastest way to raise the milk temperature, but it can also cause hot or cold spots if the bottle is not mixed correctly.

A temperature-controlled conduction heater, as shown in Figure 8.7, could ensure a more accurate temperature, eliminate hot or cold spots, and reduce pressure buildup.

Figure 8.7 - Possible bottle heating

8.7 Bottle form redesign

Feeding bottles are attached to intermediary products, such as a teat or enteral feeding system, for actual feeding to the patient. It has been identified that more than 80% of patients are fed enterally.

Liquids can be transported in various alternatives; a proposed version is shown in Figure 8.8, to rigid bottles. Various types of pouches and flexible bottles can be used as they are significantly lighter while capable of holding a similar amount of fluid. The universal screw thread allows the connection of a flexible and lightweight pouch to existing feeding products.

Figure 8.8 - Possible bottle form redesign

8.8 Bottle sealing foil

Currently, every bottle is capped to prevent milk spillage. However, every feeding procedure involves unscrewing this cap and attaching the bottle to other intermediary products, such as a teat or enteral feeding system. The cap is then attached again for disposal or disposed of separately.

The current cap is excessive as its only role is preventing accidental spillage. Switching to a sealing foil-based system, as shown in Figure 8.9, could reduce the total weight of discarded feeding bottles by around 21% while retaining a secure and tamper-proof bottle.

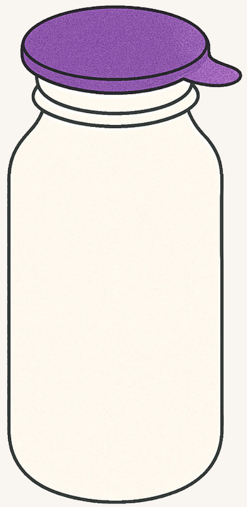


Figure 8.9 - Possible bottle sealing foil

8.9 Bottle sticker removal optimisation

Every prepared bottle is labelled with a sticker containing information on the content and confidential patient information. This sticker should be removed before disposal, but this removal is inconsistent.

Several changes, as suggested in Figure 8.10, to the sticker are possible, including a different adhesive, a different printing method, and separation of content and confidential information. Additionally, a more effective removal method could alter regular bottle disposal to allow confidential waste.

Figure 8.10 - Possible bottle sticker removal

8.10 Bottle disposal optimisation

Currently, bottles are disposed of in waste bags held in various waste bins. These bins are easily used to dispose of products other than bottles, especially other types of materials. This contaminates the otherwise separated stream, complicating any possible material extraction in a later stage.

Changing waste bins to a design that only allows bottles and similar plastic waste to be disposed of, as shown in Figure 8.11, along with increasing staff awareness of the importance of separation, can improve the waste stream.

Figure 8.11 - Possible bottle sticker removal

9. Final Design Concept

Chapter Content

This chapter presents the proposed next generation of feeding containers for formula milk used in enteral or oral feeding in a hospital context.

A bedside holder and a stackable preparation and transportation tray support the functionality of the proposed lightweight feeding pouch in the existing hospital context. Key features of the construction and material of each element of the concept are demonstrated.

9.1 Design Goal

"Design *the next generation of feeding containers* for formula milk used *in enteral or oral feeding* in *a hospital context*, which *reduces the amount of resource consumption and disposed waste.*

By integrating with existing workflows and establishing recyclable wasteflows, the transition of the Erasmus MC Sophia Children's Hospital to more sustainable healthcare is strengthened."

9.2 Design Vision

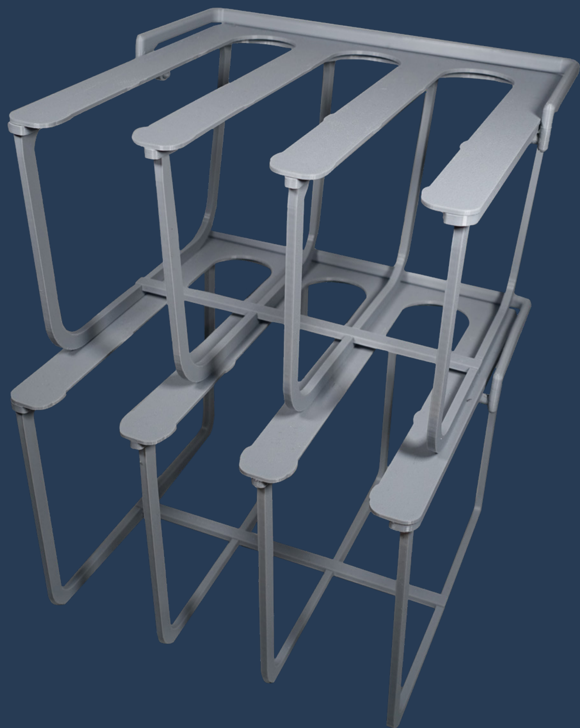
The design goal sets a clear end state: a feeding container integrated into existing workflows, while the environmental impact is lowered. This is expressed with several related physical outcomes. Introducing a new feeding container will be effective if the necessary supporting material and processes are developed alongside. All the outcomes have been developed through an iterative process of ideation, prototyping and evaluation with context-relevant hospital staff. Figure 9.1 shows the initial development of the feeding container.

While the tangible outcomes demonstrate the potential of the design, the intention is also to challenge existing practices and mindsets shaping the requirements for infant feeding in a hospital context. The use of mono-materials for recyclability, optimisation for minimal resource and integration into existing workflows is a further challenge to current feeding systems.

Introducing any new medical device, in particular one in direct contact with patients, introduces a significant regulatory challenge before implementation is possible. The proposed design is based on proven technology and materials. This allows for its influence on user interaction and behaviour to be investigated from a position of technological reliability, rather than being limited by uncertain feasibility or compliance concerns.

Figure 9.1 - A portion of the total amount of disposable feeding bottles used daily

Lightweight feeding pouch with rigid threaded collar and foil seal



Stackable preparation and transportation tray

Bedside pole feeding pouch holder

9.3 Lightweight feeding pouch with rigid threaded collar and foil seal

Design Objective

The primary objective of the flexible feeding pouch is to reduce the environmental impact of disposable feeding bottles by transporting and storing formula milk in a container of significantly less weight compared to feeding bottles. The flexible feeding pouch, shown rendered in Figure 9.2, consists of a lightweight and flexible pouch attached to a rigid collar and sealed after preparation with a foil seal.

Weight and size reduction

The feeding pouch can hold equivalent volumes of formula milk at a greatly reduced weight compared to bottles. The current 250 mL bottle is the most common size in use, as identified in the waste audit, and the proposed mono-polypropylene pouch, rigid collar, and foil closure comparatively reduces material weight by 59.3%. The large feeding bottle and cap have a combined mass of 26.43 grams, compared to 10.76 grams for the combined components of the feeding pouch.

This reduction in material provided the most direct environmental benefits, as not only a lower amount of material resources is required, but also decreased weight is transported. The density of flat pouches compared to hollow bottles reduces the total amount of embodied transportation energy and needed movements, adding to the overall reduction in impact.

Lastly, the reduction in volume of the flexible pouch in its emptied state reduces the overall physical size of disposed waste. This results in fewer required waste bags compared to an equivalent amount of hollow bottles.

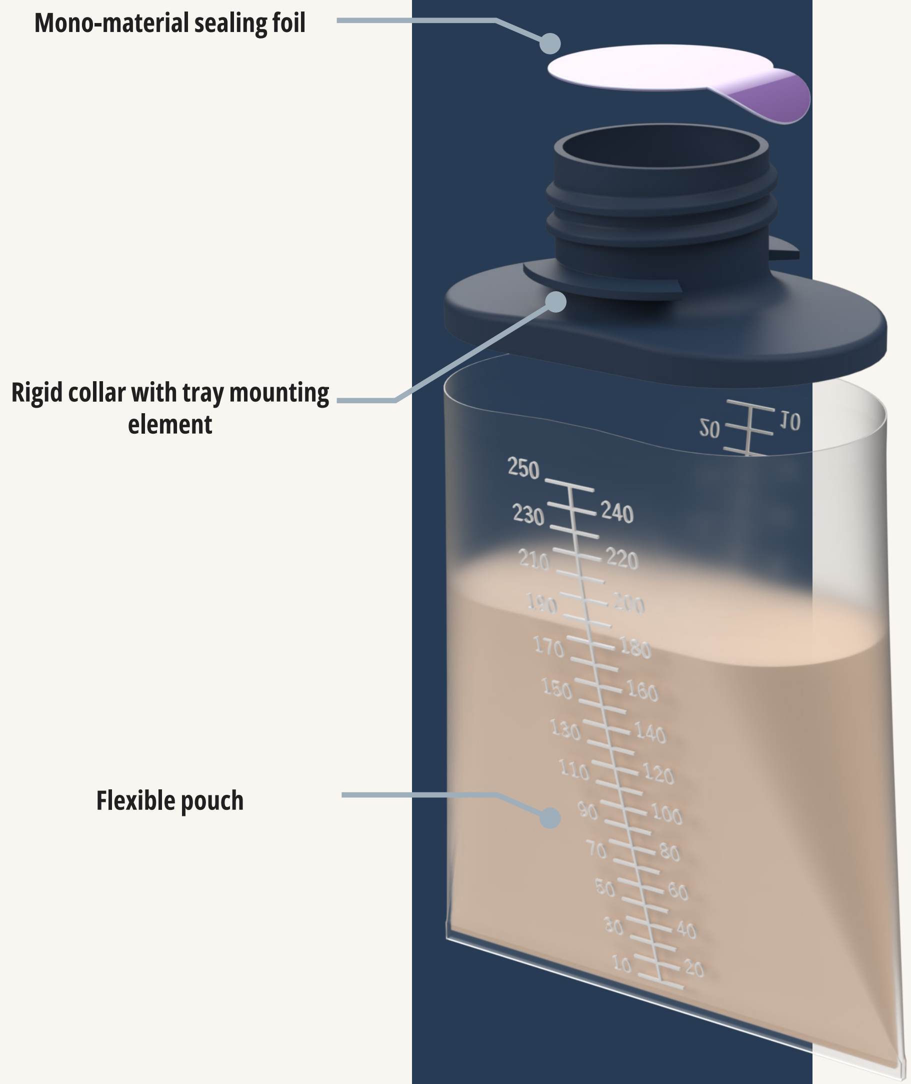


Figure 9.2 - Rendering of feeding pouch

Disposable recycling potential

The current flexible pouch is still considered a disposable item due to the difficulty in achieving multiple use cycles for feeding containers in the current context. However, due to the use of mono-material for all components, the recycling potential remains high and does not require the use of chemical or mechanical processes for the separation of laminates or material types.

Integration with existing infrastructure

The complete feeding pouch consists of a flexible bag attached to a rigid threaded collar. The collar allows for attachment of the feeding pouch to the currently used teats and enteral feeding set. The use of the feeding pouch in an inverted position is shown in Figure 9.3. The continued use of feeding accessories minimises disruption to the current feeding process. Aligning all possible feeding products to a new standard is considered beyond the scope of this project. However, several accessory items which directly influence the use of the proposed feeding pouch have been developed.

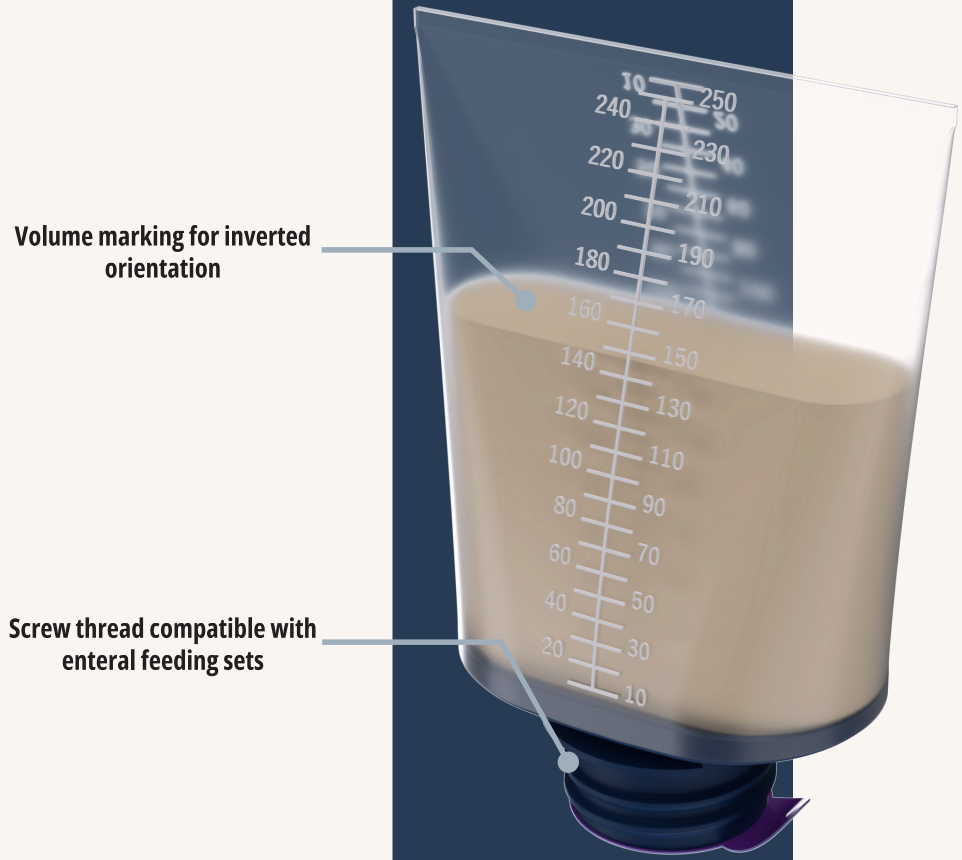


Figure 9.3 - Flexible pouch in inverted position

9.3.1 Flexible Pouch

Design Objective

The current polypropylene bottles are suited for extended use, considering the material and production method. However, according to the manufacturer's instructions, bottles must be disposed of after a single use. Compared to rigid bottles, the proposed flexible pouch, shown in Figure 9.4, is constructed from a thin layer which still effectively contains and protects the formula milk during transportation and feeding, yet allows for a far smaller and lighter container.

Construction

Compared to the extrusion blow moulding process used to create the current feeding bottles, the flexible pouch is cut from a flat sheet of mono-polypropylene. The production process, a proposal of which is shown in Figure 9.5, concludes with the attachment of the pouch to the rigid collar and a final step involving the sealing of the bottom of the pouch. A sheet of 50 μm thickness, which is in the upper range for typical products (KanzoPack, 2024), yields a pouch with a volume of 250 mL and a mass of 1.17 g. The current large feeding bottle has a mass of 22.15 grams, and thus, the same volume of fluid is held by approximately one-twentieth of the mass.

Material properties

Many of the concerns related to material properties in the context of food packaging are related to light, moisture and gases, which, in a typical use case, must be kept out for an extended time due to storage shelf life. This is not the case in this context, where the time between preparation and consumption of formula milk is between several hours and a maximum of twenty-four hours. In research comparing polyethene mono-material coatings to multi-layer configurations (Carullo et al., 2023), the mono-material not only showed lower environmental impact but also excellent performance in various material properties, especially barrier properties.

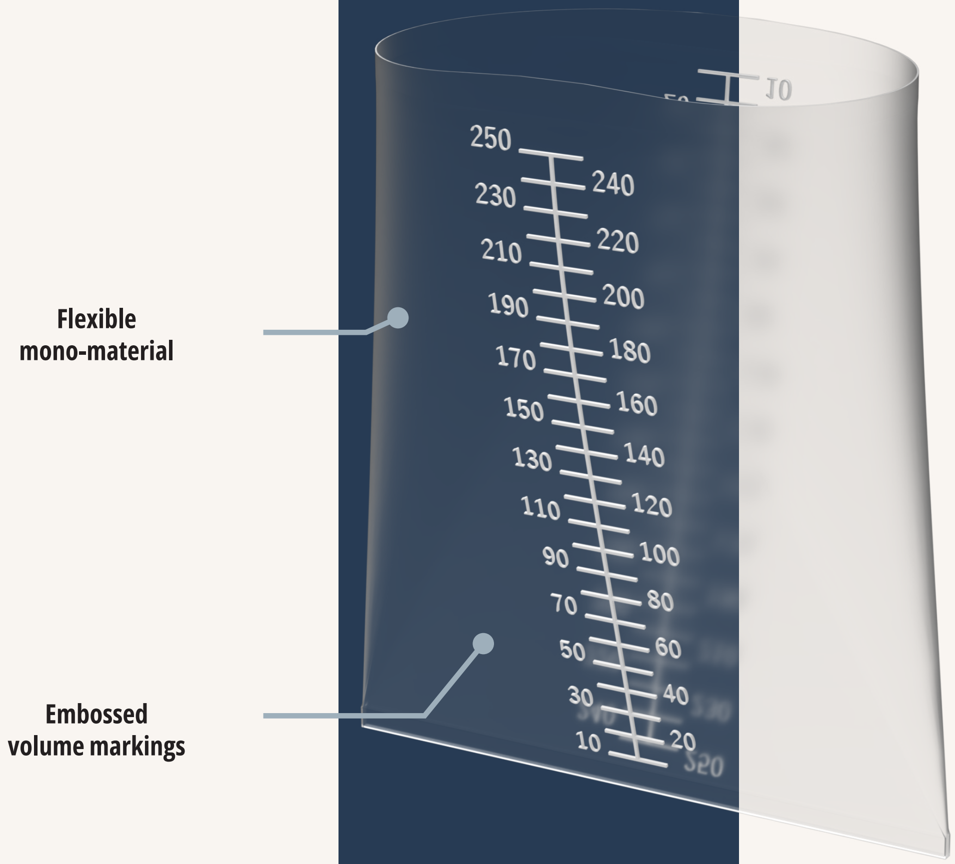


Figure 9.4 - Rendering of flexible pouch

Mono-materials in current industry

While the research by Carullo (2023) only explored the use of polyethene, a wide range of industry applications of mono polypropylene laminates, or mono-PP, have already been launched. A key example is Capri-Sun's new juice pouch, launched in 2023 (May et al., 2024), which demonstrates that not only solid products but also fluids can be safely stored in flexible mono-material containers. Further, the Pouch5 (Gualapack, n.d.) has seen use for baby food, as well as being suited for use in hot-filling and pasteurisation applications. Thus, both the stringent requirement for baby food, the potential for high temperatures and the storage of fluid are all possible to address when using mono polypropylene. High recycling yields have also been demonstrated by the product currently on the market, validating recycling potential.

Volume markings

Compared to pouches or other similar products aimed at consumers, the hospital context can reduce the need for printing various colourful consumer-oriented graphics. This cuts down both on ink and potential surface treatment needed for printing. However, this remains an option to make the feeding pouch more visually attractive to infants.

While volume indication can be printed, it is also possible to achieve this through embossing the flat sheet of material before it is folded to become the pouch. This can reduce the amount of ink necessary. In the guidelines Designing for a Circular Economy Guidelines (CEFLEX, 2023), it is noted that inks have been reported to impact the quality of the recyclate. To ensure optimum quality of post-recycling material, a maximum of 5% by weight of the total structure in inks is suggested.

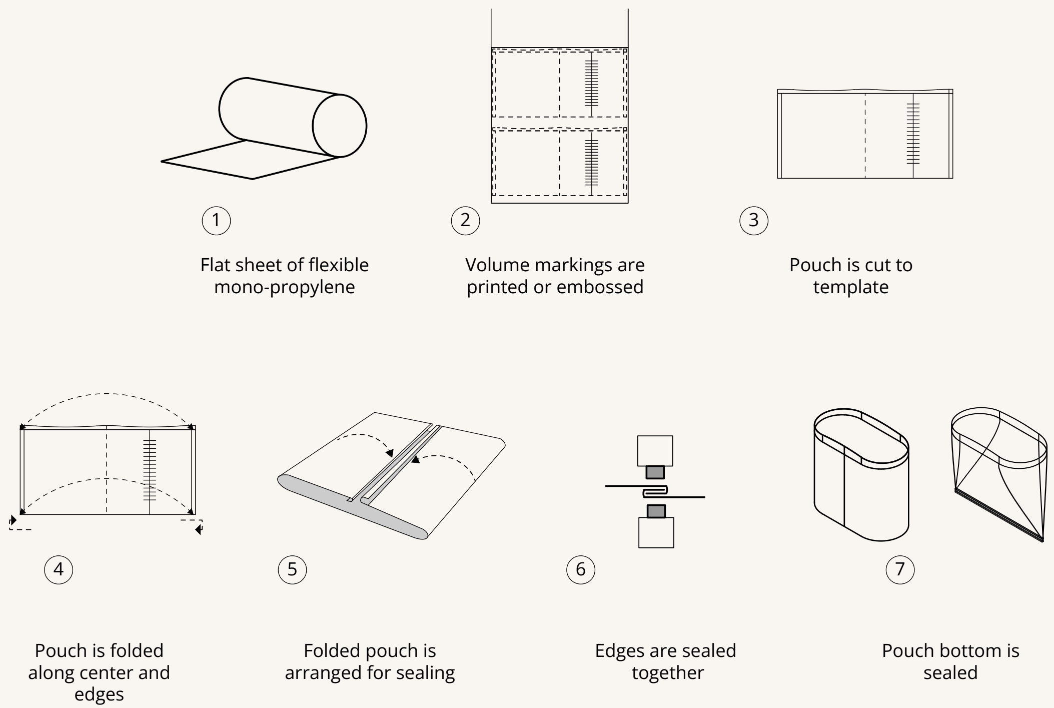


Figure 9.5 - Proposed construction method of flexible pouch

9.3.2 Rigid Collar with Universal Screw Thread

Design Objective

The feeding pouch is designed to be compatible with current enteral sets and feeding teats. The current method by which formula milk is prepared and distributed also remains possible, through a combination of the collar and the carrying and preparation tray, which is covered in a subsequent section.

Construction

A rigid collar with a threaded coupling, as shown in Figure 9.6, connects with enteral sets and feeding teats. The overall shape of the collar is a rounded slot with an overall length of 80 millimetres and a width of 50 millimetres. Compared to a circle, this shape reduces the length necessary for the pouch to contain a specific volume while still providing the bracing necessary to prevent buckling of the flexible pouch when filled with fluid. A heat or adhesive-based connection between the flexible pouch and collar is made to complete the feeding pouch.

The internal curved structure, as shown in Figure 9.7, of the collar is designed to direct liquid out of the feeding pouch, in any orientation. This reduces the amount of fluid remnants remaining in an emptied pouch, contributing both to more accurate patient feeding as well as reducing the amount of formula milk wasted by disposal.

Material properties

The rigid collar is constructed from mono polypropylene. This is based on the identified benefits in recyclability as well as the existing use by industry of this material, as described in the section on the flexible pouch. The concept collar has been produced with an additive manufacturing process, utilising PLA filament.

Figure 9.6 - Rigid collar with mounting element and surface for adhering the flexible pouch

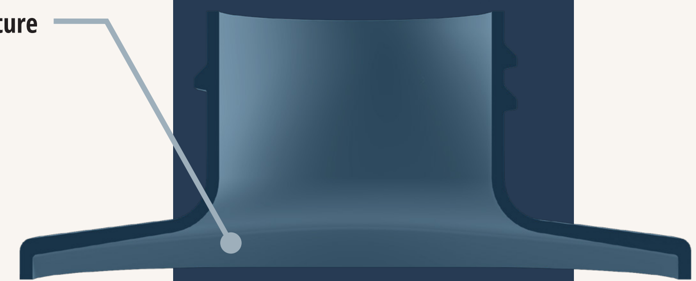


Figure 9.7 - Internal curve of rigid collar

9.4 Mono-material foil closure

Design Objective

The primary objective of the foil seal is to reduce the material weight required to effectively seal a feeding pouch with a waterproof seal.The performed waste audit identified that at least 21% of the current weight of disposed feeding bottles consists of caps. A single cap is 19% of the weight of the most commonly used bottle. Thus, for every 5.3 bottles, another bottle by weight is disposed of in caps.

Figure 9.8 - Difference between foil seals and current caps

Construction

Foil seals are much lighter compared to the current disposable screw caps, shown in Figure 9.8. Each screw cap contributes 4.28 grams of material waste per bottle, while typical sealing foils suited for the size of the current bottle can be 0.20 grams or less each. Switching from screw caps to foil seals thus reduces material weight by 95%. The foil closure is attached to the rigid collar with a heat-sealing machine, providing a tamper-evident and waterproof seal. In the personal communications (C. Brookes, email, July 18, 2025) with suppliers of induction and closure materials, it was determined that a heat-sealing machine would be effective at bonding a mono-material to the rigid collar while not leaving residue upon removal. Sealing can be integrated at the point of filling using compact, tabletop sealing units, operated by existing staff. An extended tab on the edge of the foil allows for easy removal, shown in Figure 9.9.

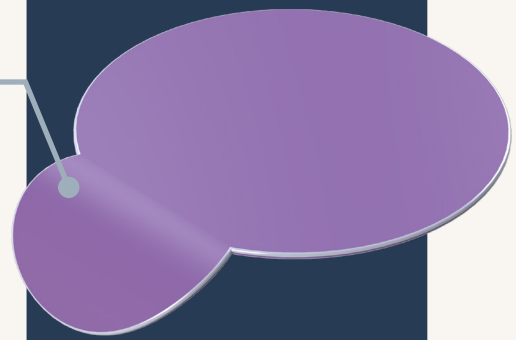


Figure 9.9 - The foil seal has been designed for removal in mind

Material properties

Foil closures can be constructed from a range of laminates and attached to a container with an induction sealing machine. However, typically this not only requires an induction liner placed in a cap which is later screwed onto a container, but also introduces unwanted laminates and material types. However, while laminate construction is typical, the use of mono-materials is also possible. In personal communications (C. Brookes, email, July 18, 2025) with a supplier of induction and closure materials, it was determined that a mono-material polypropylene sealing foil ensures the recyclability of the mix of feeding bags while still providing the necessary barrier against oxygen and water without requiring the chemical processes needed to separate laminates.

9.5 Stackable preparation and transportation tray

Design Objectives

The primary objective of the preparation and transportation tray is to allow the flexible pouches to be prepared, transported, and stored under similar conditions to rigid bottles, while eliminating previously used disposable trays. The tray is reusable and intended to be cleaned and sterilised, and is utilised in the preparation kitchen, during transportation by feeding assistance and storage in the PICU.

Construction

A total of six feeding pouches are held in the tray, spread over three channels, as shown in Figure 9.10. The integrated mounting elements of the rigid collar, along with slight protrusions in the holding channel, secure each feeding pouch.

Several trays can be stacked on top of each other, with the folded carrying handle limiting the movement of the stack, as shown in Figure 9.11. This allows for more efficient storage and transportation. The carrying handle can be unfolded and used to carry a filled tray.

Considering the long-term use of a reusable tray, the use of a minimal structure allows the greatest access for both cleaning as well as sterilisation. Rigidity of the overall structure is maintained by a crossbar connecting the four legs. The carrying handle attaches with two constrained pin joints and has a limited rotation, shown in Figure 9.12. The carrying handle is mounted on the overall point of balance to allow for one-handed carrying of the tray.

Figure 9.10 - Six feeding pouches can be stored in the tray

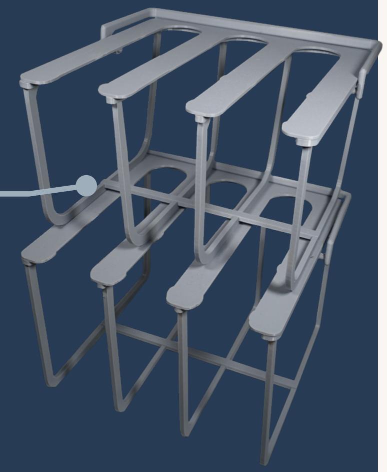


Figure 9.11 - Two trays securely stacked

Material properties

While the current concept has been produced with an additive manufacturing process, subsequent different production methods have been accounted for. As shown in Figure 9.13, all components, except the carrying handle, can be extracted from a single flat sheet of material. This allows for a range of metal or polymer-based materials to be used, depending on the demands of sterilisation as well as structural requirements. These requirements were determined to be beyond the scope of this project.

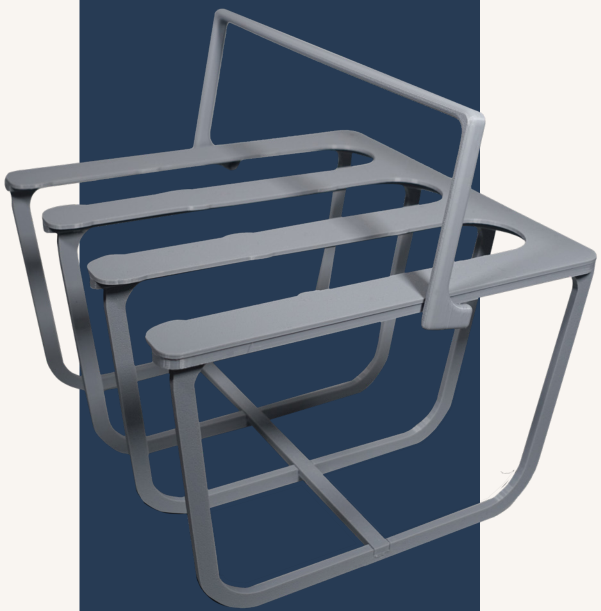


Figure 9.12 - Carry handle in extended position

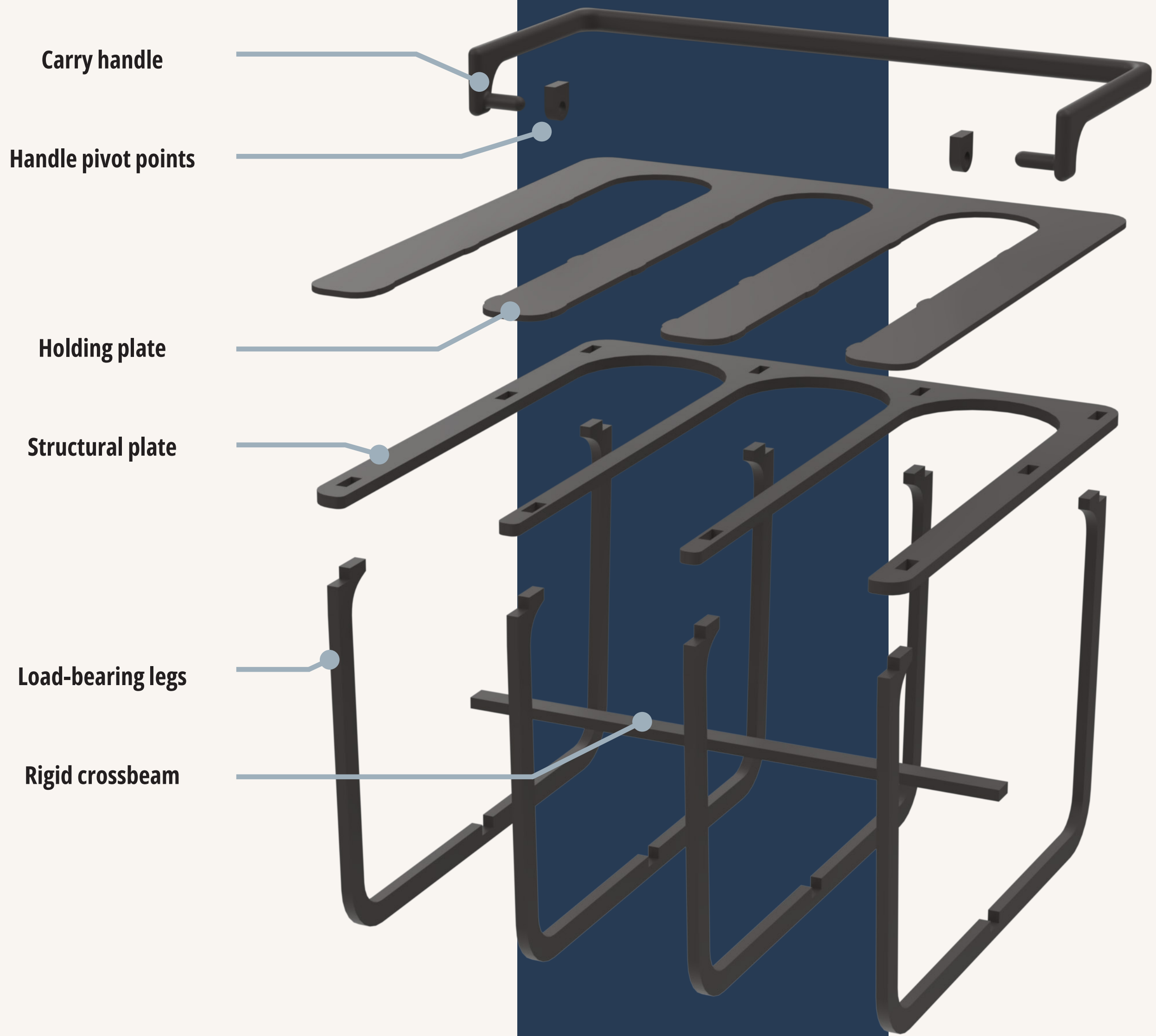


Figure 9.13 - Exploded view of all tray components

9.6 Bedside pole holder

Design Objectives

The primary objective of the bedside pole holder is to provide a secure space for mounting feeding pouches to be connected to an enteral feeding set. While the flexible feeding pouch can be used to feed a patient directly, enteral feeding remains the primary method of delivering the contained formula milk.

Construction

The feeding pouch holder is attached to a bedside hole and holds a single feeding pouch, as shown in Figure 9.14. The feeding pouch is mounted with the opening facing downwards to be connected with feeding tubes to an enteral feeding set and finally to the patient. The pole holder provides its own clamping force and remains attached to a bedside hospital pole. Similar to the reusable tray, slight protrusions in the holding channel secure the feeding pouch, shown in Figure 9.15.

Material properties

The concept pole holder has been produced with an additive manufacturing process. While this allows for rapid development of a physical item, the process produced a variable surface finish. The effect this irregular surface has on cleaning or disinfection, which is critical for a long-term device, has not been explored further in the scope of this project.

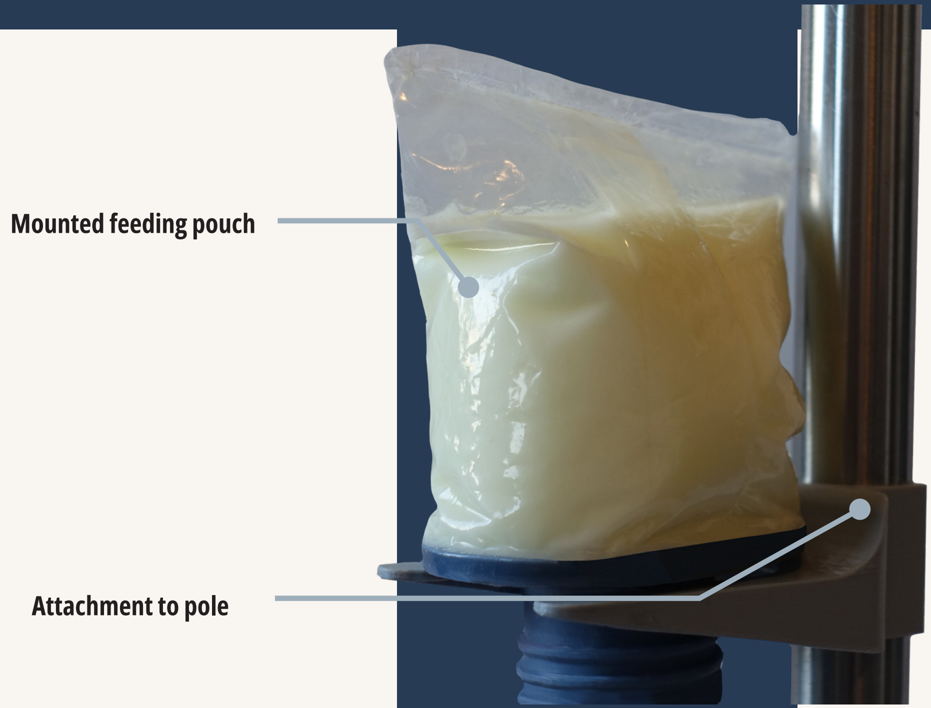


Figure 9.14 - Feeding pouch mounted in holder

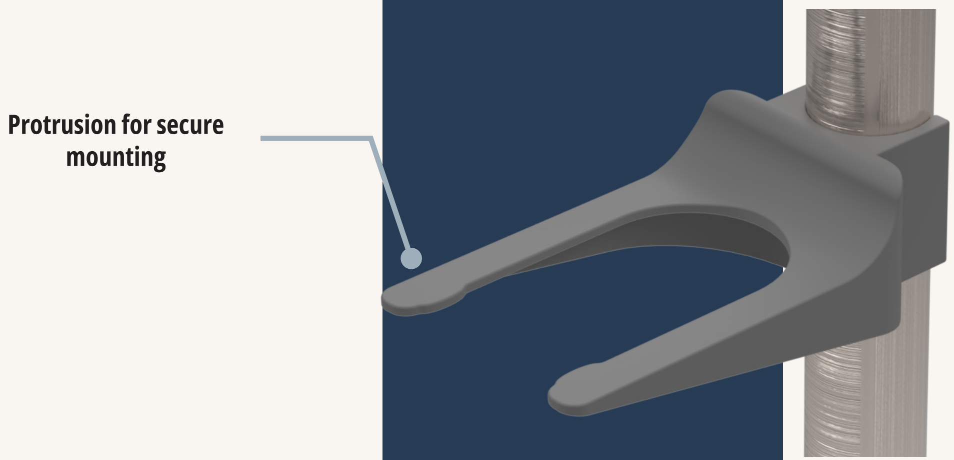


Figure 9.15 - Feeding pouch holder

10. Design concept impact

Chapter Content

This chapter presents the impact of the design concept across four areas: the reduced material weight, the minimised waste volume, the streamlined transportation and design for recyclability.

Together, these results demonstrate the potential to reduce the environmental footprint of the infant feeding process.

10.1 Reduced material weight

Reduction in the material to transport formula milk

The currently most commonly used bottle and cap have a combined mass of 26.43 grams, compared to only 10.76 grams for the complete feeding pouch, shown in Figure 10.1. The same volume of formula milk can be transported with a feeding pouch at 40.71% or less than half of the mass of a rigid feeding bottle.

Reduction in the disposed material to seal a bottle

The use of a foil seal, compared to the conventional screw cap, as shown in Figure 10.1, reduces the mass necessary to achieve a seal by 95%. The screw cap, with a mass of 4.28 grams, is replaced by a sealing foil with a mass of 0.20 grams. Aside from the mass reduction, the cap no longer requires injection moulding. The associated use of energy and development of complex tooling is eliminated.

Reduction in the annually disposed mass

Based on the performed waste audit, it has been extrapolated that annually, a minimum of 555 kilograms of feeding bottles are disposed of from just the PICU. The reduced weight of the flexible feeding pouch would decrease the disposed mass to around 226 kilograms, shown in Figure 10.2, if all bottles were replaced by pouches. As in the extrapolated annual mass, it is important to note that many external factors might influence this reduction. However, the significant reduction in mass between the current feeding bottles and the feeding pouches still results in a reduction of the overall mass by approximately 60% or more than 329 kilograms every year.

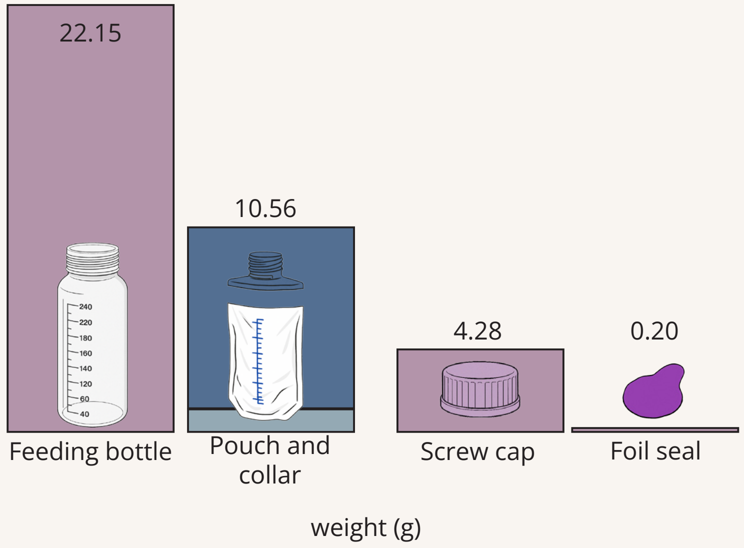


Figure 10.1 - Mass of feeding bottle and cap compared to feeding pouch and foil seal

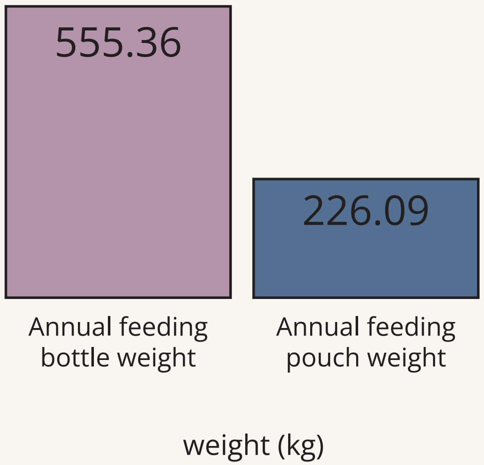


Figure 10.2 - Extrapolated disposed mass of feeding bottles and feeding caps

10.2 Minimised waste volume

Reduction in disposal volume

While the feeding pouch holds a similar amount of formula milk as a feeding bottle, when empty, it occupies about one-third of the space, as shown in Figure 10.4. The sealing foil is even smaller in size compared to the screw cap. The decrease in generated waste volume is shown in Figure 10.3. As a result, while a similar number of items are disposed of, either smaller waste bags or fewer of the currently used waste bags are necessary. In practice, hygienic requirements of the hospital context mean that the frequency of waste collection is unlikely to change.

Reduction in annual disposal

Based on the contents of waste bags collected in the waste audit and the extrapolated annual amount of feeding bottles disposed of from the PICU, the reduction in waste volume and associated waste bags can be determined. The waste audit counted 661 bottles, divided over 16 bags. This extrapolates to an annual amount of 26,807 bottles for which 649 bags would be required, or 1.8 bags daily. If the size difference of feeding pouches is directly accounted for, only 216 bags annually or 0.6 bags daily, are required. If, due to hygienic requirements, daily disposal is required, the annually disposed of 365 bags are still only 56.25% of the current amount.

Figure 10.3 - Suggested reduction in waste volume of feeding pouches

Figure 10.4 - Empty feeding pouches occupy about one-third of the total space of rigid feeding bottles

10.3 Streamlined transportation

Reduction in the material to transport formula milk

As shown in Figure 10.4, feeding pouches are approximately a third of the overall size of rigid feeding bottles. As only the rigid collar introduces notable volume, significantly more feeding pouches can be transported in similar boxes. A simplified comparison between the necessary boxes for feeding bottles and feeding pouches is shown in Figure 10.5. While the feeding foils are packaged separately, their thin profile allows a single box to contain far more foils than screw caps.

Even in optimal circumstances, transportation of empty bottles is not efficient, as the majority of the space is taken up by either the hollow bottle or the space between the cylindrical shapes. In practice, as shown in Figure 5.8, the loose packing of bottles increases this inefficiency. The flat packaging of feeding pouches. It was identified during the process research that 84 feeding bottles are transported in a single cardboard box. A similarly sized cardboard box is extrapolated to hold around 252 feeding pouches while increasing its overall mass by about 0.5 kilograms, based on the overall size difference.

Reduction in annual transportation

Assuming appropriately sized cardboard boxes, standard Euro-pallets and transportation trucks are used, an estimation of the decreased transportation volume can be made resulting from the use of flexible pouches. This can be combined with the extrapolated annual amount of feeding pouches required by the PICU to determine the saved amount of transportation.

A Euro-pallet can hold four typical 600x400x200 mm cardboard boxes per layer. Four layers in total keep the total height under one meter, improving ease of transport. Replenishing the extrapolated 26,807 annually disposed bottles from the PICU takes 320 boxes, equal to twenty loaded Euro-pallets. In comparison, 107 boxes of feeding pouches are necessary, which require seven Euro-pallets. Thus, the annually required amount of feeding pouches for the PICU, alongside sealing foils, can be delivered on 35% of the previous pallet capacity, as shown in Figure 10.6. A typical full truckload can require up to 33 pallets (Eurosender, 2025; Kuipers Logistics B.V., 2025). Feeding bottles thus require 60.6% of the capacity of a single truck, while transporting feeding pouches only needs 21.2%.

Figure 10.5 - Extrapolated disposed mass of feeding bottles and feeding caps

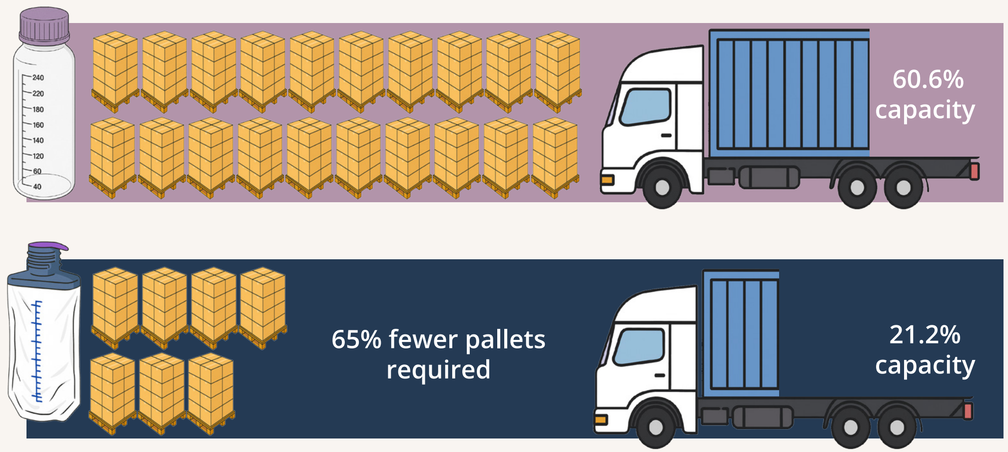


Figure 10.6 - Required Euro-pallets and truck capacity to transport the annual amount of feeding bottles for the PICU compared to feeding pouche

10.4 Designed for recyclability

All components of the proposed feeding pouch have been designed with recyclability in mind. Due to the disposable nature as well as short duration of use, this consideration is relevant for both the production as well as end of life processing.

The analysis in Gonçalves et al. (2024) showed that the use of mono-materials had a lower environmental impact across the entire life cycle. The benefits of the end of life of a product are partially noted, with an environmental impact which was found to be reduced by more than 30% due to the increased recycling rate. Plastic waste can be recycled through shredding, as shown in Figure 10.7, cleaning and eventually the creation of granulate. This granulate represents the recovery of raw material. As all components of the feeding pouch consist of the same material, they can be disposed of without contaminating the material stream. While the use of recycled material in producing new food-safe or sterile products is unlikely due to existing international standards (ISO, 2019), there are many other applications for which a recycled mono-material is suitable.

Figure 10.7 - Shredding of plastic waste to eventually produce recycled granulate

Note: Image by WEIMA Maschinenbau (2025)

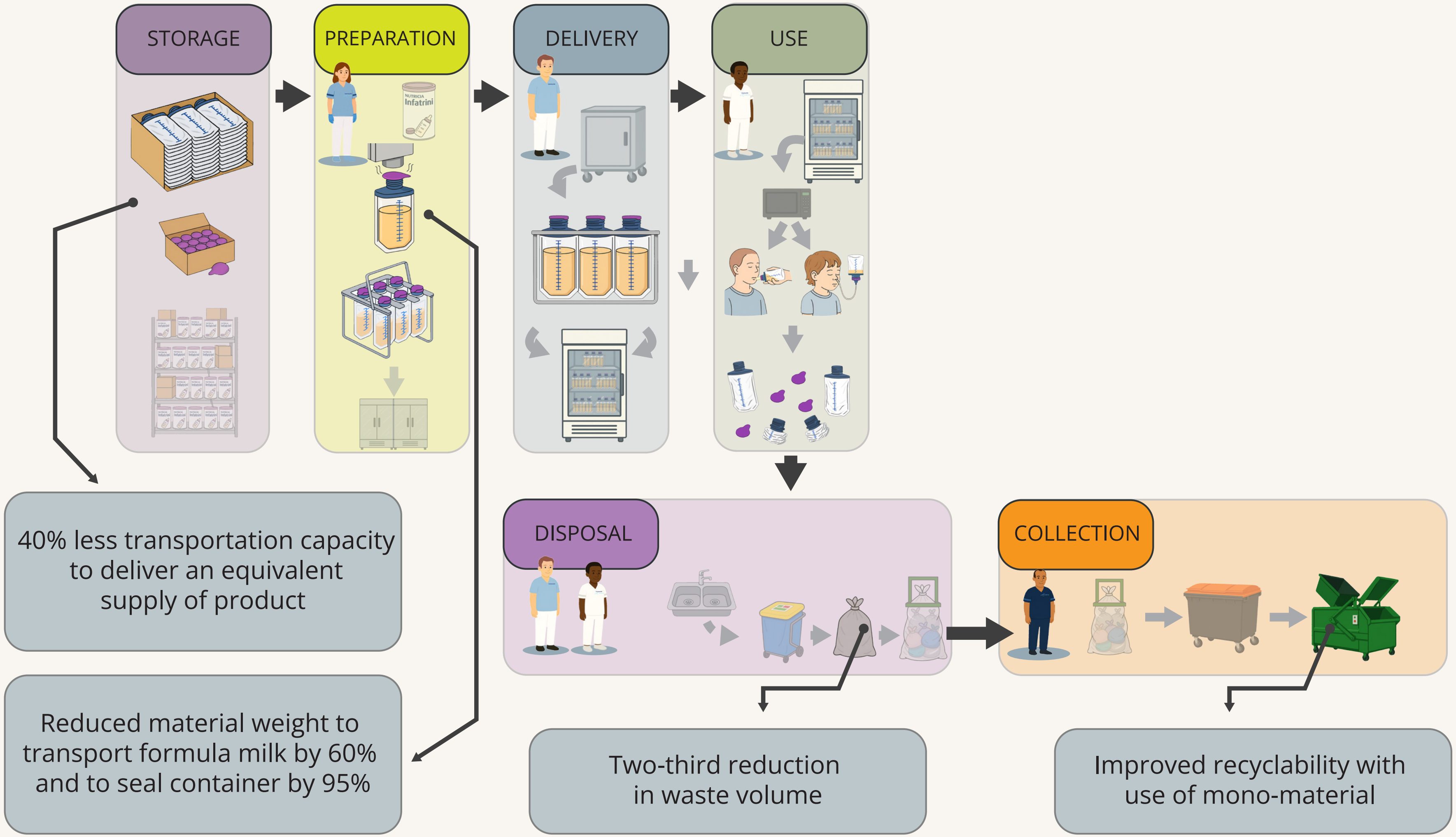


Figure 10.8 - The design concepts' four main areas in reducing the environmental footprint

10.5 Impact on process map

The four main areas of reduced environmental impact: the reduced material weight, the minimised waste volume, the streamlined transportation and design for recyclability are highlighted in Figure 10.8. The proposed concept achieves a reduction in environmental impact across every identified phase of the infant feeding process.

11. User validation of the design concept

Chapter Content

This chapter reports the waste audit of products related to the bottle feeding process from the Erasmus MC Sophia Children's Hospital PICU.

The results provide insight into the average amount of disposed feeding bottles, the overall material weight disposed, extrapolation to the daily disposal amount, as well as several further findings.

11.1 Potential of full-sized validation

The validation with users was structured with a preliminary session, as shown in being conducted in Figure 11.1, in which initial user feedback, but also necessary adjustments to the format, were to be determined. However, an unforeseen mandatory isolation limited access to key context users and cancelled the subsequent full-sized session. Due to the limited availability of the users as well as the project's time frame, it was not possible to arrange additional sessions.

The outcomes presented in this chapter were all gathered during the preliminary session performed with nursing staff in the PICU. Despite the limited envisioned scope of this session, it still resulted in a wide range of practical adjustments to the design concept. This indicates that a full-sized session could provide even further refinements. The insights gathered during the preliminary session can be divided into two categories: suggestions on the physical design and on the suggested change to the feeding process.

Figure 11.1 - Staff members engage with models of the design concept

11.2 User-based adjustments to physical design

The models of the design concept which were brought to the session differ in many physical aspects from the final design concept. These changes are based on the suggestions provided by the users.

The evaluated rigid collar incorporated two lengthwise "ears", as shown in Figure 11.2, intended to allow nursing staff to retrieve or hold the feeding bag without directly touching the screw thread. However, none of the nursing staff found this to be a necessary addition. Stressing the high pace of work, it was noted that handling the feeding bag by directly holding the bag or the neck and screw thread would be faster, while no hygienic concerns were raised with this method. These components were therefore eliminated for the final design concept, which further reduces the required material mass of the overall feeding pouch. The length of the initial rigid collar was also determined to be slightly unwieldy when used with a feeding teat. Reducing the length of the collar by 20 millimetres provided a more convenient positioning in the hand. The flexible pouch required lengthening to accommodate this reduced size.

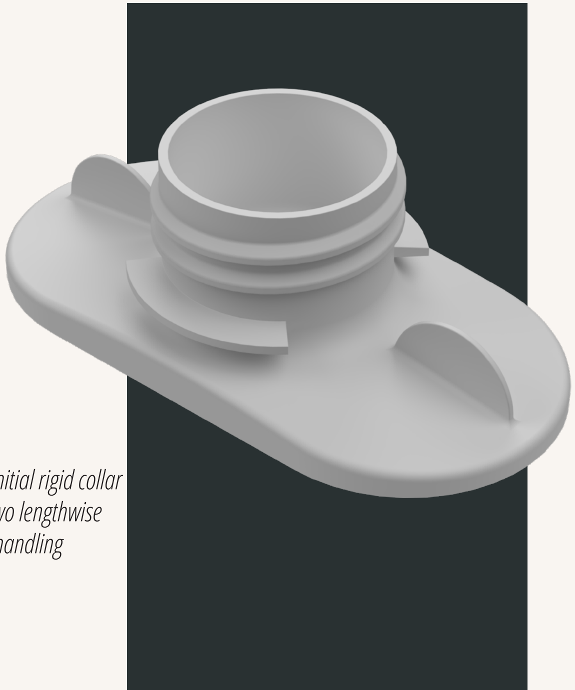


Figure 11.2 - The initial rigid collar incorporated two lengthwise "ears" for handling

It was identified that, in some cases, a syringe is used to deliver very small amounts of formula milk. Currently, this involves drawing up formula milk from a rigid bottle, which can remain upright independently. As the flexible pouch lacks this structure, a method to securely hold a feeding pouch to allow for withdrawal of milk by syringe was desirable. The bedside holder, initially intended purely for enteral feeding, was adjusted based on this need to allow the feeding pouch to be held in position in both orientations.

Nursing staff consistently mentioned the need to be able to visually inspect the formula milk. Any clumping, residue or colour difference can easily be spotted through a transparent container. Additionally, it was consistently noted that graduated volume indicators are essential for monitoring patient intake of formula milk. Marks indicating the specific millilitres volume level a container allows for a quick readout by nursing staff. Both contributions are incorporated into the final design concept, as seen in the development of initial flexible pouches shown in Figure 11.3.


Figure 11.3 - Initial development of the flexible pouch

11.3 User insights on the proposed feeding process

Due to the limited session, it was not possible to evaluate every phase of the feeding process. The validation sessions were performed with the nursing staff, and mainly, the use phase was explored.

The stackable preparation and transportation tray received few comments, and it was considered to effectively support the flexible pouches in the unit fridge. It should be noted that a validation with feeding assistants is seen as necessary to conclude this fully.

The nursing staff noted that the foil seals, which, once removed, cannot be reapplied to the collar, can be integrated into existing workflows without difficulty. Reclosing of containers was a rare occurrence, and a hybrid system was proposed as a flexible solution. A small supply of current screw caps could remain on each unit, for exceptional cases. Thus, the material saving and recyclability benefits of the mono-material foil as a primary seal are maintained while the flexibility to reclose a container when strictly necessary remains, as shown in Figure 11.4.

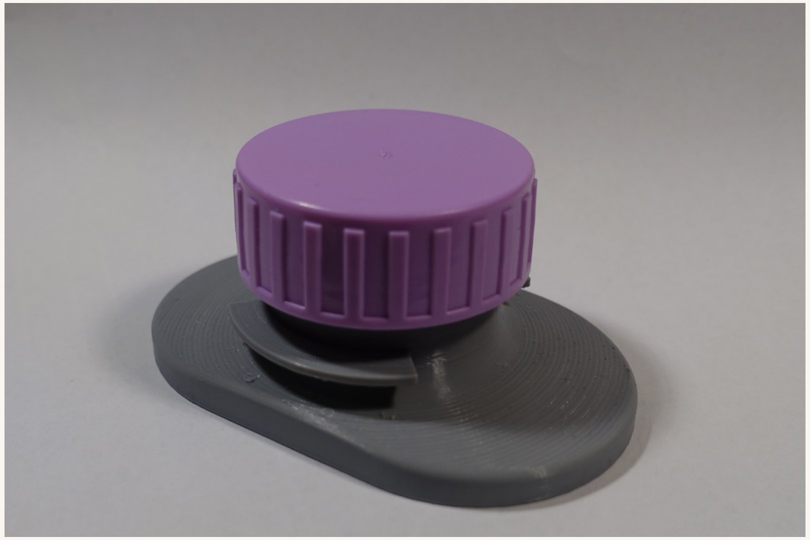


Figure 11.4 - A supply of screw caps can provide a hybrid system for sealing

12. Project conclusion

Chapter Content

This chapter presents the conclusion of the project. The main research findings and the resulting proposed design concept, as well as their impact on reducing the environmental impact of disposable feeding bottles, are summarised.

The identified limitations faced by this project are given, as well as suggested opportunities for future work on sustainable infant feeding in hospitals.

12.1 Project conclusions

Healthcare positively influences lives on many levels. Unfortunately, the healthcare sector also contributes to a growing climate crisis. The prolific use of disposable medical products has been identified as a major contributor to the overall resource consumption of the healthcare sector.

The Erasmus MC Sophia Children's Hospital currently uses disposable feeding bottles to deliver formula milk for infant feeding. Noort et al. (2024) determined that feeding bottles ranked fifth in terms of climate impact among 50 other medical disposables used in six Dutch university medical centres. Approximately 430,000 kg CO2e can be directly traced to disposable feeding bottles in 2022 alone. While glass and plastic reusable feeding bottles are commercially available, their introduction into the paediatric intensive care unit (PICU), as well as the general hospital context, is hindered by concerns about safety, hygiene, limitations in physical infrastructure and restricted financial resources.

Project research

This project performed an in-depth investigation into the current feeding process and associated waste flows at the Sophia Children's Hospital, in order to reduce the environmental footprint of disposable feeding bottles. A qualitative study outlined the journey of a feeding bottle from arriving as an empty product to its disposal as waste, identifying ten sustainability hotspots in total. A quantitative waste audit determined that more than 555 kilograms of feeding bottles are discarded from the PICU alone every year. The consistent use of accessory products, such as feeding teats or enteral feeding sets, further adds to this material waste

The ten hotspots cover a variety of products and processes, and a range of explorative interventions was developed. A key insight is that in 80% of cases, bottles are not used to directly feed a patient but rather act as a reservoir for an enteral feeding set. Together with the identified redundancy of the used screw caps and the frequent use of disposable trays to transport feeding bottles, this finding forms the foundation of the proposed design concept. Addressing these three points was determined to deliver the greatest reduction in the environmental footprint.

The outsized impact of packaged sterile water, which has been identified as more than doubling the overall mass of plastic waste related to feeding bottles, should be noted. Addressing this finding is beyond the scope of this project, yet it is suggested as a key opportunity for immediate changes by the Sophia Children's Hospital.

Design concept

The design concept proposes a lightweight feeding pouch, which reduces the material weight required to transport an equivalent amount of formula milk by 60% compared with conventional bottles. This saves more than 329 kilograms of plastic waste from the PICU annually. The smaller size of this feeding pouch reduces the volume of generated plastic waste by two-thirds and requires 40% less transportation capacity to deliver an equivalent supply of products.

The feeding pouch is recyclable by design through the mono-material construction and supports both teat-based and enteral feeding. As enteral feeding is used in more than 80% of patient cases, a bedside pole holder for the feeding pouch has been developed. Finally, the stackable preparation and transportation tray ensures safe delivery and storage in the PICU.

While the material savings and contribution of the proposed concept to reducing the environmental footprint of infant feeding are evident, introducing any new medical device is a complex challenge. Aside from the development of the next generation of feeding containers and the necessary accessory products, it is the practices surrounding infant feeding that require further examination. Thus, reducing the environmental footprint of infant feeding at the Sophia Children's Hospital requires looking beyond the bottle to the wider system of feeding practices and hospital-wide processes and infrastructure.

12.2 Project limitations

While this project, through the resulting design concept as well as the proposed initial interventions, has provided valuable insights to the Sophia Children's Hospital, several limitations should be noted that affect these results. Potential further implementation or development should consider the following points.

Single-hospital scope

This project has solely investigated the infant feeding process as it is structured at the Sophia Children's Hospital. While this is the result of this project's scope, it is reasonable to assume that other hospitals differ in their feeding practices. The main issue of disposable feeding bottles remains relevant, and different hospitals will require an in-depth investigation of a similar degree as performed in this project to determine their specific needs and conditions.

Additionally, this project has limited its scope to within the physical hospital context. While information on outside organisations related to the production as well as processing of feeding bottles and the resulting waste has been incorporated, these insights are less detailed compared to the information gathered in the hospital.

Waste audit limits

While the performed waste audit is not the first of its type to be conducted, the specific focus on feeding bottle waste leaving the PICU is novel. Due to this, many details previously unknown to the project stakeholders were discovered. However, as with any sample-based investigation, it is necessary to consider the reliability of the gathered data.

The number of patients present on the PICU during the waste collection windows naturally influences the amount of utilised feeding bottles. While the number of patients during each collection window was determined, due to the limited frequency of observations, the connection between these factors should be investigated further.

Lastly, investigation of the identified secondary waste stream was not possible in the time frame of this project. Thus, all results based on the waste audit should be seen as lower-bound estimates.

Integration and compatibility challenges

A key point of the proposed feeding pouch is its direct integration with existing hospital products. This is achieved by incorporating the same screw thread and bottleneck size as used on current feeding bottles, allowing the pouch to be attached to feeding teats as well as enteral feeding sets. This is a central element of the concept

However, incorporating these elements significantly increases the overall dimensions of the rigid collar. This limits the amount of reduced material mass. It is suspected that the size of the bottleneck is primarily to accommodate the feeding teat, as the enteral feeding tube is significantly smaller. Adjusting the entire range of supporting products was beyond the scope of this project, but aligning the entire range of feeding products to a smaller bottleneck would allow for even greater material savings.

Constraints on evaluation with context stakeholders

This project relies on the contributions of the various people working in the many departments of the Erasmus MC. While all of them were kind enough to share their experiences, they were all limited in their availability due to the highly demanding hospital environment. Thus, it was not possible to perform many formal, organised interviews. However, job shadowing and informal conversations allowed observation of real practices in context.

In particular, in the last phase of the project, an unforeseen mandatory isolation of the PICU was mandated. This severely restricted access to key context users, limiting further validation of the developed design concept.

Lack of evaluation with patients

Due to ethical concerns in performing research, and especially testing of medical devices with vulnerable patient groups, all evaluation of the design concept was limited to hospital staff feedback and simulated use. While based on existing technology and materials, the novel approach of the design concept to infant feeding could be validated with testing on human research subjects. Considering the medical context, this testing should obtain ethical approval to minimise potential risks and be performed with a more refined design concept. A move beyond the bottle should also consider revisiting the established guidelines and protocols used in the Erasmus MC.

12.3 Future recommendations

Several topics identified in this project present an opportunity for continued development. In particular, changing the use of packaged sterile water has the potential to achieve a significant reduction of the waste mass associated with the infant feeding process. The proposed design concept and the supporting process research can both be further expanded on, and this is suggested as a starting point for further projects.

Change the current use of sterile water

While not developed further in the project, the outsized impact that packaged sterile water has on the environmental impact associated with infant feeding presents a major opportunity. As has been established, the use of sterile water is supported by potentially superseded studies and has a significant associated financial cost. Thus, changing the current practices can be both medically sound and economically lucrative, an attractive combination.

The relevance of the established guidelines should be investigated in a formal study. Commercially available solutions, which can range from less densely packaged sterile water to installation of water sterilisers, should also be investigated. The possibility of using boiled and then cooled water, already present in the current guidelines, should be investigated with a view that includes the high energy associated with the extended boiling and subsequent cooling of water.

Beyond the PICU

As has been stated, this project has solely investigated the infant feeding process as it is structured in the PICU at the Sophia Children's Hospital. It is suggested that other departments, such as the paediatric medium care and the neonatal ward, are included in further developments. Differences in the quantity of patients and nursing practices compared to the PICU could highlight other environmental hotspots and offer new opportunities.

Scaling production and costs

The design concept has been produced with additive manufacturing. While this method allows for rapid development and iterative design, different manufacturing methods are envisioned for further development. Achieving a surface quality which is food safe, as well as not limiting the flow of liquid due to the differences between the deposited layers, are some of the primary considerations.

The concept proposes the use of mono-propylene as a material that is food safe and suitable for the mass production of the rigid collar. Continued development of the design concept should consider suitable production methods in greater detail. In particular, the proposed construction method for the flexible pouch should be evaluated for its practicality in collaboration with industry specialists.

The financial aspect of establishing the production and the required scale needed to introduce this next generation of feeding bottles also requires more consideration. Lastly, developing sterile production as well as packaging to adhere to guidelines on medical devices should be considered.

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Appendix

Appendix A - Disposable feeding bottles in greater detail

Appendix B - Waste management location of the Erasmus MC

Appendix C - Waste Audit overview

Appendix A - Disposable feeding bottles in greater detail

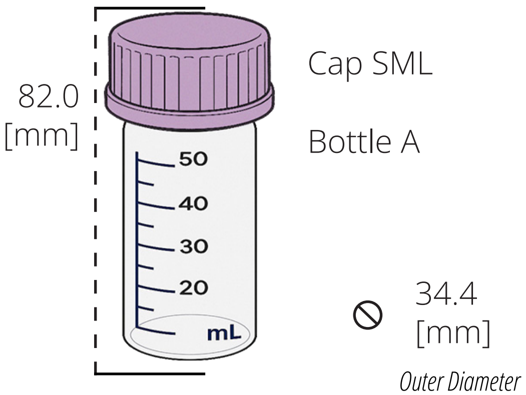
Appendix Content

There are four types of bottles currently in use in the Sophia Children's Hospital for infant feeding. A small bottle of 50 mL capacity, a medium bottle of 130 mL capacity, a large bottle of 250 mL capacity and an extra-large bottle of 500 mL capacity.

The following sections provide the overall dimensions as well as the material composition of each bottle. The material composition extends to the packaging in which is bottle is stored in the Sophia Children's Hospital.

Images of each bottle and its associated packaging are also provided.

Small Bottle, 50 mL



The smallest bottle in use. It is sometimes used for very small volume feedings, but most often in collecting and storing breast milk.

Latex-free, phthalate-free, and Bisphenol A-free

Product Manufacturer: SteriFeed

Product Details

	Material	Mass (g)	%
Packaging	Polyethylene	0.23	1.76
Bottle	Polypropylene	8.55	65.47
Cap	Polypropylene	4.28	32.77
Total	Mix	13.06	100

Figure A.1 - Small bottle and cap

Figure A.2 - Small bottle packaging

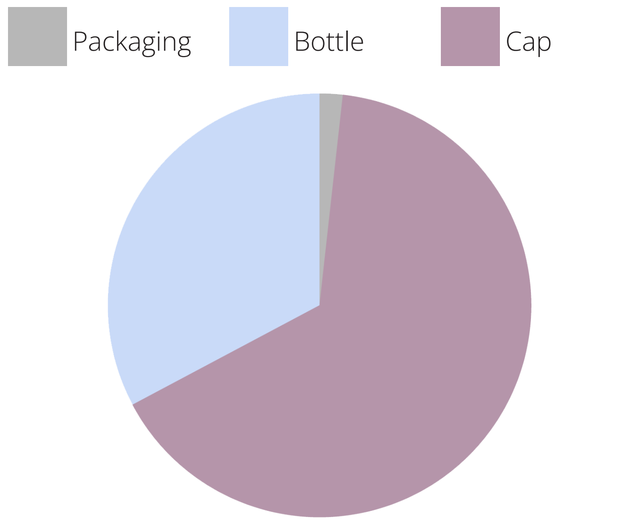
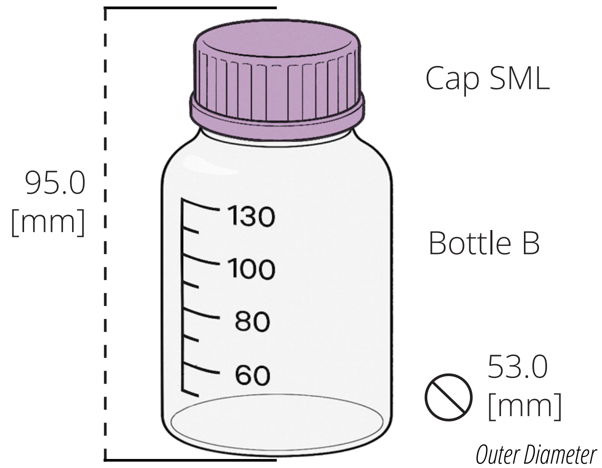


Figure A.3 - Distribution of weight of small bottle

Medium Bottle, 130 mL



Product Description

This is the medium bottle in use. This bottle shares a dieamter with the large bottle.

Latex-free, phthalate-free, and Bisphenol A-free

Product Manufacturer: SteriFeed

Product Details

	Material	Mass (g)	%
Backing	Cellulose	0.75	3.52
Blister	Polyethylene	1.45	6.81
Bottle	Polypropylene	14.80	69.55
Cap	Polypropylene	4.28	20.11
Total	Mix	21.28	100

Figure A.4 - Medium bottle and cap

Figure A.5 - Medium bottle packaging

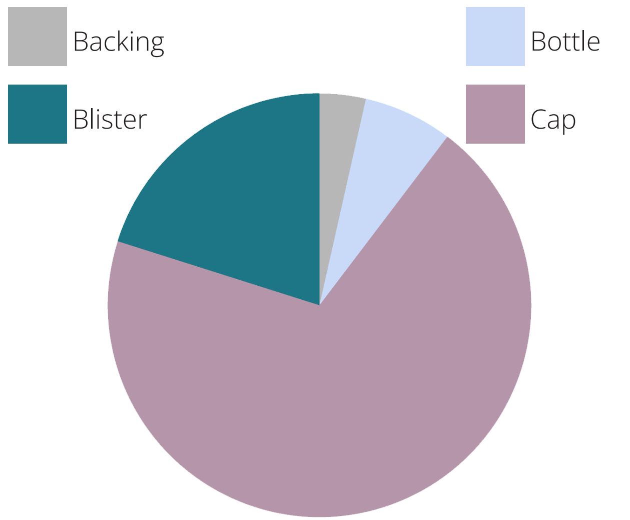
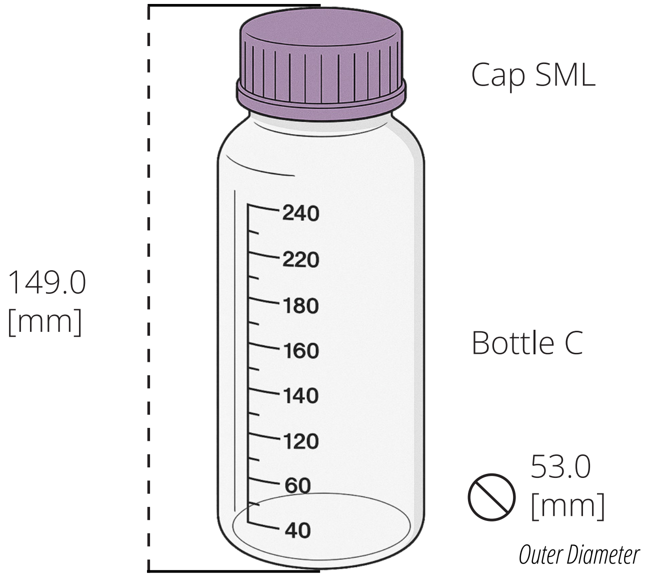


Figure A.6 - Distribution of weight of medium bottle



Product Description

This is the second to largest bottle in use. This type of bottle is the most common and shares a diameter with the medium bottle.

Latex-free, phthalate-free, and Bisphenol A-free

Product Manufacturer: SteriFeed

Product Details

	Material	Mass (g)	%
Backing	Cellulose	0.33*	1.20
Blister	Polyethylene	0.9*	3.31
Bottle	Polypropylene	22.15	80.02
Cap	Polypropylene	4.28	15.46
Total	Mix	27.66	100

**1/6th of total to allow direct comparison with other bottles*

Figure A.7 - Large bottle and cap

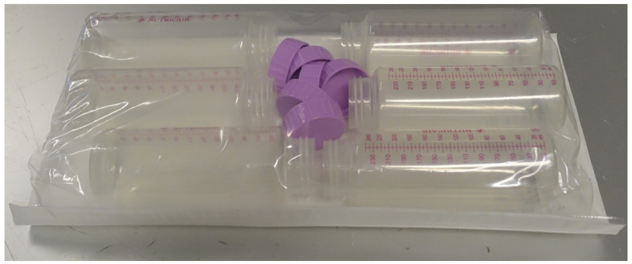


Figure A.8 - Large bottle packaging

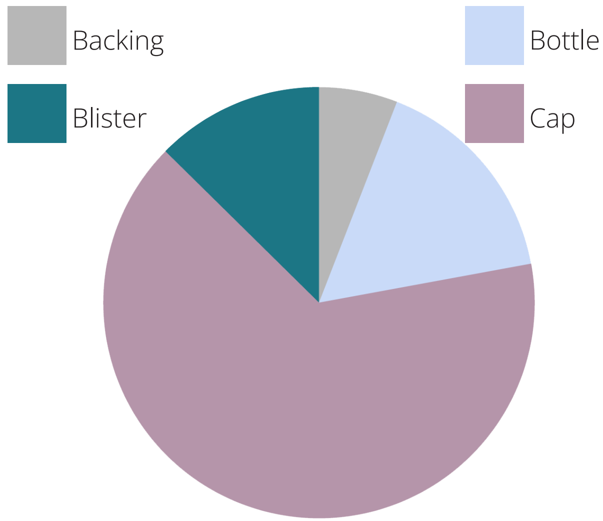
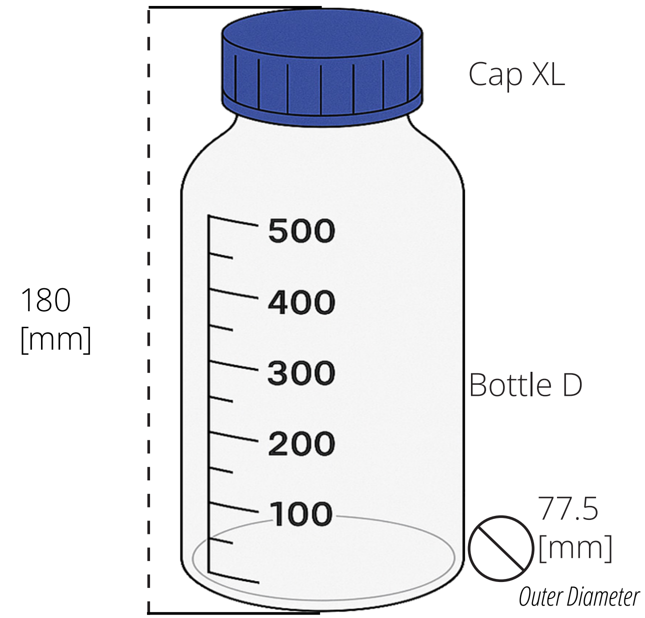


Figure A.9 - Distribution of weight of large bottle

Extra-large Bottle, 500 mL



Product Description

This is the largest bottle in use. This bottle is designed for enteral feeding, featuring an integrated mounting eye for attachment to an IV pole. Graduation embossed for both standing and inverted orientation

Latex-free, phthalate-free, and Bisphenol A-free

Product Manufacturer: Beldico

Product Details

	Material	Mass (g)	%
Backing	Cellulose	1.99	4.40
Blister	Polyethylene	3.99	8.83
Bottle	Polypropylene	34.35	75.98
Cap	Polypropylene	4.88	10.79
Total	Mix	45.21	100

Figure A.10 - Extra-large bottle and cap

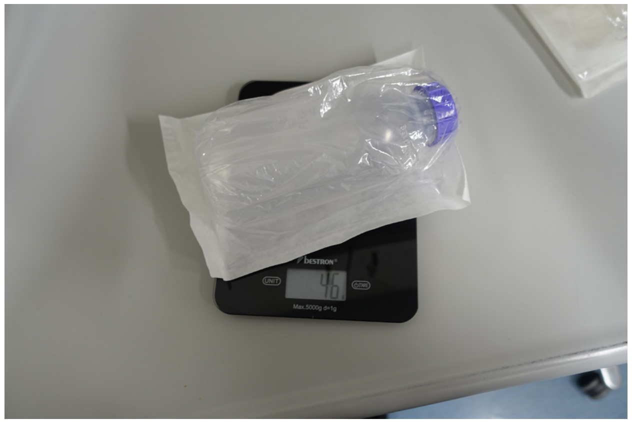


Figure A.11 - Extra-large bottle packaging

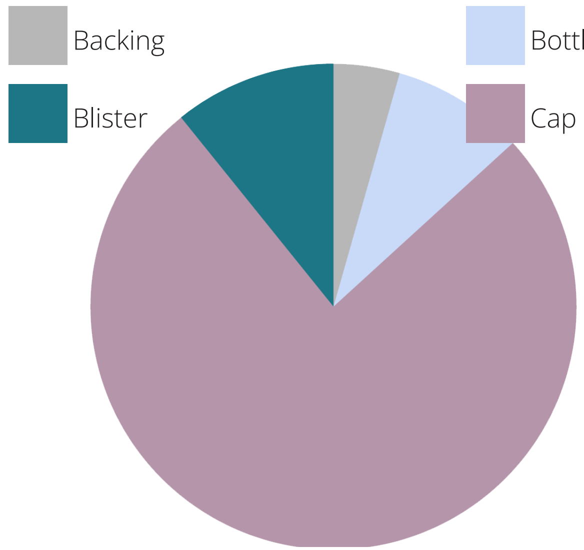


Figure A.12 -Distribution of weight of extra-large bottle

Appendix B - Waste management location of the Erasmus MC

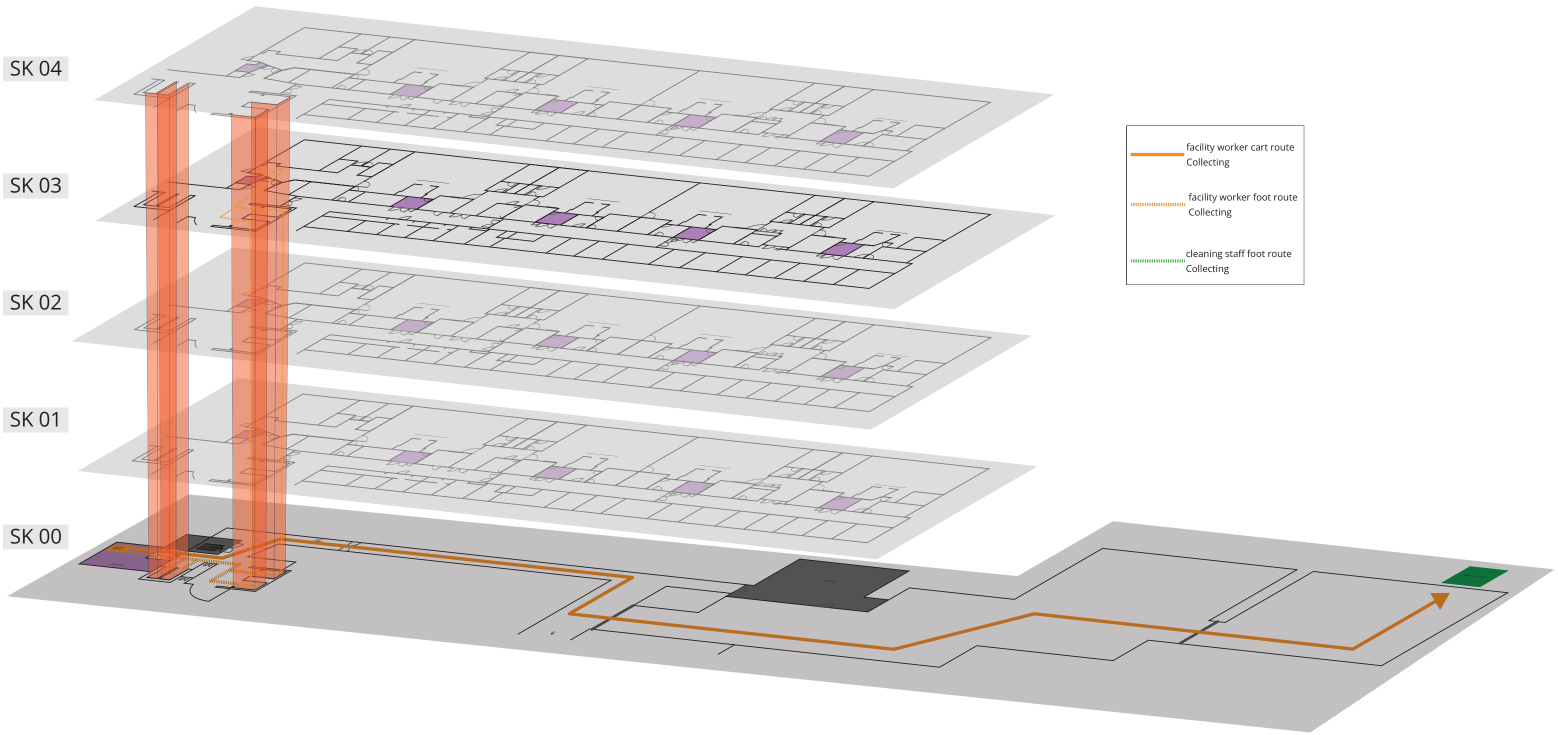


Figure B.1 The connection between the PICU and the EMC waste management location

In Figure B.1, the connection between the PICU, located on the third floor of the Sophia Children's Hospital, and the general waste management location of the Erasmus MC is shown.

Appendix C - Waste Audit overview

Visual overview of bags and content counted during Waste Audit 1.

Waste Audit 1 Wing Bag

Audit Bag 1.1

Audit Bag 1.2

Audit Bag 1.3

Audit Bag 1.4

Audit Bag 1.5

Audit Bag 1.6

Visual overview of bags and content counted during Waste Audit 2.

Waste Audit 2 Wing Bag

Audit Bag 2.1

Audit Bag 2.2

Audit Bag 2.3

Audit Bag 2.4

Audit Bag 2.5

Visual overview of bags and content counted during Waste Audit 3.

Waste Audit 3 Wing Bag

Audit Bag 3.1

Audit Bag 3.2

Audit Bag 3.3

Audit Bag 3.4

Audit Bag 3.5

Personal Project Brief – IDE Master Graduation Project

Name student Anton Kozlov **Student number** 4672321

PROJECT TITLE, INTRODUCTION, PROBLEM DEFINITION and ASSIGNMENT
Complete all fields, keep information clear, specific and concise

Project title Sustainable Bottle Feeding in the Sophia Children's Hospital

Please state the title of your graduation project (above). Keep the title compact and simple. Do not use abbreviations. The remainder of this document allows you to define and clarify your graduation project.

Introduction

Describe the context of your project here; What is the domain in which your project takes place? Who are the main stakeholders and what interests are at stake? Describe the opportunities (and limitations) in this domain to better serve the stakeholder interests. (max 250 words)

The healthcare sector in the Netherlands in 2022 was responsible for 7.3% of the consumption footprint in terms of CO2 emission equivalent (Steenmeijer et al., 2022). This research also showed that healthcare contributes significantly more to the national footprint for material extraction at 13%. The current "throwaway culture" (Steenmeijer et al., 2022) is a significant contribution. Disposable medical products are highly prevalant in the healthcare sector, with established linear supply chains providing a growing amount of disposable products, associated packaging, and the required consumables.

The Erasmus University Medical Center is aware of its impact and has committed to the Green Deal 3.0 (Erasmus MC, 2024). It aims to achieve an irreversible transition to healthcare with minimal impact on climate, the environment and living conditions by 2050. The Erasmus MC Sophia is the associated children's hospital and provides a wide range of pediatric care. This pediatric care significantly contributes to the hospital's overall carbon footprint, at 16.3%, surpassing all other departments.

A major theme of Green Deal 3.0 relating to sustainable healthcare is the need to work with materials circularly and sparingly with ongoing efforts to reduce disposables, increase reusables, and even achieve reduction. The necessity for sterility due to the risks of infections makes pre-packaged and disposable options ideal from an ease-of-use perspective. This puts the hospital's duty to patient care at odds with its mission of sustainable healthcare.

The concerns of patients and their caregivers about changing established practices and products must also be considered. The current producers of disposable products and their supply chains also contribute to the "throwaway culture" and their pressure on current and future inventory must also be considered.

Erasmus MC. (2024, January). Strategy28 The future starts with doing. https://www.erasmusmc.nl/-/media/erasmusmc/pdf/2-themaoverstijgend/strategiedoc-koers28-en-19juli.pdf
Steenmeijer, M., Pieters, L., Warmenhoven, N., Huiberts, E., Stoelinga, M., Zijp, M., van Zelm, R., & Waaijers-van der Loop, S.

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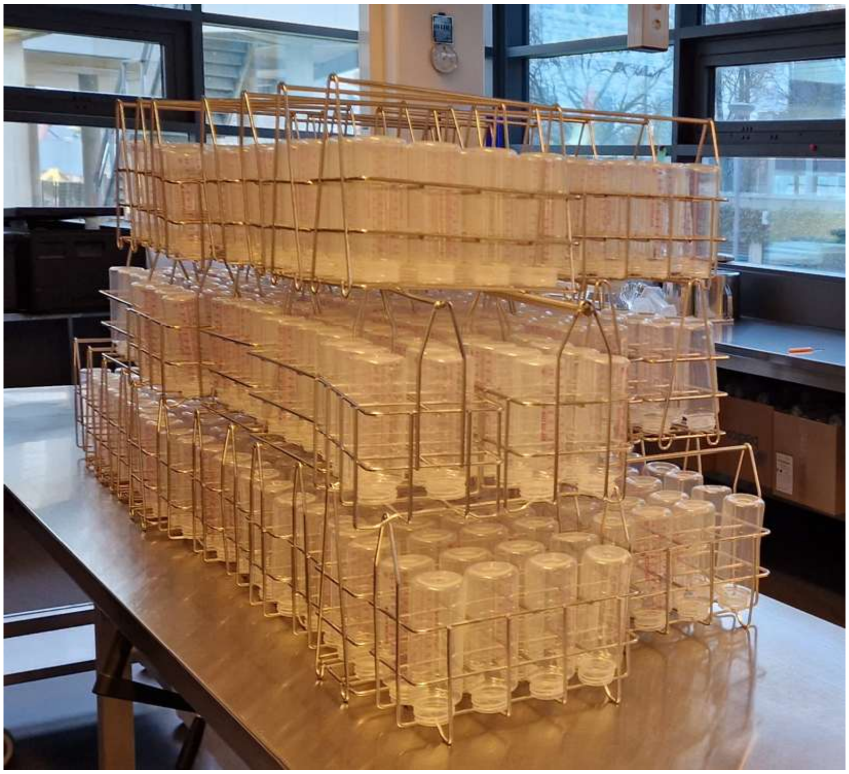

image / figure 1 Current disposable baby feeding bottles

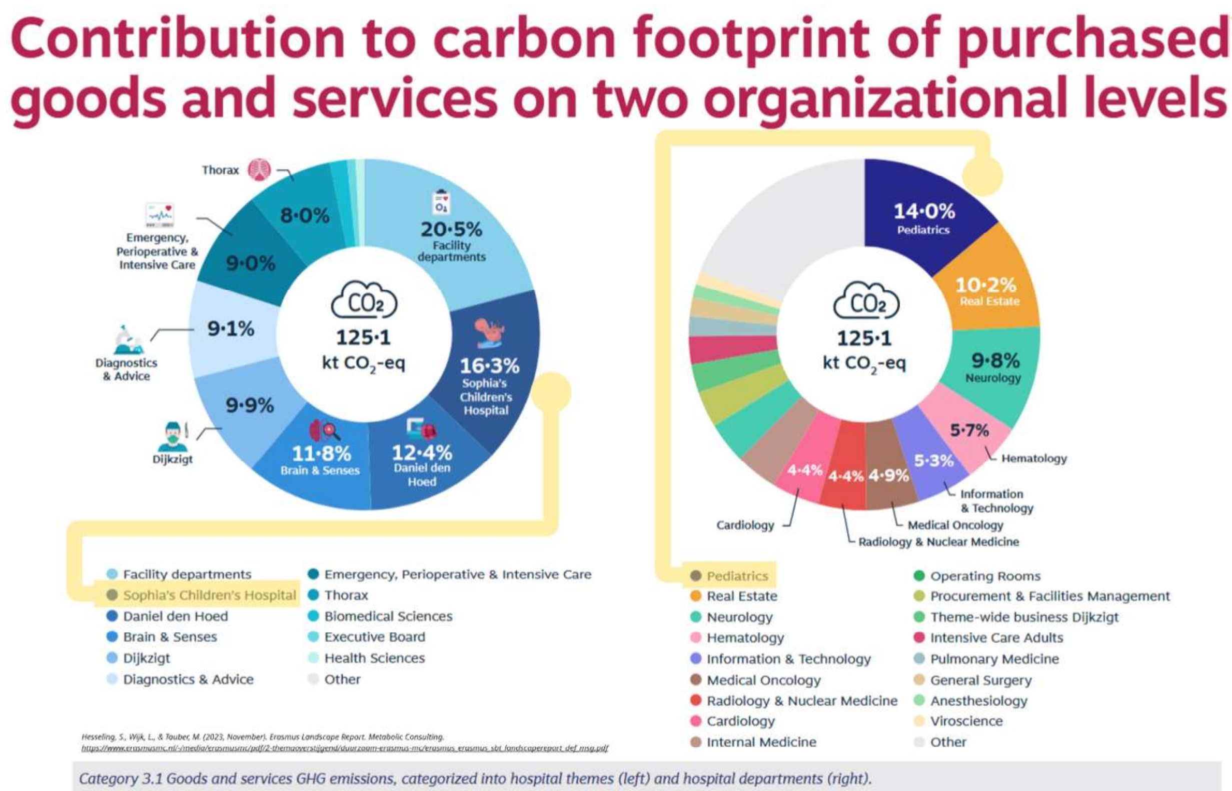

image / figure 2 Contribution to carbon footprint of purchased goods and services, with Erasmus Sophia highlighted

DESIGN FOR our future

TU Delft

Personal Project Brief – IDE Master Graduation Project

Problem Definition

What problem do you want to solve in the context described in the introduction, and within the available time frame of 100 working days? (= Master Graduation Project of 30 EC). What opportunities do you see to create added value for the described stakeholders? Substantiate your choice.
(max 200 words)

An essential task during hospital infant care is feeding. Due to various circumstances, breastfeeding is not always possible, and bottle feeding must be performed. Currently, infant bottle feeding at the Sophia Children's Hospital involves many single-use products. Every feeding involves a disposable bottle, bottle cap, feeding nipple and ring, and associated packaging for each product. Preparing each bottle involves using many other disposables, such as syringes or gloves, which are also often single-use, and other consumables such as sterile water, milk powder, and nutritional additives. This intensity of material use greatly contributes to the overall ecological footprint of the children's hospital.

The differing material composition of the feeding products and packaging and their special status as medical waste all contribute to the challenges of utilizing the material resources. Both in the post-use phase (Achterberg et al., 2016) and in any potential return of resources to a previous phase, current disposable products fall behind. Implementing any of the various R-strategies in the currently linear flow is hindered by shortages in hospital staff, financial resources, and logistic capacity. The need for infection control and adherence to regulatory constraints add to the difficulty. Considerate interventions to reduce resource consumption must assess the needs and demands of the various stakeholders and the long-term qualities of the material enablers, such as being consumable, disposable, or reusable with associated maintenance.

Assignment

This is the most important part of the project brief because it will give a clear direction of what you are heading for. Formulate an assignment to yourself regarding what you expect to deliver as result at the end of your project. (1 sentence)
As you graduate as an industrial design engineer, your assignment will start with a verb (Design/Investigate/Validate/Create), and you may use the green text format:

Design tangible interventions based on a product journey map of the disposable baby feeding product and process in order to reduce the resource consumption for the Erasmus MC Sophia in supporting the hospital's transition to sustainable healthcare.

Then explain your project approach to carrying out your graduation project and what research and design methods you plan to use to generate your design solution (max 150 words)

The project is based on a double-diamond structure, which is divided into initial gathering and synthesis, followed by ideation, conceptualisation, and testing.
The first diamond maps the current situation and aims to create a journey map with environmental hotspots. This is supported by an initial literature review to ground the map's building blocks. The review also aims to determine current practices regarding disposable medical products. The created map is iteratively verified against the healthcare staff's experiences.
The second diamond uses the journey map to develop a tangible intervention based on the hotspot with the most realistic potential for impact and change. Potential areas for change are existing practices in disposing or storing disposable feeding products and associated staff behavior.

To determine the potential change, prototypes will be used in testing sessions using future scenario-based walkthroughs. These rapid co-creative sessions allow for improvement with expert user feedback. The goal is to design for less consumption, and comparative impact analysis will be used to compare current and potential future scenarios. A recommendation on forming the future scenario with the lowest consumption will then be made.

Project planning and key moments

To make visible how you plan to spend your time, you must make a planning for the full project. You are advised to use a Gantt chart format to show the different phases of your project, deliverables you have in mind, meetings and in-between deadlines. Keep in mind that all activities should fit within the given run time of 100 working days. Your planning should include a ***kick-off meeting***, ***mid-term evaluation meeting***, ***green light meeting*** *and* ***graduation ceremony***. *Please indicate periods of part-time activities and/or periods of not spending time on your graduation project, if any (for instance because of holidays or parallel course activities).*

Make sure to attach the full plan to this project brief.
The four key moment dates must be filled in below

Kick off meeting	25 Mar 2025
Mid-term evaluation	05-22-2025
Green light meeting	07-25-2025
Graduation ceremony	08-21-2025

In exceptional cases (part of) the Graduation Project may need to be scheduled part-time. Indicate here if such applies to your project

Part of project scheduled part-time	
For how many project weeks	
Number of project days per week	

Comments:

Motivation and personal ambitions

Explain why you wish to start this project, what competencies you want to prove or develop (e.g. competencies acquired in your MSc programme, electives, extra-curricular activities or other).

Optionally, describe whether you have some personal learning ambitions which you explicitly want to address in this project, on top of the learning objectives of the Graduation Project itself. You might think of e.g. acquiring in depth knowledge on a specific subject, broadening your competencies or experimenting with a specific tool or methodology. Personal learning ambitions are limited to a maximum number of five.
(200 words max)

The Erasmus MC offers a unique opportunity to contribute to a significant problem currently encountered in the healthcare sector. Reducing the high use of disposables, while a seemingly simple problem is shrouded behind a complex web of stakeholders, well-meaning regulations, a duty of patient care, and carefully designed products. Changes to the Erasmus MC are coming from their commitment to the Green Deal 3.0 and upcoming new facilities that all provide space for sustainability and circularity.

My learning ambition includes further exploring systemic design tools and using them to design tangible results. Defining, mapping, and analysis at least part of the the complex healthcare system is very interesting to me.

My previous experience with a design project at the Amsterdam UMC showed me the unique complexity but also opportunities that exist in the healthcare sector. The expertise of medical professionals and all the other associated staff is invaluable in balancing change and innovation and a duty of care and patient safety.

I also wish to explore the differences and intersections that exist between the fields of professional design and healthcare. My access to the Erasmus MC Sophia and, in particular, its staff will be very valuable in developing an understanding of people and medical products in use.