Redesign of Ultrasound Gel Bottle: A Systematic Sustainable Solution for the Radiology Department at the Leiden University Medical Center

Tianxing Shang
Delft University of Technology
2876167
Leiden University Science Faculty
Supervisors: J.J. Faludi and L.M. Kamp
April 2023

Key words: Sustainability, Sustainable Design, Ultrasound Gel Waste, Plastic Waste

Abstract – Radiology department at the Leiden University Medical Center (LUMC) aims at preventing ultrasound gel waste of leftover ultrasound gel in the bottle and reducing the waste of plastic gel bottles. The study identified a critical environmental issue – the excessive use of disposable plastic ultrasound gel bottles in hospitals – and undertook a multifaceted investigation to address this challenge. Through examination of the environmental impact, user feedback, and risk factors associated with alternative solutions such, the research presented three sustainable redesign proposals. Among these, the gel pack design emerged as the most promising option, offering substantial improvements in environmental sustainability without compromising usability or patient safety. Successful implementation of these solutions relies on collaborative efforts involving doctors, regulatory bodies, and industry stakeholders. This research underscored the vital role of sustainability in healthcare and highlighted the potential for significant reductions in environmental impact and plastic waste while upholding healthcare standards.

Contents

1. Introduction

1.1. Background

Climate change, caused by the increasing emission of greenhouse gases, results in rising global temperature, leading to heavy rainfall and heatwaves. These changes have significant impact on healthcare. Meanwhile, healthcare also has major impact on the climate change, having huge carbon footprint. In the Netherlands, CO2 emission from healthcare accounts for 4.4% of the global CO2 emission (Sascha et al. 2023). To minimize the impact of healthcare on climate, transformation towards a sustainable healthcare is necessary, in which reduction of general waste and raw material consumption is one of many measures (M.A. Steenmeijer et al., 2022). Regarding this topic, the complete ultrasound gel bottle made of plastic is considered as general waste in the hospital, targeted to be reduced.

Diagnostic ultrasound is a non-invasive imaging technology that build up fine images of internal body structures. Because of its portability, ease of use, and various application, Ultrasound is widely used for many clinical settings throughout the world. To ensure the image quality and avoid artefacts caused by the air between skin and transducer, a coupling agent is necessary to good contact between them. The World Health Organization (WHO), in the 2011 WHO Manual of Diagnostic Ultrasound, has defined five essential ingredients in the composition of a common ultrasound gel, including carbomer, ethylenediaminetetraacetic acid (EDTA), propylene glycol, trolamine, and demineralized water. Commercially available ultrasound gel is usually contained in sterile plastic containers, such as sachets, doppler-size tube, and dispenser bottle.

Sustainability should be a matter of concern for everyone including the regulatory bodies and common man (Joseph et al, 2021). As one of many steps moving towards sustainable healthcare, reducing the amount of plastic waste and inaccessible ultrasound gel in the complete bottles will have a significant environmental improvement for the healthcare system. Currently, although are there sustainable ultrasound gel solutions proposed and verified, the challenge of unusable gel in complete bottles and plastic waste remain unsolved. This research aims at solving this challenge by aligning interests and responsibilities of relevant stakeholders, reevaluating existing regulations, and proposing a new sustainable design of the ultrasound gel bottle.

Numerous reports advocate for the prohibition of refilling ultrasound gel bottles and emphasize the implementation of hygiene protocols that limit reusability. The primary objective is to mitigate cross-infection risks. Nonetheless, the adoption of a single-use practice has exacerbated the generation of plastic waste within the healthcare sector. Insufficient studies exist to quantify the exact volume of ultrasound gel waste within completed bottles, and a comprehensive assessment of the gel bottle's carbon footprint and environmental impact in the context of this single-use practice is also lacking. To progress towards sustainable healthcare, these gaps necessitate thorough investigation and exploration in future research endeavors.

To solve the sustainability challenge of ultrasound gel bottle packaging, the main research question is:

"What are sustainable and desirable solutions to the ultrasound gel packaging?"

Corresponding sub research questions are:

1. *What is the environmental impact of the echo-gel bottle?*
2. *How might we improve desirability of refilling without compromising safety and sustainability?*
3. *How might we improve environmental impacts by reducing disposables without increasing risks of infection outbreaks?*

This report addresses the sustainability challenge of the gel bottle in following manner. Firstly, the stakeholder analysis is presented to describe the key actors with their interest in and influence. Identifying shared benefits and aligned motivations is crucial for the success of any solution, requiring collaboration among multiple actors. Secondly, baseline performance of the current gel bottle is developed and analyzed for improvement. Refilling of gel bottle is also assessed with consideration of risk and sustainability. Lastly, redesigns of the gel bottle are developed and assessed based on analyzing the current challenge, user specifications, and feedback, to present concluding recommendation and direction for future study.

1.2. Research problem

Importance of not refilling ultrasound gel bottles

As introduced by the Medical Delta and LUMC, in the past, the 250 ml ultrasound gel bottles that they have been using are allowed to be refilled with a 5-liter refill package, besides the fact that this refilling process was quite a struggle. The obvious reasons for refilling the bottles are cost effective and lower gel bottle turnover, reducing both the cost and plastic waste. However, this practice, nowadays, is against the hospital hygiene regulations, because of the potential outbreak of infections caused by the contamination of the refill package, and such outbreak is not an isolated incident. In a report of an outbreak of achromobacter xylosoxidans associated with ultrasound gel used during transrectal ultrasound guided prostate biopsy announced by Olshtain et al., the team described and studied a case in September 2008, during which 4 patients were hospitalized with fever several days after undergoing transrectal ultrasound guided prostate biopsy. The root cause of this case that the team confirmed was contaminated lubricant gel in a plastic container that was repeatedly refilled from a large bag. Similarly, in an analysis of intermittent outbreaks of nosocomial infection due to Burkholderia cepacia complex in patients without cystic fibrosis since 1992, Jacobson et al. also determined that the cause of these outbreaks was contaminated ultrasound gel from the refilling of 250 ml gel bottles and suggested that refilling and transportation of bottles between different united should be prohibited. In another study Investigating a Pseudo-outbreak of Burkholderia cepacian, Silmon et al. determined that the cause was contaminated ultrasound gel from refilling of bottles and emphasize the importance of why these bottles should not be refilled. Transmission of infection with ultrasound gel has been well reflected in the medical literature (Costello, 2020). Because of potential contamination of gel and bottle surface, the refilling of ultrasound gel containers present high risk to patients. Therefore, reusable ultrasound gel container should not be an option in the hospital.

Figure 1: Parker Aquasonic 100, gel 250 ml bottle

Waste of ultrasound gel and bottles

As mentioned above, considering the risk of infection and outbreak among patients caused by contaminated refilled ultrasound gel and its bottles, refilling of the gel bottle is prohibited. These plastic bottles must be thrown as general waste after completion. The amount of waste of these bottles is enormous, because of the high turnover of these gel bottles. At the obstetric department of LUMC alone, around 8 to 10 gel bottles are completed every day, and there are 5 other departments (radiology, intensive care unit, gynecology, cardiology, and urology) using ultrasound gel intensively. Among the total plastic waste from operating room of OLVG hospital in the Netherlands, plastic medical bottle and accessories waste takes nearly 4% of the total plastic waste (Circle Economy, 2016). Although, there is no report presenting exact amount of plastic waste resulted from ultrasound gel bottles, this plastic waste takes a nonnegligible percentage of the total plastic waste from health care.

Other than the issue of plastic waste from ultrasound gel bottles, the ultrasound gel wasted in completed bottles is also worth noticing. Because of the high viscosity of ultrasound gel, there is always certain amount of ultrasound gel inaccessible at the end of the bottle, as shown in the Figure 2. An adequate metaphor would be the last bit of ketchup in the bottle, due to their similar viscosity. Even when the gel bottle is placed upside down, the force of gravity is insufficient to break the static resistance and displace the gel (Lecluyse, 2015).

Figure 2: Inaccessible ultrasound gel in a complete bottle

Even though, this little amount of ultrasound gel looks insignificant compared to an entire bottle, the accumulated waste of ultrasound gel is nonnegligible in the hospital, considering the high turnover of the gel bottle.

Current alternatives of ultrasound gel and bottle

To prevent the ultrasound gel waste in complete bottles thrown away, the obvious solution is replacing the gel by liquids with low viscosity, such as olive or mineral oil. In a study of comparing the sonographic image quality between the examinations using gel and olive oil, Luewan (2007) conducted a study of 692 scans and concluded that there is no significant difference in image quality between using ultrasound gel and olive oil. Another study, evaluating the mineral oil as an acoustic coupling medium in clinical, also supported that mineral oil may be used as a coupling agent at the Mylar–drape interface (Gorny et al., 2007). Both olive and mineral oil can serve as coupling agent in ultrasound imaging examinations. However, they also have significant drawbacks. Oil is messy, can stain clothes, and again, does not provide enough surface contact to obtain high-quality images (Binkowski et al, 2007). Without compromising the ultrasound image quality and contaminating patients' clothes, it seems no better coupling agent better than commercially available ultrasound gels.

Another solution is using ultrasound gel container of a different shape to minimize the wasted ultrasound gel at the end. Currently available on the market, ultrasound gel packed in sterilized single-use sachets has least amount of gel remained when completed, because of the shape and physical property of the packaging as illustrated by Figure 3.

Figure 3: Single-use sachets of ultrasound gel

Moreover, as the sachets are completed and thrown away after single use, risk of cross-infection is significantly minimized, compared to the 250 ml gel bottle. Supported in a report of prevention of pathogen transmission during ultrasound use, single-use sachets of sterile ultrasound gel are relatively cheap and present the best option to minimize potential contamination and cross-infection between patients (Costello, 2020). However, use of this type of ultrasound gel packaging will aggravate the plastic waste from hospital, as 50% more plastic is used to contain a unit amount of gel.

Potential measures for a sustainable solution

As the accumulation of the plastic waste is one sustainability challenge of ultrasound gel bottle, recycling this waste into new plastic product can mitigate the issue. At hospital, classification at waste generating sources, depending upon infection chance and or plastic component (Joseph et al., 2021) has potential to improve the recycling of plastic. At the LUMC, waste is separate into 37 streams, with half is recycled (LUMC, 2022). However, there is no further classification of the gel bottle waste. Eliminating the use of this fossil-based plastic could also solve the problem from origin. Biodegradation and Biobased are often included in discussions of substitution of fossil-based plastic. Many studies have shown potential of biodegradable plastic in medical application that will not influence the current recycling process, such as locally compostable single-use items (Moshood et al. 2022, Dilkes-Hoffman et al. 2022, Colwill et al. 2012, Cornell, 2007, Song et al. 2009).

1.3. Stakeholder's information

The stakeholder's information helps to identify who should be closely involved in testing of redesigned prototypes, and what fundamental rules should be followed by redesigns. In the following figure, interest and power of stakeholders are visualized. Interest is defined as the alignment of ambition and desirability to the sustainable solution of gel bottle, whereas the power is defined as the influence of stakeholders on achieving this sustainable solution of gel bottle.

Doctors

Doctors at the LUMC refers to people working closely with ultrasound examinations. They have the most experience in use of ultrasound gel and the most interest in improving sustainability of gel bottles, proposing this sustainability challenge. Through conversations with Dr. Lap, fellow in perinatology at the LUMC, and her colleagues, they expressed the most interest in reducing both gel waste and plastic waste and improving usability, searching for alternative products and practices. However, their ability to driving such change is constrained by the hygiene rules and infection prevention department, unable to experiment products or practices that have uncertain effects on infection risk.

RIVM

The RIVM (National Institute for Public Health and the Environment) plays a significant role in promoting and advancing sustainable healthcare in the Netherlands. The RIVM is committed to safeguarding a healthy population living in a sustainable, safe and healthy environment (RIVM, 2023), aligning with sustainable healthcare. It has interest in overall sustainability in healthcare, but less in the sustainability challenge of gel bottle. Regarding the power, the RIVM has the most influence. Hygiene measures specific to ultrasound examinations are embedded in the general precautions that are common in all departments (RIVM, 2018).

LUMC

The LUMC ranks the second in interest in the sustainability challenge of gel bottle. This topic aligns with the vision of sustainability at the LUMC which aims at reducing 49% CO_2 emission and 50% raw material consumption by 2030 (LUMC, 2023). Regarding the power, the LUMC ranks higher than doctors but lower than the RIVM. The infection prevention department at the LUMC regulates and monitors procedures of ultrasound gel application under the instruction of relevant hospital hygiene rules provided by the RIVM. In conversation with Mw. U. van der Velden and Drs. M. Jungblut, experts of sterile medical devices at the LUMC, they prioritized hygiene rules and safety over sustainability of gel bottle, emphasizing the critical importance of patients' well-being.

Medical Delta

Medical Delta is a collaborative partnership between academic institutions, healthcare organizations, and industry in the South Holland region of the Netherlands. Together with companies, healthcare institutions and governments, Medical Delta works on technological solutions for sustainable healthcare (Medical Delta, 2023). In the area of sustainability, it started the Interdisciplinary Thesis Lab 'Sustainable Hospitals' with LDE Centre for Sustainability, aiming to facilitate on the pathway to sustainable hospitals, providing valuable opportunity to research on actual sustainability issues of hospitals and the industry. “New insights from young researchers on this theme are desperately needed to make healthcare more sustainable,” said Medical Delta chairman Prof. Dr. Frank Willem Jansen.

Parker Laboratories

Parker Laboratories, Inc. is the manufacture of ultrasound gel products used in the LUMC. As a leading global medical products company that develops, manufactures, and sells ultrasound and electromedical contact media, as well as leading lines of institutional cleaners and disinfectants, Parker Laboratories is focused on consistently providing products that meet or exceed industry standards and customer expectations (PARKER, 2023). However, without specific information available regarding Parker Laboratories' sustainability initiatives or official statements, it is challenging to determine the extent of their power and interest in sustainable healthcare. Therefore, Parker Laboratories is assumed to have the lowest power and interest.

As stated in this analysis, doctors at the LUMC present the most interest in solving this sustainability challenge of gel bottle; they were closely involved in the prototype testing of redesigns. Their feedback was collected through tests as design requirements. As the RIVM holds the most power in regulating procedures in hospitals, the hygiene measures of ultrasound examination provided by RIVM was the fundamental rule followed by redesigns of ultrasound gel bottle.

2. Research methods

2.1. Baseline performance of gel bottle

Fast-track LCA

Fast-track LCA is the main tool to assess the environmental impact of the gel bottle. The Fast-track LCA is a simplified tool of estimating the environmental impact of products. For this LCA, the IDEMAT 2021 tool was used, to establish the baseline impact of the current gel bottle. This tool was provided in the course material of Sustainable Design Strategies for Product (ID5356) at Delft University of Technology. Data used in the LCA is from the IDEMAT 2021 tool, Ecoinvent database, and measurement.

System & system boundaries

The geographical boundary is within the LUMC, and the focus is redesigning the 250ml ultrasound gel bottle for only application in external ultrasound examinations. The gel supplier is Parker Laboratories, Inc. and the product is 0.25L Aquasonic CLEAR® Ultrasound Gel. The LCA boundary is cradle to grave. Packaging of the product is not included. The ink of painting on the bottle is also not considered. The transportation method from the USA to the Netherland is container ship, and from the Rotterdam port to the LUMC is truck.

Definition of Functional unit

The functional unit of this fast-track LCA is weight of annual gel consumption at the LUMC, excluding wasted gel. Assuming each department at the LUMC consumes 10 gel bottles every day on average, and there are 6 departments that use this type of gel bottle, the number of annual gel bottle consumption at the LUMC is 21900 bottles/yr. Translating number of bottles to actual weight of gel consumed, the functional unit is 5058.9 kg/yr. The focus is the environmental impact of gel bottle consumption at the LUMC for a year, translated to CO_2 eq.

Data source

Input of the IDEMAT tool for this fast-track LCA requires raw material type, weight of items, eco-intensity data, transportation method and distance, and uncertainty. The bottle is made of low-density polyethylene (LDPE) as marked on the bottom of the product. Weight of the bottle and gel waste were measured on digital kitchen scale form HEMA. Manual of diagnostic ultrasound published by the WHO was used to identify ultrasound gel ingredients and their ratio. Transportation method from Parker in the USA to Rotterdam port was assumed to be container ship, and this distance was calculated by using sea distance calculator provided by ShipTraffic.net. On-land transportation method was assumed to be truck, and distances from Rotterdam to LUMC and from LUMC to Renewi were calculated by using Google Maps. Eco-intensity data of EDTA, propylene glycol, trolamine are acquired from Ecoinvent database. The eco-intensity data of carbomer 940 could not be found, and since it is one derivative of acrylic acid (Ohara, 2020), the eco-intensity data of carbomer 940 is assumed to be the same as that of acrylic acid, also acquired from Ecoinvent database. Other eco-intensity data are provided within the IDEMAT tool. Uncertainty was assigned as guided by the IDEMAT tool, 10% for precise data & perfect database match, 30% for plausible substitution, 100%+ for wild guess.

2.2. Assessment of refilling

It is believed by Dr. Lap and other doctors that refilling gel bottle is a more sustainable practice, considering less plastic waste resulted from extended life of bottle. This refilling practice was assessed from two different aspects, assessment of risk and assessment of sustainability. In the assessment of risk, sixteen hospital outbreak cases related to the use of ultrasound gel (Abdelfattah et al, 2018; Dogra et al, 2021; Du et al, 2021; Garay et al, 2012; Hell et al, 2011; Hutchinson et al, 2004; Jacobson et al, 2006; Nannini et al, 2015; Olshtain et al, 2011; Provenzano et al, 2013; Ramanathan et al, 2018; Shaban et al, 2017; Silmon et al, 2019; Solaimalai et al, 2019 ; Viderman et al, 2020; Wang et al, 2014) are reviewed to determine the ratio of each fundamental causes of infection, assessing the actual risk of refilling gel bottle.

In the assessment of sustainability fast-track LCA was conducted using the same IDEMAT tool, to assess environmental impact of refilling gel bottle and compare to that of the baseline. System boundary and functional unit remain the same as that of baseline for a standardized comparison. The 5-liter SONICPAC® refill pack form the same manufacture was the additional product added to this LCA. Instruction of use provided by Parker Laboratories was used to determine period of refilling and cleaning material. Total consumption of bottles and refill packs are calculated based on period of refilling. Soap and water are additional materials required for cleaning of bottles before being refilled. Packaging material of this refill pack is also LDPE plastic, indicated on the product. Same digital kitchen scale was used to measure weights of gel waste and material of this refill pack, as well as soap. Eco-intensity data of soap was acquired from Ecoinvent database, and all other inputs remain the same as that of baseline.

2.3. Design process: prototypes, testing, iteration

Sustainable design strategy

In this research, a sustainable redesign of ultrasound gel bottle will be proposed based on the result of LCA of the current gel bottle, aiming at reducing gel waste and environmental impact, enabling circularity of the gel bottle, and remaining within the hospital hygiene rules. The sustainable design strategy will be utilized in the redesign process, consisting of eco-design, cradle-to-cradle (C2C) design, and biomimicry design elaborated in the following.

- **Eco-design**
  Eco-design is a set of strategies evaluating the sustainability performance at different stages of a product, providing a clear understanding of possible strategies for new product design (van Boeijen, et al. 2020) with minimized environmental impact. This set of strategies is visualized in the following figure of the EcoDesign Strategy Wheel.

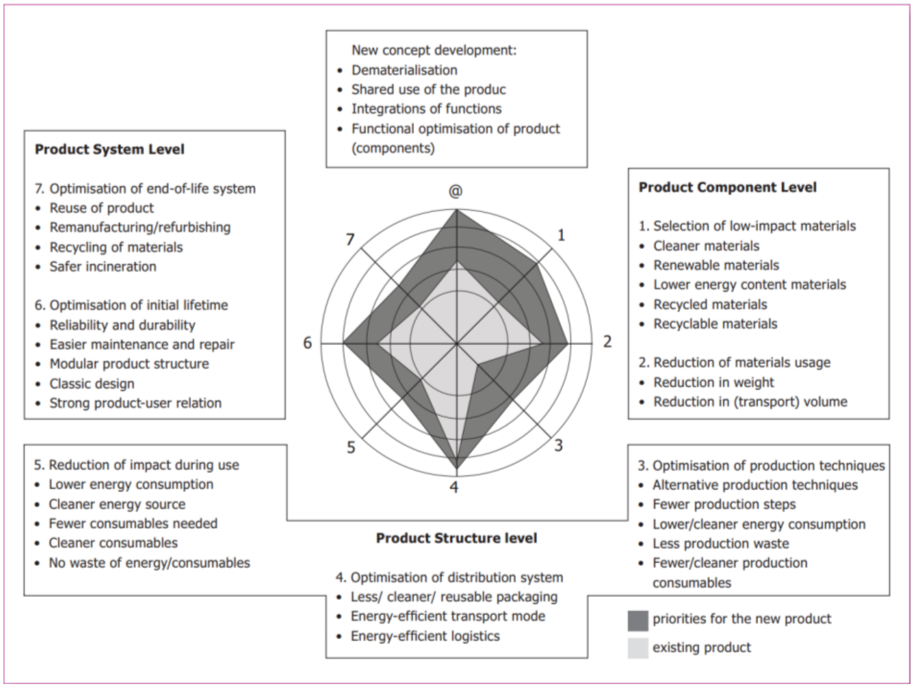


Figure 4: The EcoDesign Strategy Wheel (Brezet and van Hemel, 1995)

- **C2C design**

  Instead of downcycling, C2C design enables circularity of materials through technical cycle, biological cycle, or both, abandoning the concept of waste. A roadmap of C2C design consists of five stages which can be used as a guide to improve consecutive product generations (van der Grinten, 2022). The five stages are shown in the following.

  1. **Produce without harmful contaminants: X-list materials** (harmful to life and impossible to guarantee 100% retrieval like PVC and cadmium) are phased out.
  2. **Follow informed personal preference:** Contents of stock materials are not always known. Choose on available information and common sense and involve suppliers as valued co-developers.
  3. **Create a passive positive list:** Create a positive list/ P-list of beneficial materials that could phase out the harmful ones and pick the easy improvements first.
  4. **Activate the positive list:** The product is fundamentally redesigned using p-list materials and using design with intent; defining desired effects of the product and accepting no adverse effects.
  5. **Rediscover:** Review the design assignment beyond the biological and technical cycles. Think of auxiliary benefits that a product could bring, making a positive impact on its context.

- **Biomimicry design**

  Biomimicry design is a process emulating nature's genius, a way of seeking sustainable solutions by borrowing life's blueprints, chemical recipes, and ecosystem strategies (Benyus, 2015). The Life's Principles illustrated in the following figure will be used to guide the redesign of ultrasound gel bottle.

Figure 5. Life's Principles for biomimicry design (Benyus, 2015)

Prototypes and iteration

Prototypes were designed and made by utilizing sustainable design strategies mentioned above, and they were tested through iterations with participants listed in the following table. Most of these participants were involved throughout testing iterations.

Participant	Title
Dr. Lap	Gynaecologist, Fellow perinatology at LUMC
Dr. Snoep	Doctor of prenatal medicine at LUMC
Dr. PN Adama van Scheltema	Senior doctor in prenatal medicine at LUMC
Dr. Smit	Doctor of prenatal medicine at LUMC
Dr. van den Berg	Innovation manager at Medical Delta
Dr. L. van Persijn - van Meerten	Abdominal radiologist at LUMC

Table 1. Participants in prototype testing

The insights gained from the assessment of desirability informed the iterative design process of the gel bottles. Feedback from medical professionals guided refinements and adjustments in the bottle design to address identified issues and improve user satisfaction. Finally, three redesigns, one from each design strategy, were proposed and evaluated quantitatively and qualitatively.

2.4. Assessment of desirability

The assessment of desirability for the redesigned gel bottles aims to ascertain the acceptance and suitability of the redesigned gel bottles within the medical community, with a particular focus on medical professionals, notably doctors mentioned above. In this subsection, specific methods and criteria employed to evaluate the desirability of the redesigned gel bottle prototypes among medical professionals are outlined.

Interviews were conducted with doctors, to assess the desirability of both current and redesigned gel bottles. These interviews served to gather expert opinions on various aspects of the bottles. Special attention was paid to assessing the usability and functionality of the redesigned gel bottles. This encompassed evaluating how easily healthcare professionals could interact with and utilize these bottles in their daily activities. Factors such as ease of handling, dispensing efficiency, and compatibility with existing medical equipment were evaluated. This assessment aimed to pinpoint specific areas where the redesigned bottles excelled and areas where potential improvements were needed. In addition to usability and functionality, the extent to which the redesigned bottles met the specific needs and preferences of healthcare practitioners was assessed with medical professionals. Understanding these needs and preferences is pivotal in ensuring that the redesigned bottles align with the requirements of the medical community.

Meanwhile, prototype testing sessions were conducted with doctors. During these sessions, medical professionals interacted with the redesigned gel bottles to simulate real-world usage scenarios. Participants were encouraged to assess how easy it was to handle and dispense the gel from the redesigned bottles. Comfort and efficiency of using the redesigned bottles were also assessed with feedback on physical comfort while handling the bottles, preventing discomfort or fatigue from prolonged usage. Given the diverse application of ultrasound gel and associated devices used in healthcare settings, participants assessed the compatibility of the redesigned gel bottles with their existing tools, including evaluating whether the bottles could seamlessly integrate with gel warmer, ultrasound machine, and different types of examinations.

The assessment of desirability for the redesigned gel bottles involved structured interviews with medical professionals and prototype testing. This process ensured that the redesigned gel bottles met the needs and preferences of healthcare practitioners and complied with the necessary medical standards, enhancing their overall desirability within the medical community.

3. Results and discussion

3.1. Baseline performance

In this subsection, necessary information for analyzing the gel bottle is listed in the following table. The weight of a full gel bottle is measured 291 g, and empty bottle of 27 g. The gel waste in the complete bottle is measured around 33 g, 12.5% of total weight of gel in a full bottle. This gel waste is classified into the use phase to better compare the environmental impact of each category. This shipping distance is calculated 7256.1 km. On-land transportation distances from Rotterdam to LUMC and from LUMC to Renewi are 41.9 km and 88.1 km respectively.

Manufacturing		**Eco-intensity (impacts/kg)**	**Mass per item (kg)**		**Items per func.unit (#)**	**Uncertainty %**
	LDPE	1.87	0.027		21900.00	10%
	Bottle Making	0.91	0.027		21900.00	10%
Transport		**Eco-Intensity (impacts/ ton-km)**	**Mass per item (ton)**	**Distance per item (km)**	**Items per func.unit (#)**	**Uncertainty %**
	From PARKER (USA) to Rotterdam Port	0.00480	3E-05	7256.10	21900.00	10%
	From Rotterdam to LUMC	0.00103	3E-05	41.900	21900.00	10%
	From LUMC to Renewi	0.00103	3E-05	88.100	21900.00	10%
Use		**Eco-Intensity (impacts/MJ or other)**	**Amount per item (MJ or other)**		**Items per func.unit (#)**	**Uncertainty %**
	Carbomer 940	2.2339	0.0006		21900.00	30%
	EDTA	4.3407	0.000015		21900.00	10%
	Propylene glycol	4.39	0.005		21900.00	10%
	Trolamine (triethanolamine)	3.03	0.0007500000		21900.00	10%
	Distilled water	0.00	0.024		21900.00	10%
End of Life		**Eco-Intensity (impacts/kg)**	**Mass per item (kg)**		**Items per func.unit (#)**	**Uncertainty %**
	Plastic waste handling	0.088	0.0270000000		21900.00	10%
	LDPE Plastic Incineration	0.054	0.0270000000		21900.00	10%

Table 2: Basic information of the gel bottle

A LCA is created to find out what the impact is of the gel bottle consumption at the LUMC and set the baseline performance. The following Figure 6 illustrates the environmental impact by category.

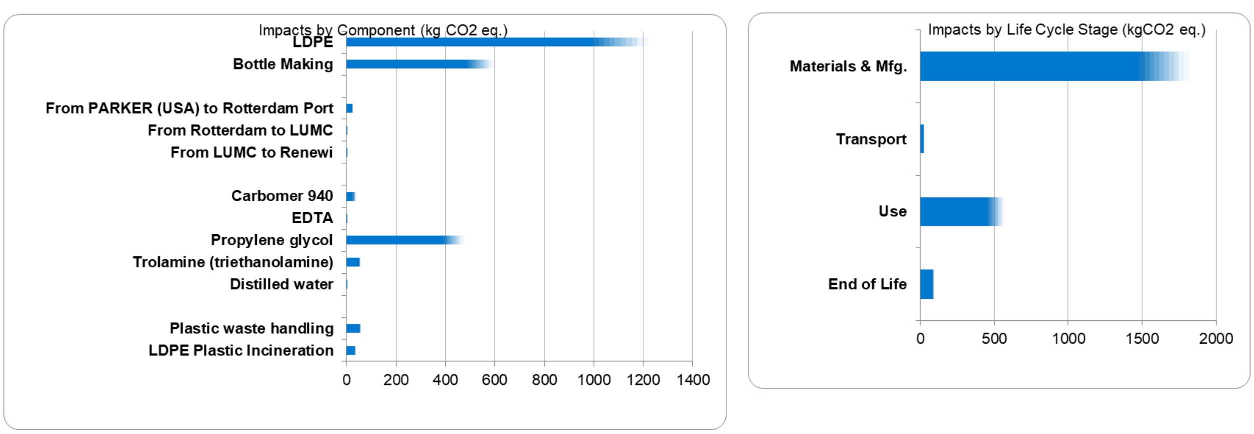


Figure 6: LCA results of 250ml Gel bottle annual consumption at the LUMC.

The total impact is estimated around 2200 kg CO_2 eq /yr, with majority form raw material and manufacturing. Even though the product is shipped from the US, the transportation is not environmentally impactful compared to raw material and manufacturing. Environmental impact caused by gel waste is responsible about 25% of the total impact, not as much as that of raw material and manufacturing but nonnegligible.

User feedback
User feedback of the current gel bottle is also necessary for analyzing the baseline performance from user's perspective. Feedback is summarized from the problem statement, as well as gathered from interviews with doctors in the radiology department of the LUMC. Regarding the sustainability of the bottle, plastic waste and gel waste are the main concerns of doctors. Other than the sustainability, the usability of the gel bottle is another target area. The majority of complains is focusing on the repetitive shaking near the complete of the bottle to extract gel sticking on the inner wall. The other minor complain is regarding the hygiene rule that prevents refilling the empty bottle. Some of the doctors consider this rule is an overprotection, given that the infection risk is minimum in ultrasound examination on intact skin. Other the other hand, the size and weight of the bottle receive much positive feedback, indicating that the current design well fits user's ergonomics.

3.2. Assessment of refilling

Assessment of risk

Hospital hygiene rules are set to maintain a clean and safe environment within healthcare facilities, such as hospitals, clinics, and other medical settings, preventing the spread of infections, reduce the risk of healthcare-associated infections and protecting the health and well-being of patients, healthcare workers, and visitors. Regarding the use of ultrasound gel, the rules emphasize the prevention of contamination and infection, and use as indicated by instruction. Currently, this gel bottle is designed as disposable. It must be thrown away once completed or reach the expiration date. Therefore, any kind of procedure to reuse or refill the bottle is prohibited, as well as extraction of leftover gel. On the other hand, from interviews with doctors who conduct ultrasound scans, infection risk of using refilled gel bottle is believed minimum in external ultrasound examination on intact skin, considering the sterilization process and immune system of human. Although many studies emphasis the risk of infection of refilling gel bottles, the fundamental cause of infection are mainly factory contamination or undetermined, and most cases are involved with invasive procedures. From reviewing sixteen cases related to the use of ultrasound gel, nine are caused by factory contamination, five by refilling, and two are undetermined, as the following figure shows.

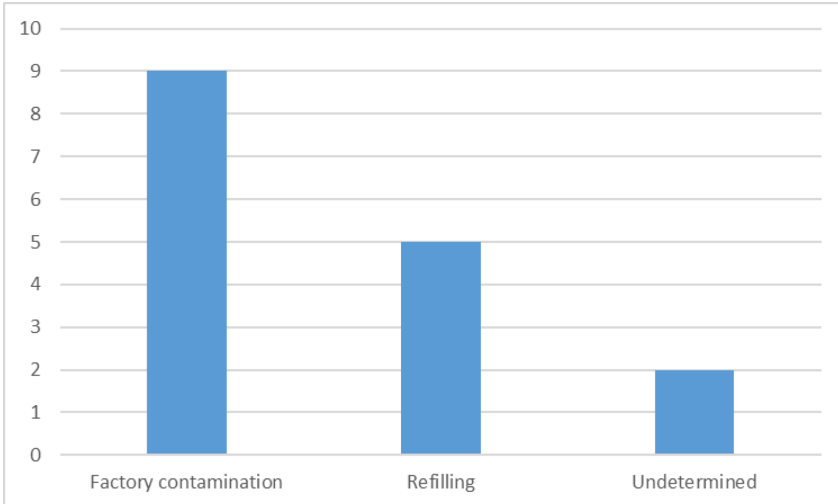


Figure 7. Causes of outbreak in use of ultrasound gel from review of 16 cases (Abdelfattah et al, 2018; Dogra et al, 2021; Du et al, 2021; Garay et al, 2012; Hell et al, 2011; Hutchinson et al, 2004; Jacobson et al, 2006; Nannini et al, 2015; Olshtain et al, 2011; Provenzano et al, 2013; Ramanathan et al, 2018; Shaban et al, 2017; Silmon et al, 2019; Solaimalai et al, 2019 ; Viderman et al, 2020; Wang et al, 2014)

Given most of the root cause of such outbreak is from factory contamination, it is arbitrary to prevent refilling bottles for all kinds of ultrasound examination. Therefore, the risk of using refilled gel bottle in external scans on intact skin should be reevaluated.

Assessment of sustainability

With the assumption that refilling gel bottles is allowed and instruction of use provided by Parker Laboratories, bottles should be cleaned with soap water before being refilled and discarded after one month. As a result, the gel bottle consumption is reduced to 720 bottles/yr. These bottles are refilled with 5-liter SONICPAC® refill pack, with consumption calculated around 967 packs/yr. Additionally, gel waste was also found when emptying these packs, measured around 109 g/pack. This refill pack is also made of LDPE, and its wait of material was measured 150 g/pack. Soap and water used in cleaning gel bottle for refilling were measured, around 3 g/cleaning and 200 g/cleaning respectively. The following table presents complete list of data used for this fast-track LCA.

Manufacturing	Eco-intensity (impacts/kg)	Mass per item (kg)	Items per func.unit (#)	Uncertainty %
LDPE (Gel Bottle)	1.87	0.027	720.00	10%
Bottle Making	0.91	0.027	720.00	10%
LDPE (Refill Pack)	1.87	0.150	967.00	10%
Refill Pack Making	0.91	0.150	967.00	10%

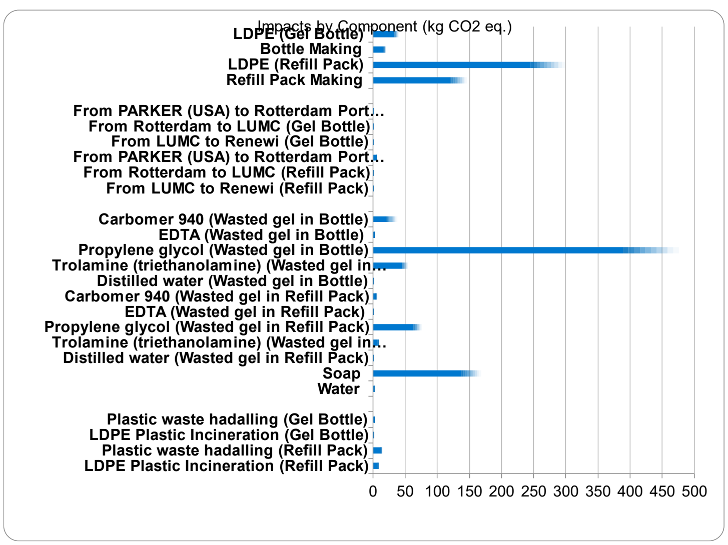
Transport	Eco-Intensity (impacts/ ton-km)	Mass per item (ton)	Distance per item (km)	Items per func.unit (#)	Uncertainty %
From PARKER (USA) to Rotterdam Port (Gel Bottle)	0.00480	3E-05	7256.10	720.00	10%
From Rotterdam to LUMC (Gel Bottle)	0.00103	3E-05	41.900	720.00	10%
From LUMC to Renewi (Gel Bottle)	0.00103	3E-05	88.100	720.00	10%
From PARKER (USA) to Rotterdam Port (Refill Pack)	0.00480	2E-04	7256.10	967.00	10%
From Rotterdam to LUMC (Refill Pack)	0.00103	2E-04	41.900	967.00	10%
From LUMC to Renewi (Refill Pack)	0.00103	2E-04	88.100	967.00	10%

Use	Eco-Intensity (impacts/MJ or other)	Amount per item (MJ or other)	Items per func.unit (#)	Uncertainty %
Carbomer 940 (Wasted gel in Bottle)	2.234	0.0006	21900.00	30%
EDTA (Wasted gel in Bottle)	4.341	0.000015	21900.00	10%
Propylene glycol (Wasted gel in Bottle)	4.389	0.0045	21900.00	10%
Trolamine (triethanolamine) (Wasted gel in Bottle)	3.027	0.00075	21900.00	10%
Distilled water (Wasted gel in Bottle)	0.001	0.024135	21900.00	10%
Carbomer 940 (Wasted gel in Refill Pack)	2.234	0.00218	967.00	30%
EDTA (Wasted gel in Refill Pack)	4.341	0.0000545	967.00	10%
Propylene glycol (Wasted gel in Refill Pack)	4.389	0.01635	967.00	10%
Trolamine (triethanolamine) (Wasted gel in Refill Pack)	3.027	0.002725	967.00	10%
Distilled water (Wasted gel in Refill Pack)	0.001	0.0876905	967.00	10%
Soap	2.409	0.003	21180.00	10%
Water	0.001	0.2	21180.00	10%

End of Life	Eco-Intensity (impacts/kg)	Mass per item (kg)	Items per func.unit (#)	Uncertainty %
Plastic waste hadalling (Gel Bottle)	0.088	0.027	720.00	10%
LDPE Plastic Incineration (Gel Bottle)	0.054	0.027	720.00	10%
Plastic waste hadalling (Refill Pack)	0.088	0.150	967.00	10%
LDPE Plastic Incineration (Refill Pack)	0.054	0.150	967.00	10%

Table 3: Basic information of refilling gel bottle

The fast-track LCA result of this refilling practice is presented in the following figure, illustrating environmental impact by category.



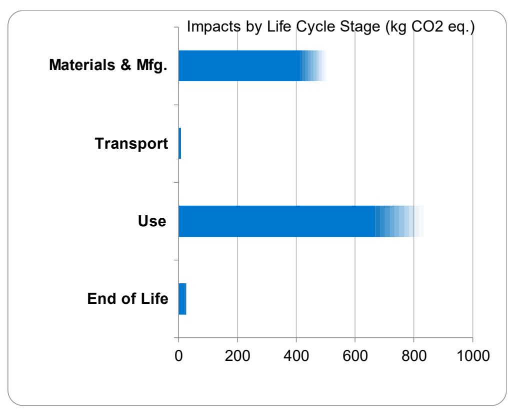


Figure 8: LCA result of refilling gel bottle

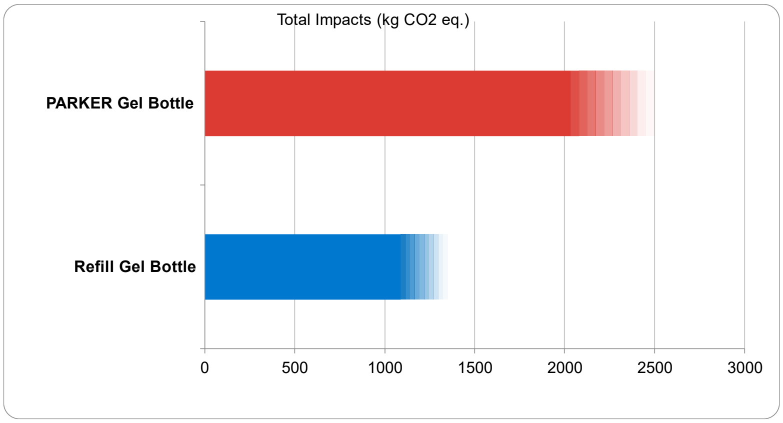


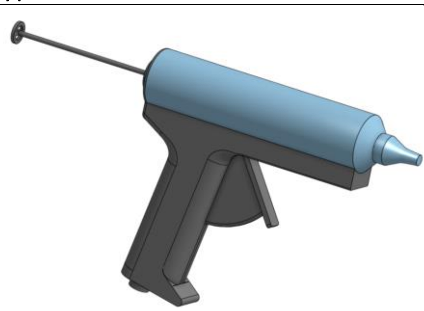
Figure 9: LCA results comparison of current gel bottle and refilling

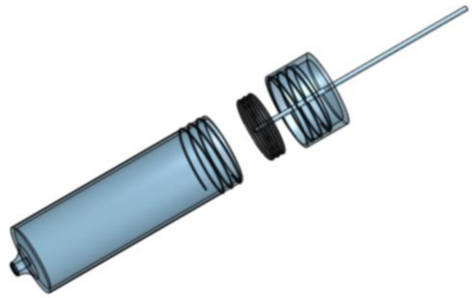
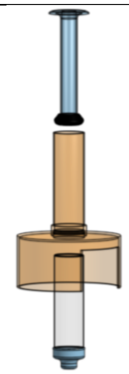
The total impact of this refilling practice is estimated around 1200 kg CO_2 eq /yr. Gel waste in the use phase contributes near two-third of the total impact, around 750 kg CO_2 eq /yr, because additional gel waste from refill pack and use of soap water for cleaning. Raw materials and manufacturing are less impactful, around 450 kg CO_2 eq /yr, more than one-third of total impact. Transport and end of life phases remain not environmentally impactful. Compared to the baseline, refilling gel bottle presents nearly 50% reduction in environmental impact, significantly more sustainable.

3.3. Redesigned gel bottle

3.3.1. Prototypes and desirability

With the baseline performance set in the previous section, sustainability of the gel bottle is targeted to be improved by reducing or preventing gel waste and plastic. Regarding the usability, advantages are to be maintained and disadvantages are to be addressed. In this section, redesigns are given to address the sustainability challenge and usability of the gel bottle. Prototypes are presented in following table, and desirability of each prototype is summarized in the feedback.

Prototype	Name	Description	Feedback
	Gel gun	Inspired by the glass glue application gun, this gel gun features complete use of gel, with a main body and replaceable gel bottle.	The entire set is too heavy and requires too many pulls for large amount of gel application.

	Gel syringe	This design features complete use of gel and reusable body made of stainless steel, like a syringe.	No gel and plastic wastes are desirable, but it is not as easy to use. The hospital has no more sterilization capacity.
	Table gel dispenser	The design features no gel waste and reduced plastic waste. The kit is with replaceable gel pack and main body set on table.	It is not easy to use, and the size may look scary to patients.
	Moving seal	This design features a movable seal that moves as gel depleting in the bottle, ensuring complete use of gel.	The shape is similar to the current bottle and easy to use. However, it fails to reduce plastic waste and the leakage may occurs at seal.
	Super hydrophobic coating	The idea of this design utilizes the feature of superhydrophobic to prevent gel waste.	However, the performance of this coating is not ideal, still having remaining gel stuck in the container.

	Tanked gel dispenser system	This design features a reusable 5 L gel tank connected to a pump with a soft tube. Gel is dispensed through nozzle on the pump, encouraging less gel and plastic wastes.	This system looks innovative. However, it feels not easy to use, considering maintenance and cleaning. The current ultrasound machine has no more space to fit this system.
	Gel pad	This gel pad, having gel contained in latex film, features high reusability and preserves high imaging quality, reducing plastic and gel waste.	This idea is innovative, and the reusability is highly desirable. However, this pad is hard to move on skin, not easy to use in practice.

Table 4: Prototypes and feedback

3.3.2. User Specification

The term "user specification" refers to the requirements or specifications defined by the users or customers of a product or service. These specifications outline the specific needs, expectations, and desired outcomes of the users, which serve as the basis for the design and development process. Regarding the use of ultrasound gel in the LUMC, user specifications are gathered and continuously updated through interviews and tests of prototypes. Following are the user specifications summarized.

1. Satisfy hospital hygiene rules.
2. Instruction must be developed for new designs.
3. Minimize gel waste, plastic waste, and infection risk.
4. Avoid shaking the bottle to settle gel.
5. Can be handled by single hand.
6. Should not be heavier than the current bottle.
7. Should contain similar amount of gel as the current bottle.
8. Gel should be directly applied onto patient’s skin.
9. Amount of gel applied can be easily adjusted.
10. Should not looks scary to patient.
11. Material can withstand 70% medical alcohol solution.
12. Can be stored for at least 2 years.
13. Waterproof and leak-free.
14. Preferably able to fit into the gel warmer.

The list of user specification above can be summarized into 3 main categories, including waste reduction, ease of use, and risk prevention. In the waste reduction, the gel waste and plastic waste are targeted to be minimized. Even though the raw material LDPE contributes most of the environmental impact, the gel waste reduction is also prioritized in the redesigns, as this feature is highly valued during the interviews with doctors at the LUMC. In the category of ease of use, shape and weigh of the should be maintained in the redesign, but the extraction of gel near the completion should be improved, avoiding repetitive shakings. In the risk prevention, the redesign should not increase the risk of contamination and infection to patients. Therefore, redesigns are made based on the current hospital hygiene rules, not to be refilled.

3.3.3. Eco-design (Gel Pack)

This strategy aims at minimizing the negative impacts of the gel bottle by using the eco-design strategy wheel, identifying possible areas for improvement in 8 categories. In the process of eco-design, the environmental performance of the current gel bottle is evaluated and visualized in the following figure. With plastic waste and gel waste reduction in mind while satisfying the hygiene rules, several spots are targeted to be improved.

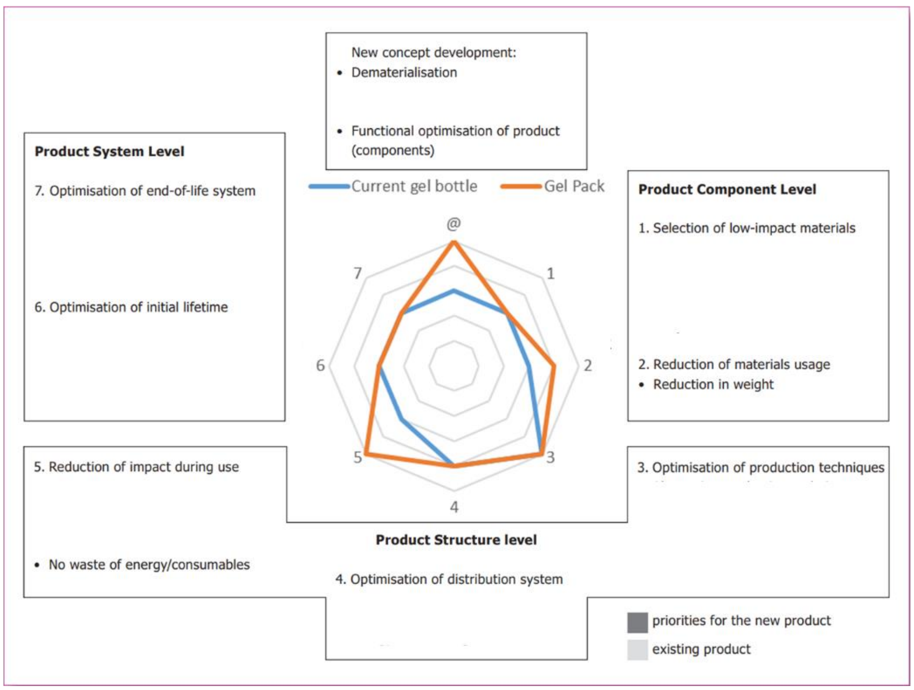


Figure 10. Eco-design strategy wheel options comparing gel pack and current gel bottle.

The gel pack, shown in the following figure, is the redesign to improve the environmental impact of material and waste reduction, while maintaining a similar shape and volume to fit the current ultrasound system. In this design, the overall goals are dematerialization and functional optimization. Material consumption of the gel pack is significantly reduced by thinning the bottle wall to form a soft pack, during prototype testing, gel waste can be eliminated by this design, and repetitive shaking of the bottle can be avoided, resulting in less annual gel consumption and better user experience.

Figure 11: Digital model of 250ml Gel Pack

Environmental impact of this redesign is also assessed by using the fast-track LCA with the same boundaries and standard as that of the baseline performance. The functional unit still resemble the weight of annual gel consumption at the LUMC, but the gel pack consumption is reduced to 19162.5 packs/yr, because of the elimination of 12.5% gel waste. As the following table shows, mass of the bottle is reduced from 27g to 15g, and gel waste in the use phase is removed. 30% uncertainty was assigned in this LCA, because the weight of gel pack is measured on prototype, and the weight of actual product may vary. Distance of each transportation remains the same, as manufacture is assumed to be the same. Eco-intensity data is still provided by the fast-track LCA tool.

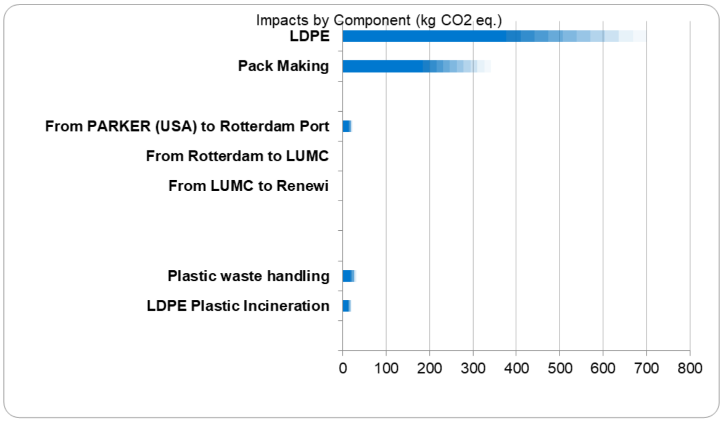
Manufacturing	**Eco-intensity (impacts/kg)**	**Mass per item (kg)**	**Items per func.unit (#)**	**Uncertainty %**
LDPE	1.87	0.015	19162.50	30%
Pack Making	0.91	0.015	19162.50	30%

Transport	**Eco-Intensity (impacts/ ton-km)**	**Mass per item (ton)**	**Distance per item (km)**	**Items per func.unit (#)**	**Uncertainty %**
From PARKER (USA) to Rotterdam Port	0.00480	3E-05	7256.10	19162.50	30%
From Rotterdam to LUMC	0.00103	3E-05	41.900	19162.50	30%
From LUMC to Renewi	0.00103	3E-05	88.100	19162.50	30%

Use	**Eco-Intensity (impacts/MJ or other)**	**Amount per item (MJ or other)**	**Items per func.unit (#)**	**Uncertainty %**

End of Life	**Eco-Intensity (impacts/kg)**	**Mass per item (kg)**	**Items per func.unit (#)**	**Uncertainty %**
Plastic waste handling	0.088	0.015	19162.50	30%
LDPE Plastic Incineration	0.054	0.015	19162.50	30%

Table 5. Basic information of 250ml Gel Pack



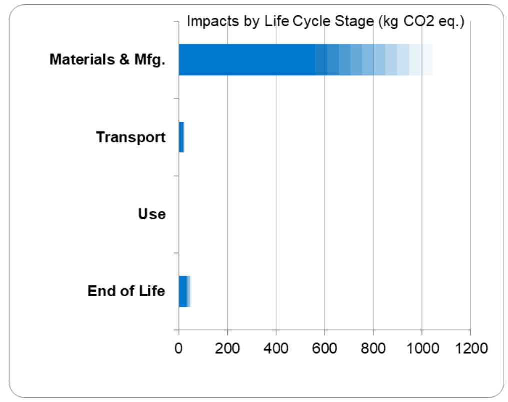


Figure 12: LCA results of 250ml Gel Pack annual consumption at the LUMC

As the LCA result shown in the figure 12, the total impact is estimated around 860 kg CO_2 eq /yr, with majority from raw material and manufacturing. This significant reduction in the total impact is achieved by material reduction and gel waste elimination.

3.3.4. C2C design (Paper Sachet)

This strategy aims at treating waste as food with the end goal of doing good instead of less bad (van der Grinten, 2022). In the process of C2C design, the cycle of a gel bottle is visualized in the following figure. When the bottle is finished, the waste is first collected on site and then transported to the waste treatment facility where it is prepared for incineration. Emission from incineration enters the atmosphere, which never returns to the cycle, since the LDPE plastic is made of monomer ethylene sourced from fossil fuel (Malpass, 2010).

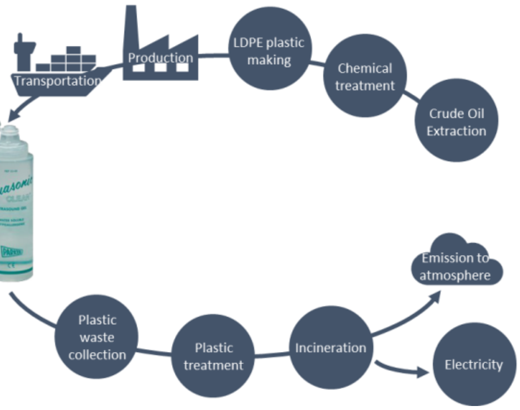


Figure 13: Cycles of gel bottle

Paper gel sachet, a C2C redesign of the gel bottle, aims at enabling a closed loop cycle of material while satisfying users' requirements. Regarding the sustainability, the sachet is made of FSC (Forest Stewardship Council) certified kraft paper made from well managed forest, standing for eco-friendly and sustainable (FSC, 2011). As shown in the following figure, the loop is achieved biologically and technologically. After waste collection and separation, emission from incineration is absorbed by well-managed forest that supplies raw material for the production. Through technological cycle, the paper waste can be recycled after treatment for secondary paper production, replacing virgin paper. Regarding other criteria of user specification, this paper sachet, during prototype testing, allows complete use of ultrasound gel and ease of use, avoiding gel waste and shakings. The sachet is designed to contain 60g of gel separated into 6 equal sections, enough for a regular ultrasound scan while adjustable for additional applications.

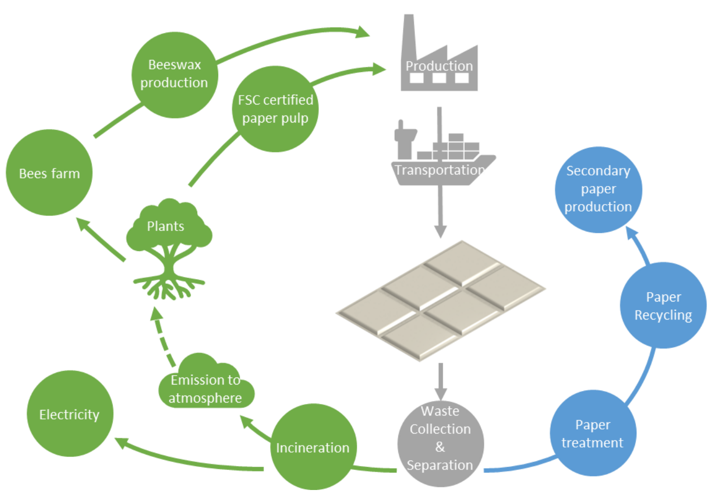
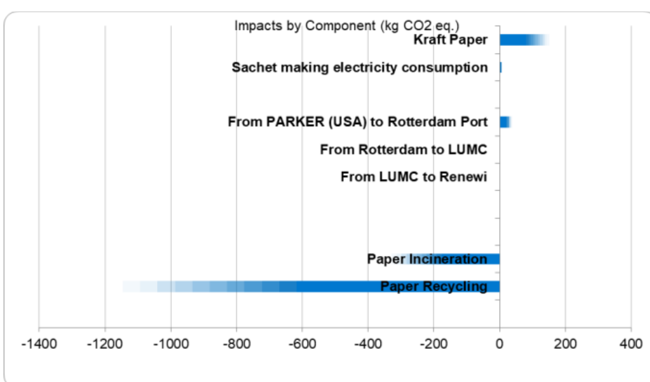


Figure 14: Cycles of 60g kraft Paper Sachet. (The dash arrow line represents that a portion of emission to the atmosphere is absorbed by plants that support bees farm and FSC certified paper production)

Environmental impact of kraft paper gel sachet is assessed by using the fast-track LCA with the same boundaries and standard as that of the baseline performance, shown in the following table and figure. Compared to a standard gel bottle that contains 263g of gel, this sachet only contains 60g. Therefore, the annual paper sachet consumption 83996 sachets/yr, still maintaining the same functional unit as that of the baseline. Beeswax is used for water impermeable layer. Electricity consumption is approximated from energy consumption of paper cup production (Garrido & Alvarez del Castillo, 2007). 30% uncertainty was assigned in this LCA, because the weight of paper sachet is measured on prototype, and the weight of actual product may vary.

Manufacturing	**Eco-intensity (impacts/kg)**	**Mass per item (kg)**		**Items per func.unit (#)**	**Uncertainty %**
Kraft Paper	0.20	0.007		83996	30%
Beeswax	0.17	0.003		83996	30%
Sachet making electricity consumption	0.003	0.013		83996	30%
Transport	**Eco-Intensity (impacts/ ton-km)**	**Mass per item (ton)**	**Distance per item (km)**	**Items per func.unit (#)**	**Uncertainty %**
From PARKER (USA) to Rotterdam Port	0.00480	1E-05	7256.10	83996	30%
From Rotterdam to LUMC	0.00103	1E-05	41.900	83996	30%
From LUMC to Renewi	0.001	1E-05	88.100	83996	30%
Use	**Eco-Intensity (impacts/MJ or other)**	**Amount per item (MJ or other)**		**Items per func.unit (#)**	**Uncertainty %**
End of Life	**Eco-Intensity (impacts/kg)**	**Mass per item (kg)**		**Items per func.unit (#)**	**Uncertainty %**
Paper Incineration	-0.884	0.003		83996	30%
Paper Recycling	-1.59	0.0066		83996	30%

Table 6: Basic information of 60g Paper Sachet



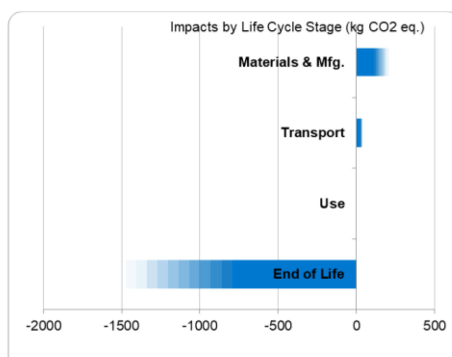


Figure 15: LCA results of 60g Paper Sachet annual consumption at the LUMC.

The fast-track LCA of this design results in around -940 kg CO_2 eq/yr. Impact from raw material and manufacturing is significantly reduced by use of low-impact material, kraft paper. Another significant improvement of environmental impact is from end-of-life phase. This negative total impact is achieved by replacing virgin paper production with recycled kraft paper and incineration for energy.

3.3.5. Biomimicry design (Gel Pod)

The strategy aims at taking inspiration from nature to improve the design of gel bottle, using the e principles laid out by the framework of biomimicry design (Benyus, 2015). First, current design on Life's principles is evaluated and summarized in the following figure. Adapting to changing condition is presented in the current gel bottle as it can be warmed for better comfortability and used in multiple types of ultrasound scans across 5 departments at the LUMC. The current design also presents locally attuned and responsive, using LDPE plastic widely used in the matured bottle making industry. Resource efficient is presented in the waste treatment by incinerating LDPE plastic for electricity generation. Design opportunities are found in resource efficient and using life-friendly chemistry by minimizing gel waste and using biobased plastic.

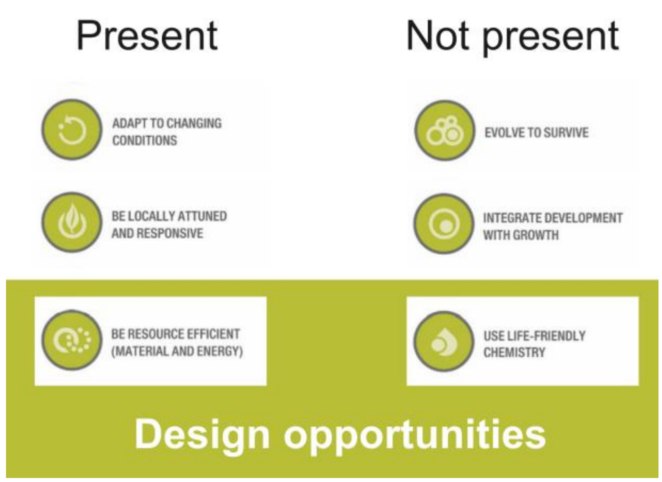


Figure 16: A summary of the Life principles evaluations of the gel bottle.

From exploring how nature holds dispense gel-like liquid, aloe vera is chosen as an inspiration for the redesign, since it contains abundant liquid gel that leaks form where the damage occurs. As illustrated in the following figure, the mechanism is simple that the liquid gel in contained in the cell wall, and gel leaks out when the cell wall is damaged. Emulated from this mechanism, the gel pod (Figure 18) uses starch-based thermoplastic (TPS), resembling the cell wall, to contain ultrasound gel. The gel pod is designed to contain 20g of ultrasound gel which is enough for the scan that requires least amount of gel. Meanwhile, during prototype testing, this design also results in zero gel waste, and gel can be easily squeezed out by either fingers or ultrasound probe.

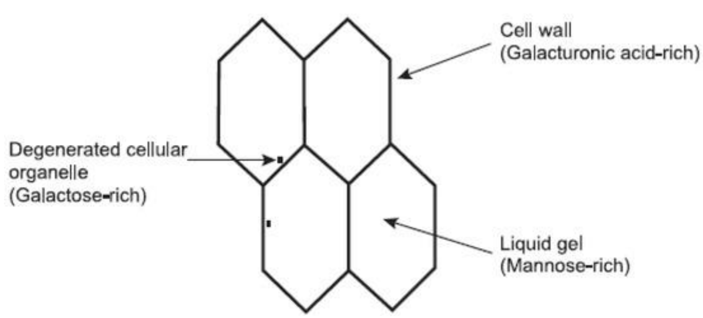


Figure 17: Schematic representation of aloe vera leaf pulp structure (Hamman, 2008).

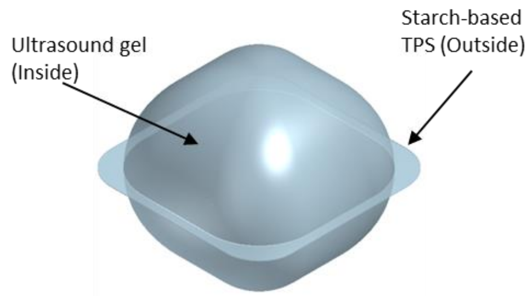
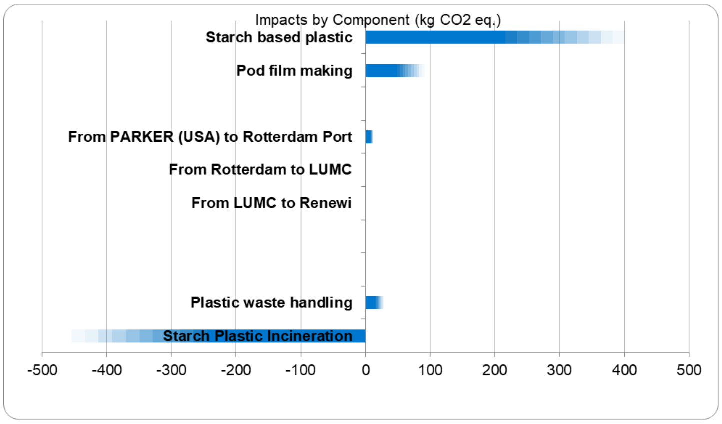


Figure 18: Digital model of 20g Gel Pod

Environmental impact of kraft paper gel sachet is assessed by using the fast-track LCA with the same boundaries and standard as that of the baseline performance, shown in the following table and figure. Compared to a standard gel bottle this gel pod only contains 20g gel. Therefore, the functional unit is changed to 251987 pods/yr, still resembling the annual gel consumption at the LUMC. 30% uncertainty was assigned in this LCA, because the weight of gel pod is measured on prototype, and the weight of actual product may vary.

Manufacturing		**Eco-intensity (impacts/kg)**	**Mass per item (kg)**		**Items per func.unit (#)**	**Uncertainty %**
	Starch based plastic	1.22	0.001		251987	30%
	Pod film making	0.28	0.001		251987	30%
Transport		**Eco-Intensity (impacts/ ton-km)**	**Mass per item (ton)**	**Distance per item (km)**	**Items per func.unit (#)**	**Uncertainty %**
	From PARKER (USA) to Rotterdam Port	0.00480	1E-06	7256.10	251987	30%
	From Rotterdam to LUMC	0.00103	1E-06	41.900	251987	30%
	From LUMC to Renewi	0.001	1E-06	88.100	251987	30%
Use		**Eco-Intensity (impacts/MJ or other)**	**Amount per item (MJ or other)**		**Items per func.unit (#)**	**Uncertainty %**
End of Life		**Eco-Intensity (impacts/kg)**	**Mass per item (kg)**		**Items per func.unit (#)**	**Uncertainty %**
	Plastic waste handling	0.088	0.0010000000		251987.00	30%
	Starch Plastic Incineration	-1.387	0.0010000000		251987.00	30%

Table 7: Basic information of 20g Gel Pod



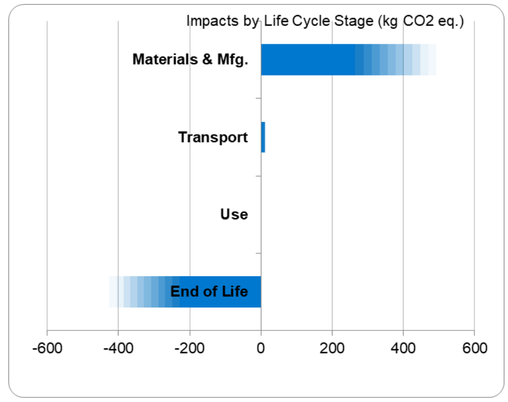


Figure 19: LCA results of 20g Gel Pod annual consumption at the LUMC.

The fast-track LCA of this design results in around 50 kg CO_2 eq/yr. Impact from raw material and manufacturing is significantly reduced to around 370 kg CO_2 eq/yr, achieved by using low impact material. This low impact material, starch-based plastic also enables the negative impact in the end-of-life phase, incinerated for electricity production instead of burning fossil fuel.

3.4. Assessment of redesigns

Assessment of improvement in the environmental impact of redesigns is shown in the following figure. Compared to the baseline (PARKER Gel Bottle), all three redesigns present reduction in the total impact, with the gel pod having the most significant reduction. This significant impact reduction of paper sachet is achieved by incineration for electricity and paper recycling replacing virgin paper in the end-of-life phase, where the carbon footprints are -0.88 kg CO_2 eq and -1.6 kg CO_2 eq respectively, because incineration consumes bio-based material for electricity generation instead of fossil fuel.

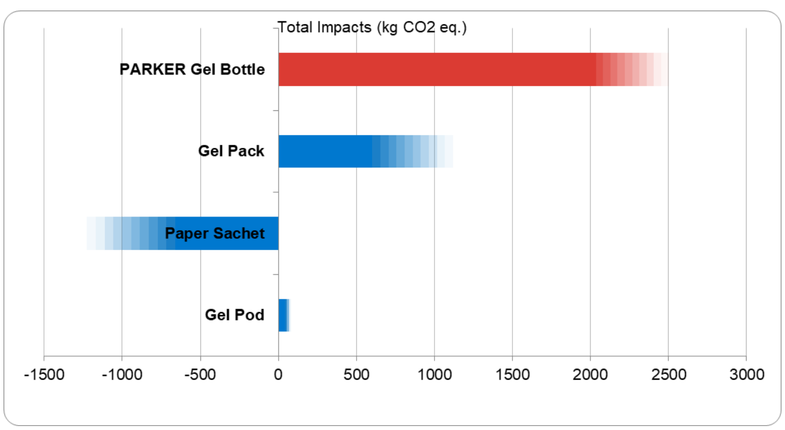


Figure 20: LCA results comparison of 3 redesigns and the current gel bottle.

Along with the sustainable impact, these three redesigns are further evaluated by using the Harris profile (Boeijen et al., 2014) shown in the following figure. The order is in hierarchy; the top factor (sustainable impact) is most important, the bottom (innovativeness) is the least important. Sustainable impact represents the total carbon footprint of the design. Feasibility represents the technology readiness of material and production method used by the design. Viability represents the long-term practicality of the design in the hospital environment. Desirability reflects feedback of the design from doctors during prototype testing. Innovativeness reflects the uniqueness of the design compared to other medical products.

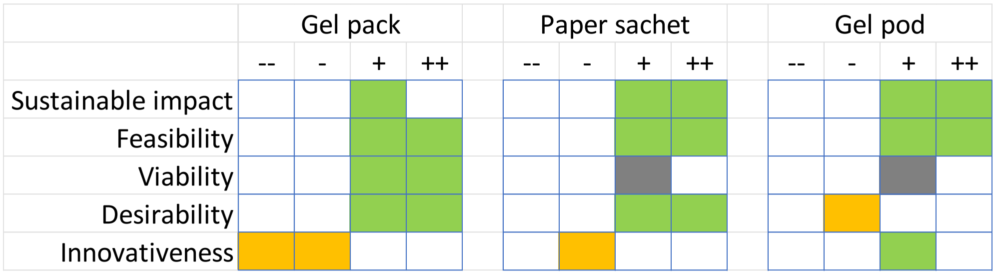


Figure 21: Harris profile comparing the three redesigns.

As shown in the Harris profile, the gel pack that utilizes eco-design scores high in every part other than innovation. Sustainable impact scores “+”, as this redesign reduces environmental impact by nearly half compared to the baseline, but not as much as other two redesigns. Its feasibility scores “++”, as this design targets material reduction; its production method is mature in the industry, having similar product such as soft fluid flask. It also scores “++” in viability, as it is practical for long-term reliable usage in the hospital environment, like IV fluid bag. It is also highly desirable to doctors, scoring “++”. They described that “this gel pack fells similar to the bottle but much more handy. It is nice to have reduced plastic waste and no gel waste, and also a bonus that it fits into the warmer on the ultrasound machine.” Because there are abundant of similar products available on the market, is not innovative compared to other two redesigns, resulting in “- -” score.

From Harris profile, the paper sachet utilizing the C2C design strategy scores highest in sustainable impact, feasibility, and desirability, with slightly less score in sustainable impact and viability. Having the most reduction in environmental impact, the paper sachet scores “++” in sustainable impact. Through taking material from nature and treating waste as food, the C2C designed paper sachet use FSC certified kraft paper to achieve circularity. The feasibility also scores “++”, as its ability to contain and dispense ultrasound gel is tested by prototypes and production method is mature in the industry. Viability of this redesign only scores “+” with gray color, since the prototype testing is only short-term; its long-term storage stability and application in hospital environment are unknown. This design is also highly desirable to doctors, as they are using similar product but for the sterilized ultrasound examinations, scoring “++” in desirability. “It is nice to have no plastic and gel wastes,” said by doctors in prototype testing, “It is not as handy as gel pack, but only slightly. The warmer can fit multiple of this sachet, which is a bonus. But can this packaging material hold gel for a year, for storage?” On the other hand, this design of a paper liquid container is unpresidential in the medical use, but similar products using different material can be found in medical use, resulting in “-” score.

Biomimicry design is the solution emulated from the nature. The gel pod utilizing this strategy scores highest in the sustainable impact and feasibility, since it significantly reduces the carbon footprint utilizes starch based TPS that already available, resulting in “++” in both sustainable impact and feasibility. Its viability scores “+” with gray color, because the prototype was tested viable in the short term, but unknown for the long-term storage stability and application in hospital environment. Despite its superior sustainability, it is not so desirable to doctors, scoring “-”. Said by doctors participated in prototype testing, “this gel pod looks really interesting; use of biobased material and no gel waste are nice. The warmer can also fit many of this pod but may hard to reach near bottom. It is hard to use when large amount of gel is required, like scanning for overweight patients. Reliability of this biobased material for long-term storage is also concerning.” Innovativeness of this redesign scores “+”, since use of this biobased material is unpresidential in medical use, and no similar product can be found in hospital.

From result of Harris profile, the gel pack is recommended as a design solution to the gel bottle. Even though the gel pack is not the most sustainable design among the three, it is the most desirable, feasible, and viable. Gel pod is the most innovative design and sustainable, but it is not desirable to doctors, because of limited use situation. Paper sachet has the most potential to replace gel pack as final recommendation, if it can be tested viable for long-term application in hospital environment.

3.5. Discussion and practical implementation

The pursuit of sustainability, both environmentally and financially, within healthcare institutions has become a paramount concern. The findings of this research dedicate to presenting desirable and sustainable solutions in ultrasound gel packaging at the LUMC. Through stakeholder analysis, doctors who perform ultrasound examinations at the LUMC were primary participants involved in prototype testing of redesigns, as they presented the most interest in solving the sustainability challenge of ultrasound gel packaging. Hygiene measures specific to ultrasound examinations provided by the RIVM was the fundamental rule followed by redesigns, as the RIVM holds the most power in regulating medical procedures and products.

Firstly, environmental impact of gel bottle was assessed to establish a baseline performance. By conducting a fast-track LCA with IDEMAT tool, the total environmental impact of annual ultrasound gel consumption at the LUMC was estimated around 2200 kg CO_2 eq /yr, with majority contributed by raw material, manufacturing, and gel waste. Meanwhile, user feedback on the gel bottle was collected, revealing pressing needs in reduction of plastic and gel wastes, as well as improving usability.

Following was the assessment of refilling which was desirable and believed more sustainable by many doctors but prohibited by hygiene rules. This assessment approached the problem from two directions, risk and sustainability. Results of the assessment indicates that using refilled gel bottle on intact skin is not as risky as factory contamination, and this practice can reduce nearly half of environmental impact compared to baseline.

Finally were three redesigns using the sustainable design strategy, dedicating to providing desirable and sustainable design solution to the challenge of ultrasound gel packaging. These designs all presented significant improvement in environmental impact compared to the baseline. The gel pack was the recommended as the final design solution, given its high desirability and viability. The paper sachet could be the best solution overall, if its long-term application in hospital can be tested viable.

Implementing these solutions also requires corporation of multiple stakeholders. Doctors should propose the design of gel pack and paper sachet to the LUMC and collaborate with Medical Delta, experimenting safety of these designs in long-term application. Doctors should also actively contact with Parker

Laboratories and express their needs for a more sustainable and user-friendly ultrasound gel packaging. Meanwhile, given the superior sustainability of refilling, risk of using refilling gel bottle in examinations on intact skin should be reevaluated with collaboration of RIVM, Medical Delta and other healthcare institutions, to provide evidence-based suggestion for enabling reusing ultrasound gel packaging without compromising safety.

3.6. Limitations & recommendations for future work

Based on findings of this research, there are several potential directions for future investigation and development that involves environmental, financial, and waste management aspects. Firstly, a comprehensive examination of the implementation of the recommended eco-designed gel pack could provide valuable insights into its real-world impact on reducing raw material consumption and minimizing wastes. This could involve not only tracking its usage and user satisfaction but also conducting a cost analysis to evaluate its financial feasibility compared to the current gel bottle.

Moreover, the long-term practicality of the C2C designed paper sachet as a sustainable solution warrants further exploration, including its financial viability. Rigorous stability testing under various conditions and over extended periods would be necessary to ascertain its viability as a medical liquid container. Simultaneously, a thorough cost-benefit analysis could provide a clear understanding of its financial feasibility in the context of the LUMC's operations.

Additionally, it's essential to consider the impact of waste treatment facilities on material circularity, especially in collaboration with companies like Van Straten Medical, which specializes in recycling polypropylene plastic medical waste and medical instruments into new medical products (Bijleveld, 2020). Exploring corporation with Van Straten Medical's vision of expanding the types of plastic recycled could facilitate the transformation towards material circularity.

4. Conclusion

Climate change, driven by escalating greenhouse gas emissions, induces global temperature rises, leading to increased precipitation and heatwaves, with profound consequences for healthcare. Simultaneously, healthcare significantly contributes to climate change. To mitigate healthcare's environmental impact, a shift toward sustainable practices is imperative, encompassing measures like waste reduction and decreased resource consumption, exemplified by efforts to reduce plastic waste, notably the single-use plastic ultrasound gel bottles in hospitals. Addressing this issue necessitates collaboration among stakeholders, regulatory reevaluation, and the development of a sustainable ultrasound gel bottle design. This research has delved into the critical pursuit of sustainability within healthcare institutions, focusing on the specific challenge of ultrasound gel packaging at the LUMC. By engaging stakeholders, primarily doctors performing ultrasound examinations, and adhering to the rigorous hygiene guidelines set by the RIVM, this study has embarked on a journey to offer desirable and sustainable solutions.

The initial assessment of the environmental impact of the gel bottle established a baseline performance, revealing significant contributions from raw materials, manufacturing processes, and gel waste. User feedback emphasized the urgency of reducing plastic and gel waste while enhancing usability. Exploring the potential of refilling, a solution favored by many doctors, required a dual evaluation, taking both risk and sustainability into consideration. The results suggested that refilled gel bottles, when used on intact skin, posed a lower risk compared to factory contamination, while substantially reducing environmental impact. Three redesigns, guided by sustainable design principles, were proposed to address the challenge of ultrasound gel packaging. These designs demonstrated notable improvements in environmental impact compared to the baseline, with the gel pack emerging as the recommended solution, due to its high desirability and feasibility. The paper sachet, while promising, awaits further testing for long-term hospital application.

The implementation of these solutions necessitates collaborative efforts from multiple stakeholders. Doctors are encouraged to advocate for the adoption of the gel pack and paper sachet designs within the LUMC, partnering with organizations like Medical Delta to assess their safety in real-world scenarios. Additionally, engagement with Parker Laboratories can help drive the development of more sustainable and user-friendly ultrasound gel packaging. Furthermore, the reevaluation of the risk associated with using refilled gel bottles in examinations on intact skin is essential. Collaboration between the RIVM, Medical Delta, and other healthcare institutions can provide evidence-based recommendations, potentially paving the way for the safe reuse of ultrasound gel packaging without compromising patient safety.

This research underscores the paramount importance of sustainability within healthcare institutions, particularly in addressing the challenge of ultrasound gel packaging. Through a comprehensive approach involving stakeholder engagement, environmental impact assessment, and sustainable design strategies, this study has presented viable solutions. There is potential for substantial reductions in environmental impact and plastic waste, while maintaining the highest standards of hygiene and patient safety. Collaboration among healthcare professionals, regulatory bodies, and industry stakeholders is crucial to bring these sustainable solutions to fruition, marking a significant step towards a more environmentally responsible and financially efficient healthcare system.

Reference

Abdelfattah, R., Al-Jumaah, S., Al-Qahtani, A., Al-Thawadi, S., Barron, I., & Al-Mofada, S. (2018). Outbreak of Burkholderia cepacia bacteraemia in a tertiary care centre due to contaminated ultrasound probe gel. Journal of Hospital Infection, 98(3), 289-294. https://doi.org/10.1016/j.jhin.2017.09.010

Allison Binkowski, Christine Riguzzi, Daniel Price, Jahan Fahimi, 2014. Evaluation of a Cornstarch-Based Ultrasound Gel Alternative for Low-Resource Settings. https://www.sciencedirect.com/science/article/pii/S0736467913010640?casa_token=gqitMeEWYZkAAAAA:ySEDE-0Z7I9oZNg5bVmKb8JQBOYyMxs_DVNyOEipNikpk6UJ5yJrfeSNMIf571WVagtepWEC7g#bib7

Ángeles-Garay, U., Zacate-Palacios, Y., López-Herrera, J. R., Hernández-Sánchez, E. A., Silva-Sánchez, J., & de Jesús Ascencio-Montiel, I. (2012). Hospital outbreak of urinary tract infections by lubricant gel contaminated with. Revista Medica Del Instituto Mexicano Del Seguro Social, 50(6), 615-622. https://www.medigraphic.com/cgi-bin/new/resumenI.cgi?IDARTICULO=41752

Annemiek van Boeijen, Jaap Daalhuizen, Jelle Zijlstra, Roos van der Schoor, 2020. Delft design guide, Part 2. https://arl.human.cornell.edu/PAGES_Delft/Delft_Design_Guide.pdf

Blessy Joseph, Jemy James, Nandakumar Kalarikkal, Sabu Thomas, 2021. Recycling of medical plastics, Advanced Industrial and Engineering Polymer Research. https://www.sciencedirect.com/science/article/pii/S2542504821000348

Bram van der Grinten, 2022. Cradle to Cradle in a nutshell: C2C summary in 2 pages. Course material of Sustainable Design Strategies for Product (ID5356) at Delft University of Technology.

Brezet, H. (1997). Ecodesign-A promising approach to sustainable production and consumption. United Nations Environmental Programme (UNEP).

Circle Economy, 2016. HEALTHCARE PLASTIC WASTE: ANALYSIS OF OLVG HOSPITAL PLASTIC WASTE STREAMS. https://milieuplatformzorg.nl/documents/Onderzoek_plastics_OLVG_OK.PDF

Costello, C., Basseal, J. M., Yang, Y., Anstey, J., & Yastrebov, K. (2020). Prevention of pathogen transmission during ultrasound use in the Intensive Care Unit: Recommendations from the College of Intensive Care Medicine Ultrasound Special Interest Group (USIG). Australasian journal of ultrasound in medicine, 23(2), 103–110. https://doi.org/10.1002/ajum.12205

D.D. Cornell, 2007. Biopolymers in the Existing Postconsumer Plastics Recycling Stream. https://link.springer.com/article/10.1007/s10924-007-0077-0#citeas

David A. Provenzano, Michael A. Liebert, Barbara Steen, Debra Lovetro, and David L. Somers, 2013. Investigation of Current Infection-Control Practices for Ultrasound Coupling Gel: A Survey, Microbiological Analysis, and Examination of Practice Patterns. http://dx.doi.org/10.1097/AAP.0b013e3182a0e12f

Dogra, S., Angrup, A., Kanaujia, R., Vig, S., Kaur, R., Paul, R. A., ... & Ray, P. (2021). Burkholderia m ultivorans Sepsis Outbreak in a Neonatal Surgical Unit of a Tertiary Care Hospital. Indian Journal of Pediatrics, 88, 725-725. https://doi.org/10.1007/s12098-021-03757-x

Du, M., Song, L., Wang, Y., Suo, J., Bai, Y., Xing, Y., ... & Liu, Y. (2021). Investigation and control of an outbreak of urinary tract infections caused by Burkholderia cepacian-contaminated anesthetic gel. *Antimicrobial Resistance & Infection Control*, *10*(1), 1-7. https://doi.org/10.1186/s13756-020-00855-x

Forest Stewardship Council, 2011. FSC Standard for Chain of Custody Certification. https://cdn.scsglobalservices.com/files/standards/fsc-std-40-004_v2-1_en_chain_of_custody_certification_dir-40-004_40-004a.pdf

Garrido, N., Alvarez del Castillo, M.D. Environmental evaluation of single-use and reusable cups. Int J Life Cycle Assess 12, 252–256 (2007). https://doi.org/10.1065/lca2007.05.334
Hell, M., Abel, C., Albrecht, A., Wojna, A., Chmelizek, G., Kern, J. M., ... & Apfalter, P. (2011, December). Burkholderia cepacia–outbreak in obstetric patients due to intrinsic contamination of non-sterile ultrasound gel. In *BMC Proceedings* (Vol. 5, pp. 1-1). BioMed Central. https://doi.org/10.1186/1753-6561-5-S6-O75

Hutchinson, J., Runge, W., Mulvey, M., Norris, G., Yetman, M., Valkova, N., ... & Lepine, F. (2004). Burkholderia cepacia infections associated with intrinsically contaminated ultrasound gel: the role of microbial degradation of parabens. *Infection Control & Hospital Epidemiology*, *25*(4), 291-296. https://doi.org/10.1086/502394

Jacobson, M., Wray, R., Kovach, D., Henry, D., Speert, D., & Matlow, A. (2006). Sustained Endemicity of Burkholderia cepacia Complex in a Pediatric Institution, Associated With Contaminated Ultrasound Gel. Infection Control & Hospital Epidemiology, 27(4), 362-366. doi:10.1086/503343.
https://www.cambridge.org/core/journals/infection-control-and-hospital-epidemiology/article/abs/sustained-endemicity-of-burkholderia-cepacia-complex-in-a-pediatric-institution-associated-with-contaminated-ultrasound-gel/97FB089EBB6E9ABB72D998372B8178E0

Janine Benyus, 2015. BIOMIMICRY DesignLens: a visual guide.
https://static1.squarespace.com/static/59d81f72b7411cdef9af3e92/t/59e9112264b05f84daceb154/1508446503474/Biomimicry38_DesignLens_g1.1.pdf

J. A. Colwill, E. I. Wright, S. Rahimifard & A. J. Clegg, 2012. Bio-plastics in the context of competing demands on agricultural land in 2050, International Journal of Sustainable Engineering https://www.tandfonline.com/doi/full/10.1080/19397038.2011.602439?scroll=top&needAccess=true&role=tab&aria-labelledby=full-article

J. H. Song, R. J. Murphy, R. Narayan and G. B. H. Davies, 2009. Biodegradable and compostable alternatives to conventional plastics. https://royalsocietypublishing.org/doi/10.1098/rstb.2008.0289

K R Gorny et al., 2007. Evaluation of mineral oil as an acoustic coupling medium in clinical MRgFUS. https://iopscience.iop.org/article/10.1088/0031-9155/52/1/N02/meta?casa_token=giVyeUf4OrMAAAAA:Op3mzklenMLiQ3djR7FHZ2Uj3KEG3vVlugU_f1HjMw9C3iCvMlBPWyRF2RNmvoUTScMlwrzFMg

L.S. Dilkes-Hoffman, S. Pratt, P.A. Lant, B. Laycock, 2019. The Role of Biodegradable Plastic in Solving Plastic Solid Waste Accumulation. https://www.sciencedirect.com/science/article/pii/B9780128131404000194#bib77

Lecluyse, V. Understanding the physics and fluid dynamics governing ultrasound gel behaviour facilitates its use: the ketchup analogy!. Can J Anesth/J Can Anesth 62, 427–428 (2015). https://link.springer.com/article/10.1007/s12630-014-0258-y

Luewan MD, et al., 2007. A Comparison of Sonographic Image Quality between the Examinations using Gel and Olive Oil, as Sound Media. https://www.thaiscience.info/Journals/Article/JMAT/10402059.pdf

LUMC, 2023. Corporate Social Responsibility, Sustainability. https://www.lumc.nl/over-het-lumc/het-lumc/maatschappelijk-verantwoord-ondernemen/duurzaamheid2/

M.A. Steenmeijer et al., 2022. The Impact of Dutch Healthcare on the Environment: Environmental footprint method, and examples for a health-promoting healthcare environment. https://www.rivm.nl/bibliotheek/rapporten/2022-0159.pdf

Malpass, D. B. (2010). *Introduction to industrial polyethylene: properties, catalysts, and processes*. John Wiley & Sons.

Medical Delta & LDE-CfS Interdisciplinary Thesis Labs, 2022. Bottoms up! Time for a more environmental- and user-friendly design of ultrasound gel bottle. https://www.centre-for-sustainability.nl/uploads/cfs/attachments/07%20Bottoms%20up%21%20Redesign%20ultrasound%20gel bottles.pdf

Medical Delta, 2022. Interdisciplairy collaboration key in making healthcare more sustainable. https://www.medicaldelta.nl/en/news/interdisciplairy-collaboration-key-in-making-healthcare-more-sustainable

Nannini, E. C., Ponessa, A., Muratori, R., Marchiaro, P., Ballerini, V., Flynn, L., & Limansky, A. S. (2015). Polyclonal outbreak of bacteremia caused by Burkholderia cepacia complex and the presumptive role of ultrasound gel. *Brazilian Journal of Infectious Diseases*, *19*, 543-545. https://doi.org/10.1016/j.bjid.2015.06.009

Ohara, T., Sato, T., Shimizu, N., Prescher, G., Schwind, H., Weiberg, O., Marten, K. and Greim, H. 2011. Acrylic Acid and Derivatives. Ullmann's Encyclopedia of Industrial Chemistry. https://doi.org/10.1002/14356007.a01_161.pub4

Olshtain-Pops, K., Block, C., Temper, V., Hidalgo-Grass, C., Gross, I., Moses, A. E., Gofrit, O. N., & Benenson, S. (2011). An outbreak of achromobacter xylosoxidans associated with ultrasound gel used during transrectal ultrasound guided prostate biopsy. The Journal of urology, 185(1), 144–147. https://doi.org/10.1016/j.juro.2010.08.093

Parker Laboratories Inc., 2023. About Parker Laboratories Inc. https://www.parkerlabs.com/about-us/

Parker Laboratories, Inc., Aquasonic CLEAR® Ultrasound Gel. https://www.parkerlabs.com/products/aquasonic-clear-ultrasound-gel/

Ramanathan, Y. V., Venkatasubramanian, R., Nambi, P. S., Ramabathiran, M., Venkataraman, R., Thirunarayan, M. A., ... & Ramakrishnan, N. (2018). Carbapenem-resistant enterobacteriaceae screening: A core infection control measure for critical care unit in India?. *Indian journal of medical microbiology*, *36*(4), 572-576. https://doi.org/10.4103/ijmm.IJMM_18_437

RIVM, Sustainable Care. https://www.rivm.nl/duurzamezorg

RIVM, 2023. About RIVM. https://www.rivm.nl/en/about-rivm

Rijksinstituut voor Volksgezondheid en Milieu, 2018. WIP-richtlijn Echografisch onderzoek en TEE, hygiënemaatregelen. https://www.rivm.nl/wip-richtlijn-echografisch-onderzoek-en-tee-hygienemaatregelen-zkh

Sascha Verbruggen, Suzan Cochius-den Otter, Hanneke Bakker, 2023. Sustainability at Erasmus MC

Shaban, R. Z., Maloney, S., Gerrard, J., Collignon, P., Macbeth, D., Cruickshank, M., ... & Derrington, P. (2017). Outbreak of health care-associated Burkholderia cenocepacia bacteremia and infection attributed to contaminated sterile gel used for central line insertion under ultrasound guidance and other procedures. American journal of infection control, 45(9), 954-958. https://doi.org/10.1016/j.ajic.2017.06.025

Solaimalai, D., Ragupathi, N. K. D., Ranjini, K., Paul, H., Verghese, V. P., Michael, J. S., ... & James, E. J. (2019). Ultrasound gel as a source of hospital outbreaks: Indian experience and literature review. *Indian journal of medical microbiology*, *37*(2), 263-267. https://doi.org/10.4103/ijmm.IJMM_19_249

Taofeeq D. Moshood, Gusman Nawanir, Fatimah Mahmud, Fazeeda Mohamad, Mohd Hanafiah Ahmad, Airin AbdulGhani, 2022. Sustainability of biodegradable plastics: New problem or solution to solve the global plastic pollution?. https://www.sciencedirect.com/science/article/pii/S2666086522000157

Tiffany Silmon, Dana Chapman, What's in Your Bottle? Investigating a Pseudo-outbreak of Burkholderia cepacia, American Journal of Infection Control, Volume 47, Issue 6, Supplement, 2019, Pages S8-S9, ISSN 0196-6553, https://www.sciencedirect.com/science/article/pii/S0196655319303803

UK Health Security Agency, 2022. Good infection prevention practice: using ultrasound gel. https://www.gov.uk/government/publications/ultrasound-gel-good-infection-prevention-practice/good-infection-prevention-practice-using-ultrasound-gel#aim

Viderman, D., Khudaibergenova, M., Kemaikin, V., Zhumadilov, A., & Poddighe, D. (2020). Outbreak of catheter-related Burkholderia cepacia sepsis acquired from contaminated ultrasonography gel: the importance of strengthening hospital infection control measures in low resourced settings. Le Infezioni in Medicina, 28(4), 551-557. https://europepmc.org/article/med/33257630

Wang, M., Zhang, L., Xia, S., Wu, H., Zhang, R., Fan, M., & Wang, T. (2014). An investigation on surgical-site infection among post cesarean section patients with Burkholderia cepacia contaminated ultrasonic couplant. Zhonghua liu Xing Bing xue za zhi Zhonghua Liuxingbingxue Zazhi, 35(5), 566-568. https://europepmc.org/article/med/25059369

Willem Bijleveld, 2020. How Van Straten Medical transformed from wholesaler to circular service provider. https://www.linkedin.com/pulse/how-van-straten-medical-transformed-from-wholesaler-willem-bijleveld/?originalSubdomain=nl

World Health Organization, 2011. Manual of diagnostic ultrasound. 2nd ed. https://www.who.int/publications/i/item/9789241547451

Ecoinvent data source

David FitzGerald, 2007, EDTA production, RoW, Allocation, cut-off by classification, ecoinvent database version 3.9.1 https://ecoquery.ecoinvent.org/3.9.1/cutoff/dataset/9376/impact_assessment

Roland Hischier, 2007, propylene glycol production, liquid, RoW, Allocation, cut-off by classification, ecoinvent database version 3.9.1 https://ecoquery.ecoinvent.org/3.9.1/cutoff/dataset/8318/impact_assessment

Ecoinvent, 2023, market for triethanolamine, GLO, Allocation, cut-off by classification, ecoinvent database version 3.9.1 https://ecoquery.ecoinvent.org/3.9.1/cutoff/dataset/8616/impact_assessment

Roland Hischier, 2007, acrylic acid production, RoW, Allocation, cut-off by classification, ecoinvent database version 3.9.1 https://ecoquery.ecoinvent.org/3.9.1/cutoff/dataset/2717/impact_assessment

Rainer Zah, 2007, soap production, RER, Allocation, cut-off by classification, ecoinvent database version 3.9.1 https://ecoquery.ecoinvent.org/3.9.1/cutoff/dataset/7025/impact_assessment

Appendix A: Relevant hygiene rules

Hospital hygiene rules are a set of guidelines and practices aimed at maintaining a clean and safe environment within healthcare facilities to prevent the spread of infections and ensure the well-being of patients, staff, and visitors. Regarding the use of ultrasound gel, rules are set not only to enhance the quality of ultrasound imaging, but also to minimize the risk of infection to patients, considering that standard ultrasound gel is unsterilized, and patients range from those who are ‘fit and well’ to vulnerable individuals (UKHSA, 2022). Following 10 points are the summary of hygiene rules to follow when using ultrasound gel:

1. Hand Hygiene: Always clean your hands thoroughly with soap and water or use an alcohol-based hand sanitizer before and after handling ultrasound gel.
2. Single-Use Containers: Prefer single-use, disposable containers of ultrasound gel whenever possible. These containers should be sealed and properly labeled with expiration dates.
3. Contamination Prevention: Avoid touching the tip of the ultrasound gel bottle or container with gloves or any other surface to minimize the risk of contamination.
4. Clean and Intact Packaging: Inspect the packaging of ultrasound gel before use. Ensure it is clean and intact, without any signs of damage or tampering.
5. Application Technique: Use a clean, sterile, or disinfected spatula or dispenser to remove the gel from the container. Avoid direct contact between the ultrasound probe and the container to prevent cross-contamination.
6. Avoid Cross-Contamination: Never reuse ultrasound gel from one patient to another. Each patient should have a fresh, unused portion of gel to minimize the risk of infection transmission.
7. Spillage Management: If there is any spillage of ultrasound gel, clean it up immediately using appropriate cleaning methods and disinfect the area to prevent the spread of pathogens.
8. Storage: Store ultrasound gel containers in a clean and dry area, away from direct sunlight and extreme temperatures. Follow the manufacturer's instructions for storage conditions and shelf life.
9. Proper Disposal: Discard used ultrasound gel containers, spatulas, and any contaminated materials in accordance with the healthcare facility's waste management protocols and local regulations.
10. Training and Education: Healthcare professionals involved in ultrasound procedures should receive proper training on the correct handling and usage of ultrasound gel. Stay updated on best practices and guidelines related to ultrasound gel hygiene.

Appendix B: LCA Excell file of refilling

Excell file is included in the deliverable package.
File name: Refilling LCA-calculator-IDEMAT-2021-v2.1

Appendix C: LCA Excell file of redesigns

Excell file is included in the deliverable package.
File name: Gel Bottle Redesign LCA-calculator-IDEMAT-2021-v2.1