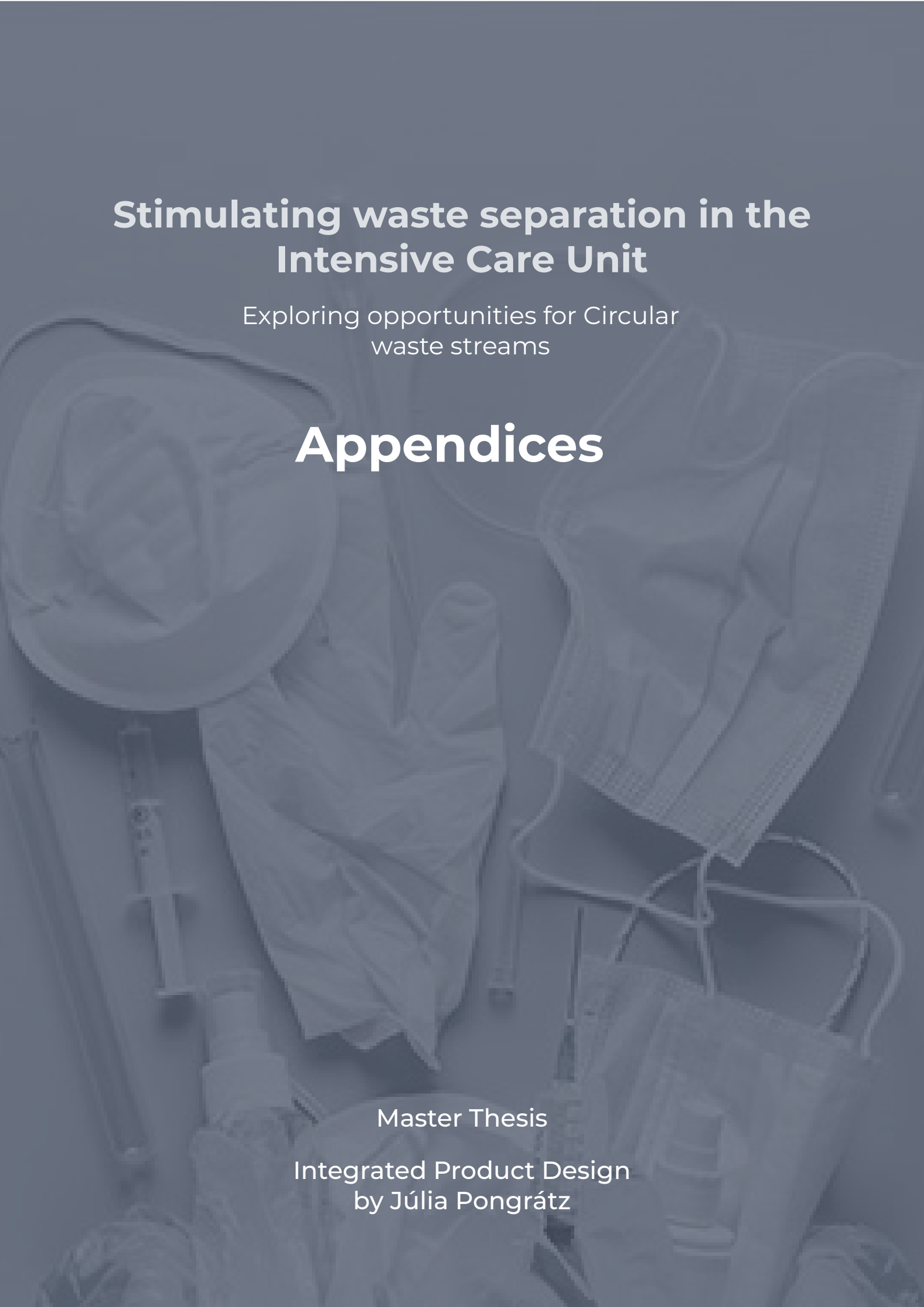
Stimulating waste separation in the Intensive Care Unit

Exploring opportunities for Circular waste streams

Appendices



Master Thesis

Integrated Product Design
by Júlia Pongrátz

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DESIGN FOR our future

Appendix A Graduation Brief

TU Delft

IDE Master Graduation

Project team, Procedural checks and personal Project brief

This document contains the agreements made between student and supervisory team about the student's IDE Master Graduation Project. This document can also include the involvement of an external organisation, however, it does not cover any legal employment relationship that the student and the client (might) agree upon. Next to that, this document facilitates the required procedural checks. In this document:

- The student defines the team, what he/she is going to do/deliver and how that will come about.
- SSC E&SA (Shared Service Center, Education & Student Affairs) reports on the student's registration and study progress.
- IDE's Board of Examiners confirms if the student is allowed to start the Graduation Project.

USE ADOBE ACROBAT READER TO OPEN, EDIT AND SAVE THIS DOCUMENT

Download again and reopen in case you tried other software, such as Preview (Mac) or a webbrowser.

STUDENT DATA & MASTER PROGRAMME

Save this form according the format "IDE Master Graduation Project Brief_familyname_firstname_studentnumber_dd-mm-yyyy".
Complete all blue parts of the form and include the approved Project Brief in your Graduation Report as Appendix 1 !

family name: Pongrátz
initials: J given name: Júlia
student number: 5202981
street & no.:
zipcode & city:
country:
phone:
email:

Your master programme (only select the options that apply to you):

IDE master(s): ★ IPD ○ DfI ○ SPD
2nd non-IDE master:
individual programme: - - (give date of approval)
honours programme: ○ Honours Programme Master
specialisation / annotation: ○ Medisign
○ Tech. in Sustainable Design
○ Entrepeneurship

SUPERVISORY TEAM **

Fill in the required data for the supervisory team members. Please check the instructions on the right !

** chair: J.C. Diehl dept. / section: SDE/ Dfs
** mentor: A. Ruiter dept. / section: HCD/AED
2nd mentor: N.G.M. Hunfeld
organisation: Erasmus MC
city: Rotterdam country: The Netherlands

comments (optional)

Chair should request the IDE Board of Examiners for approval of a non-IDE mentor, including a motivation letter and c.v..

Second mentor only applies in case the assignment is hosted by an external organisation.

Ensure a heterogeneous team. In case you wish to include two team members from the same section, please explain why.

Procedural Checks - IDE Master Graduation

APPROVAL PROJECT BRIEF
To be filled in by the chair of the supervisory team.

chair J.C. Diehl date 09 - 09 - 2022 signature jdiehl Digitally signed by jdiehl Date: 2022.09.10 17:18:46 +02'00'

CHECK STUDY PROGRESS
To be filled in by the SSC E&SA (Shared Service Center, Education & Student Affairs), after approval of the project brief by the Chair.
The study progress will be checked for a 2nd time just before the green light meeting.

Master electives no. of EC accumulated in total: _____ EC

Of which, taking the conditional requirements into account, can be part of the exam programme _____ EC

List of electives obtained before the third semester without approval of the BoE

YES all 1st year master courses passed

NO missing 1st year master courses are:

name _____ date - - signature _____

FORMAL APPROVAL GRADUATION PROJECT
To be filled in by the Board of Examiners of IDE TU Delft. Please check the supervisory team and study the parts of the brief marked **.
Next, please assess, (dis)approve and sign this Project Brief, by using the criteria below.

- Does the project fit within the (MSc)-programme of the student (taking into account, if described, the activities done next to the obligatory MSc specific courses)?
- Is the level of the project challenging enough for a MSc IDE graduating student?
- Is the project expected to be doable within 100 working days/20 weeks ?
- Does the composition of the supervisory team comply with the regulations and fit the assignment ?

Content: APPROVED NOT APPROVED

Procedure: APPROVED NOT APPROVED

comments

name _____ date - - signature _____

Personal Project Brief - IDE Master Graduation

Stimulating waste separation in the Erasmus MC Intensive Care Unit — project title

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

start date 06 - 09 - 2022 17 - 03 - 2023 end date

INTRODUCTION **
Please describe, the context of your project, and address the main stakeholders (interests) within this context in a concise yet complete manner. Who are involved, what do they value and how do they currently operate within the given context? What are the main opportunities and limitations you are currently aware of (cultural- and social norms, resources (time, money,...), technology, ...).

Currently, the healthcare sector is one the most polluting areas, contributing to 4.8% of global net greenhouse gas emissions and toxic air pollutants, which nevertheless negatively affects public health. In the Netherlands, this number is even more excessive, the country's high-quality healthcare results in 5.9% of its carbon footprint (Karliner et al., 2020). Modern healthcare practices require a large amount of material, more than two third of the emissions are from the production, transportation and disposal of medical goods.
Patients with critical illnesses are treated in the Intensive care units (ICU) of hospitals, which use the largest amount of resources due to the required constant assistance. The majority of the used products are fossil-based, single-use equipment with very short life-cycle that usually ends in incineration (Metabolic, 2021).
Since the start of the pandemic in 2020, the use of infection-preventing equipment has increased as well, which contributes to an even more significant impact on the environment.

The awareness of these negative effects is growing in the healthcare community and some institutions take the initiative to address them. A green movement has started among Operating Rooms in the Netherlands to transition from a linear to a circular approach (Metabolic, 2021). As such, the Erasmus Medical Center (MC) in Rotterdam has begun to work towards a future with sustainable medical practices by aiming to organize the highly complex ICU department in a more circular way . As a first step, a Material Flow analysis and impact assessment was conducted by Metabolic in 2019 to identify the highest impact material flows in the system. This provided a base for a series of graduation projects in collaboration with TU Delft to design sustainable solutions particularly for the ICU, of which this project is also a part.

In the ICU the amount of products used and disposed per patient each day fills six garbage bags (Figure 1). Sadly, the majority of this waste is not separated and due to safety mechanisms for hazardous material or hospital specific waste, is incinerated (Figure 2). However, according to research from McGain et al., a large amount (approx. 44%) of this waste is non-infectious and could be potentially recycled with proper logistics, safety measure and training of staff. Therefore this project focuses on stimulating waste separation to enable the recycling of the non-infectious waste stream.

The project relies on a multidisciplinary cooperation of different stakeholders, as it involves a wide range of parties. The healthcare team of the ICU, such as nurses and care assistance are in direct contact with the waste and interior of the ICU, as well as the patients and the waste management company (Prezero). Apart from them, the Erasmus MC, the healthcare equipment manufacturers, procurement, TU Delft and policy makers also play important roles.

Due to the medical environment, challenges related to the complex regulations and protocols, adaptability or resistance of the ICU staff, financial concerns and logistical issues need to be considered and taken into account.

Browne-Wilkinson, S., van Exter, P., Bouwens, J., Souder, J., & Chatel, E. (2021). Circular Intensive Care Unit - opportunities for human and planetary health. Metabolic and Erasmus MC.
Karliner, J., Slotterback, S., Boyd, R., Ashby, B., Steele, K., & Wang, J. (2020). Health care's climate footprint: the health sector contribution and opportunities for action. European Journal of Public Health, 30(Supplement_5). https://doi.org/10.1093/eurpub/ckaa165.843
McGain, F., Story, D., & Hendel, S. (2009). An audit of intensive care unit recyclable waste. Anaesthesia, 64(12), 1299–1302. https://doi.org/10.1111/j.1365-2044.2009.06102.x

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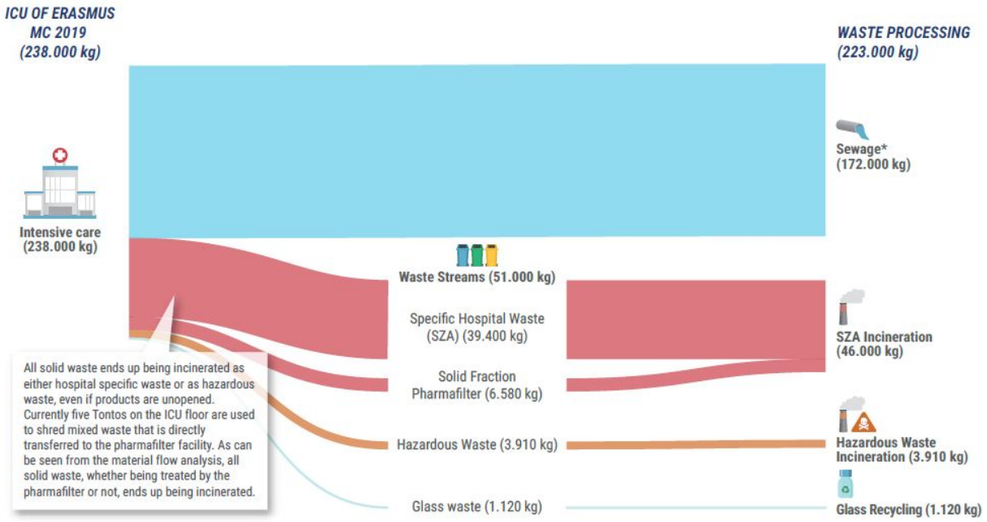


image / figure 1: Waste flow of the ICU of Erasmus MC in 2019 (Metabolic, 2021)

image / figure 2: Amount of waste per patient per day in the ICU room and the waste bin (Erasmus MC, 2021)

PROBLEM DEFINITION **

Limit and define the scope and solution space of your project to one that is manageable within one Master Graduation Project of 30 EC (= 20 full time weeks or 100 working days) and clearly indicate what issue(s) should be addressed in this project.

Hospitals, especially the most resource-demanding department, the ICU produces a large amount of waste. The waste generated each day per patient is equivalent to six garbage bags. Currently most of this waste is collected in one wastebin within each room without separation. Only the sharp infectious waste (needles, etc), and some glasses are collected separately. The separation opportunities during the design of the room have not been taken into account. The garbage bins are emptied at each shift and the bags are taken to the trash room. As a separate solution, part of the general waste is fed into a Pharmafilter machine, which is able to clean it from bacteria and medicine. Originally, the filtered waste should be turned into biogas, but due to the problem of not enough material for that, it is incinerated as well. The potentials of this (high-cost) investment are not used to its capacity due to difficulties with logistics.
Moreover, current cleaning protocol requires the disposal of the entire inventory of the ICU box before the arrival of a new patient, which in some cases means 9 kg of sterile equipment in their original packaging going to the same wastebins. This also contributes to the problem. A large part of the general waste consists of packaging of products, disposable clothes, masks and gloves, bed liners and syringes (Metabolic, 2021). Many of these are non-infectious recyclables that are being incinerated, resulting in financial and environmental burden. If correctly separated from infectious waste to avoid cross-contamination, the materials could be recovered (McGain et al, 2009).
The workload on nurses and doctors is high in the ICU and saving lives is priority over environmental concerns. The current method of having one waste stream is saving trouble and time for the staff and their working method is adapted to this system. Furthermore, the situation is complicated by infection regulations that the ICU room needs to comply with, such as the rule of opening the product packaging strictly inside the room.
Despite these barriers, how can we empower the staff with solutions and training to enable waste separation while helping adaptation and commitment and avoiding cross contamination of waste streams? Which material streams are suitable for recycling? What are the logistical challenges? What are the opportunities with the Pharmafilter machine?

ASSIGNMENT **

State in 2 or 3 sentences what you are going to research, design, create and / or generate, that will solve (part of) the issue(s) pointed out in "problem definition". Then illustrate this assignment by indicating what kind of solution you expect and / or aim to deliver, for instance: a product, a product-service combination, a strategy illustrated through product or product-service combination ideas, ... In case of a Specialisation and/or Annotation, make sure the assignment reflects this/these.

The research will mainly focus on the analysis of the current disposal process and waste management system, as well as safety and health protocols. Based on the analysis, ideas will be generated in close collaboration with the stakeholders, and will be further developed into a final design that stimulates the separation of waste in order to enable the recycling of certain materials, complemented by a roadmap with recommendations towards circular waste managemt.

It is essential to have a solid understanding of the healthcare system and processes in the ICU to create solutions that fit the context and the users. Multiple perspectives need to be taken into account, such as the healthcare staff and patient needs, habits and behavior, the logistics inside and outside of Erasmus MC, the recycling possibilities, the environmental impacts, the regulations and protocols, costs and procurement. Therefore the research will get a large focus in the project.
A good understanding of the context of the stakeholders is needed.

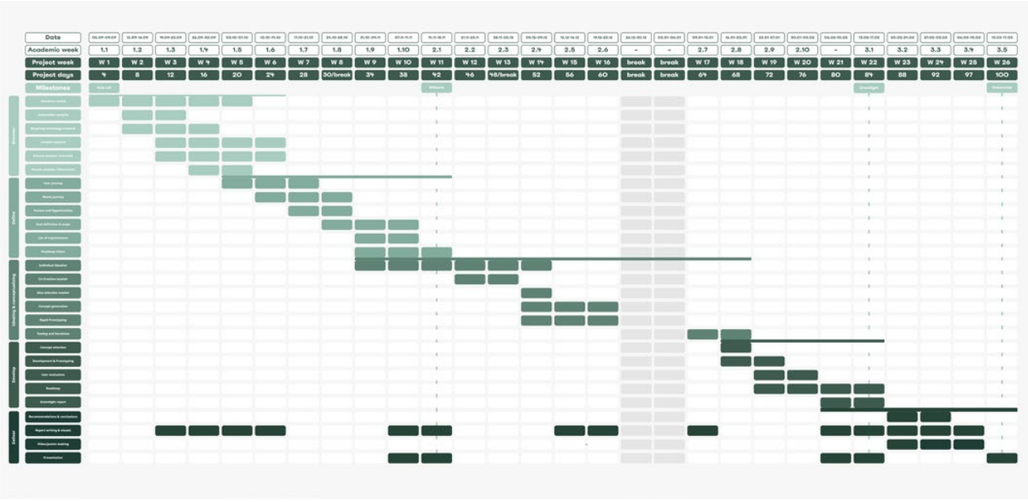
I aim to deliver a result that can be implemented in the close future, creating an immediate positive effect. Next to that, a roadmap with a comprehensive approach for further steps towards circular waste management will be provided. The direction of the final concept will be based on the results of the analysis. By selecting a specific material flow with high impact and opportunities for separation, a demostrator can be created for the basis of a larger system.

Possible solutions for the final implementation include:
- a physical sorting system inside or outside the room with changes in protocol
- redesign of the ICU interior to create adequate space for and ease separation
- a logistics plan for the waste management
- education and motivation of healthcare staff

PLANNING AND APPROACH **

Include a Gantt Chart (replace the example below - more examples can be found in Manual 2) that shows the different phases of your project, deliverables you have in mind, meetings, and how you plan to spend your time. Please note that all activities should fit within the given net time of 30 EC = 20 full time weeks or 100 working days, and your planning should include a kick-off meeting, mid-term meeting, green light meeting and graduation ceremony. Illustrate your Gantt Chart by, for instance, explaining your approach, and 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 activities.

start date 6 - 9 - 2022 17 - 3 - 2023 end date



I plan to spend 25 weeks/100 days on the graduation project. I will work four days a week on the project and will spend one day for my student assistant work. I am planning to have a longer holiday during the Christmas break and two shorter breaks (long weekends) around the midterm presentation.
The project is divided into five phases. In the first part, I will gather data through literature research, interviews and observation in the topics mentioned in the "assignment". User and waste journey mapping is planned to be conducted to gain information about the roles of stakeholders, and the environmental, logistical and staff challenges. After that, I will analyse the data, create visuals and formulate specific design goal and scope as well as a vision for the roadmap. In the third part, I will generate and select ideas, develop them into concepts and make quick tests. As the actual implementation of the solution will highly depend on the frequency of healthcare workers to properly use it, long-term motivational strategies are likely to be used.
For this engagement, co-creations sessions are planned. In the development phase, iterations and prototyping of a chosen concept is followed by user evaluations. Furthermore, the final product -system's environmental impact needs to be taken into account, since we don't want to create a new environmental issue while solving one. Calculations will be made to determine the impact. A roadmap outlining the steps to recycling ICU waste will be created. During the previous phases, I will constantly work on the report and hand in a draft version before the greenlight. In the last part, visuals are created, the report is finalized and the final presentation is made. Recommendations and conclusions are formulated.

MOTIVATION AND PERSONAL AMBITIONS

Explain why you set up this project, what competences you want to prove and learn. For example: acquired competences from your MSc programme, the elective semester, extra-curricular activities (etc.) and point out the competences you have yet developed. Optionally, describe which personal learning ambitions you explicitly want to address in this project, on top of the learning objectives of the Graduation Project, such as: in depth knowledge a on specific subject, broadening your competences or experimenting with a specific tool and/or methodology, ... Stick to no more than five ambitions.

I like projects, where multiple parties are involved and when it is possible to work with the user group closely.
I believe I can make the most positive impact in my life with designing for our environmental crisis, therefore I chose to direct my Master studies towards sustainability expertise in the elective semester. However, I also have an interest in the medical field, which I followed in the first part of my master, where my two main design projects were medisign related, a rehabilitation device and a navigation device for visually impaired people. In this project I have the opportunity to combine these two areas and hopefully make an actual, measurable impact with the design solution. A project addressing an actual need and creating value is what I imagined for my graduation topic.

I hope to apply my experiences from my electives in sustainable design strategies and further develop my practical knowledge in circular design. I am especially looking forward to the research phase, where I can sink into exploring the system and the testing part in the actual context.

During the project, I hope to further develop my project management skills, for which this is a great opportunity with the multiple involved parties. I have experience in 3D visualisation of interiors and products, but I would also like to try myself in the visualization of data and processes to strengthen my visual communication skills.
Furthermore, I am excited for the challenge of designing in the medical field complexity and navigating in its regulated environment with conflicting ambitions, such as sterility, ease of use, time management, material integrity. I am confident I will gain valuable experience as a designer and as an individual.

FINAL COMMENTS

In case your project brief needs final comments, please add any information you think is relevant.

Appendix B
On-site waste management systems

A possible solution for the ICU waste management would be an on-site treatment method which is able to sterilize the waste in a way that the materials in the end can be recovered. This way, the transportation and external waste contractors could be avoided, potentially reducing costs for the hospital. The technology needs to render the waste similar to household waste. There are existing commercially available systems which aim to provide new solutions for healthcare waste management as a whole. Their aim is to reduce emissions and make a safe and easy processing at the same time directly in the hospital. It is interesting to examine these solutions and compare it to the Pharmafilter system, then explore whether these could be potentially implemented in Erasmus MC.

Curo

Curo was developed in the UK by the NHS (Northumbria Healthcare) and is specialised in clinical waste management. It is an on-site solution that needs to be setup on the hospital location. The physical machinery is developed by an Italian company, CISA. Cure claims to reduce the carbon emission by 100%, meaning 0 kg C02 production through their 'innovative technology'.
Their solution starts with disposing the waste in 2 different bins depending on infectious level of the waste type (hazardous or non-infectious clinical waste). The waste is transported in a larger cart to the Curo waste unit in the hospital. All the bags from both waste categories are weighed and provided with a barcode before they are placed into the Curo System for scanning and processing. The size of the installation is unknown. The processing method seems confidential, but it is probably a high temperature and pressure solution. The outcome is called Floc (a shredded mix of material), which is said to be suitable for making garden furniture, plant pots, food containers, clothing fibres and electricity. There are also biomass pellets produced, which can be used as an alternative fuel source. The energy recovered from the waste can be used to power the waste plant. This way, the landfilling or incineration of clinical waste is avoided, and carbon emissions are reduced (Benefits, n.d.)). Another advantage is that it reduces the volume by 80%.
Based on the official website and the conversation with a company representative, this is all that can be known about the technology and no information is available about the material composition of the final shredded flakes or if there is any separation performed during the process. The sterilization or other treatment method is also not known which makes the whole system and its impact questionable. Some limited information implies that in the end the waste is somehow separated into three categories, recyclable plastic, biomass, and a mixed part which can incinerated for energy recovery. However, the proportions and the type of plastic is still unspecified.

Ecosteryl

Figure X: Ecosteryl decontamination and R-Steryl sorting installations and recovered streams (R-steryl : Decontaminated Medical Waste Sorting Center, 2023).

Another system called Ecosteryl is already available in the Netherlands (Medisch-afval-decontamineren-en-recyclen, n.d.). It's sterilization unit operates with continuous microwave sterilization and integrated pre-shredding. First, the waste is shredded to a maximum size of 20mm and then heat treatment is performed at 100 °C for one hour to remove all infectious substances. As opposed to steam sterilization methods, the materials in the end are dry and no additional water is required for sterilizing. The size of the installation ranges from 25 m2 to 100 m2 depending on capacity. The sterilized waste is ready for sorting by Ecosteryl's own sorting centre, the R-steryl. R-steryl can sort the waste by air and optical sorting to 3 separate streams, plastic, solid waste for fuel and residual fraction (Figure X). The plastic is already in a granulate form which can be recovered for plastic industry. It is able to recovery 80% of the waste at the end of the sorting process. The capacity of R-steryl in 0,5-1 ton/hour and the size is 85 m2 (R-steryl :Decontaminated Medical Waste Sorting Center, 2023).
The typical division of the sorted decontaminated waste is 20% light waste, used as refuse-derived fuel, 60% Polypropylene and Polyethylene granules and 20% residual fraction which is not economically viable to recycle today, therefore incinerated (R-steryl, n.d.). This typical result composition can differ based on the type of waste in the hospital. In Erasmus MC, indeed a large part of the plastic types are PP and PE, but together still they only form 50% of the synthetic fabrics are not counted. (metabolic). The question still remains what can be done with the mixed PP- PE plastic waste, since for optimal recycling, the plastic types should be separate.

Figure X: Waste composition after sorting by R-steryl (R-steryl : Decontaminated Me-

dical Waste Sorting Center, 2023) .

Sterilwave

Figure X : Sterilwave 250 Waste treatment solution (Hazardous Waste Disposal - Blending and Sterilization of Bio Hazardous Medical Waste, 2022))

Sterilwave is a compact size machine which is able to sterilize all type of biohazardous waste through microwave sterilization. The materials are shredded by rotating blades, which reduced the volume by more than 80% and the weight by 25%. The microwave sterilization heats up the waste for 110 C° for 20 minutes which ensures a sterile result. It requires 12 m2 of space and is able to treat 50 kg waste per hour. It is important that all type of materials are accepted, including metals, glasses and liquids. The final product is a mix of shredded material that can be disposed of as municipal waste (Hazardous Waste Disposal - Blending and Sterilization of Bio Hazardous Medical Waste, 2022)).

Sterimelt

Figure X: Sterimelt machine (Sterimelt - TCG Solutions, n.d.)

The company TCG Solutions have a range of specialised machines focusing on the sterilization of specific waste types, such as single use Polypropylene disposables, Styrofoam and mixed waste. Sterimelt, the PP recovery installation (Figure X) claims to save carbon emission by 50% and reduce the volume by 85%. It is compact in size and produces a single clean plastic type by the end which is ready for recycling (Sterimelt - TCG Solutions, n.d.)). However, it is limited to one type of plastic and does not provide solutions for the rest of the waste stream. It would be an optimal solution for polypropylene that needs to be decontaminated before it can be recycled. If this is the case for Erasmus MC it can be considered, but if the PP can be collected as considered clean, sending it directly to the recycler is a better option.
Another product, Styromelt recovers EPS by a thermal compaction process, in which the polystyrene is melted, and the volume is reduced by 90%. Sterile solid polystyrene blocks are produced as the end result (Styromelt - TCG Solutions, n.d.). For Erasmus MC, this machine does not provide new solutions, since their Styrofoam waste is clean and already compressed (without melting) before sent to recycling.
MassMelt, the mixed waste option is focusing on reducing moisture content and waste volume, through melting the waste together but does not produce a recyclable stream as end product (Massmelt - TCG Solutions, n.d.). The positive impact lies in decreased cost of disposal and more efficient transport. It also takes up considerably more space.

Shredded and sterilized medical waste after treatment (Medical Sharps Waste Disposal and Shredder for Recycling, n.d.)

There are still many other similar solutions for compact-sized on-site waste treatment, such as Sterishred by the French Tesalys (steam sterilization), Sterimed (chemical), Meteka (microwave) and Celitron (steam) (TESALYS, 2023), (SteriMed S15 | SteriMed S70 | Clinical Waste Disposal Products, n.d.), (Waste Decontamination - METEKA, 2021d), (Medical Sharps Waste Disposal and Shredder for Recycling, n.d.).
They are very similar in principle, only the sterilization method and the exact capacity is changing. All of them are shredding, sterilizing and dewatering the waste, resulting in a multimaterial shredded micture. (Figure X). There were attempts to the recycling the solid residue of these all-in types of sterilizing machines, however, making use of this mixed material is difficult because it is too variable or rough (Wheeler, 2021). The value is in the consistency and purity of the material for the manufacturers; therefore, it needs to be collected separately.

For all these systems, a special container and procedure would be needed to ensure safe collection and transport within the hospital.

Cleanbags /D2

FGiure X: CleanBags machine (CleanBags/D2 - Tecno Trust Srl, 2022)

The CleanBags /D2 machine from TechnoTrust is different from the previous options. It was developed for cleaning and emptying liquid-containing bags, such as urine bags and dialysis bags. The machine automatically empties and internally disinfects the bags in 10 seconds, delivering the empty bags at the bottom but has to be operated manually. It is able to collect 30 bags in the bottom compartment ready to be recycled. (CleanBags/D2 - Tecno Trust Srl, 2022). It is a relatively small device that can be placed on corridors without causing space issues. However, it also needs to be connected to the water mains and the sewage system (TecnoTrust,2022). The means of sterilization is chemical disinfection, and the disinfectant is chlorhexidine digluconate, which is less environmentally friendly compared to other methods. A unique attribute of this product is that it does not shred the bags, so they can be still separated by plastic type during the near- infrared separation process. Unfortunately, it can only process one bag at a time and based on the size of the opening, it seems, that not all size of bags used in the ICU would fit.

Conclusions

Most of the solutions focus on turning infectious waste into normal household waste and reducing its volume and weight by shredding and drying it. This way, special waste transportation and incineration is no longer necessary. Although the environmental impact might decrease with the transportation of a lower volume stream and avoiding high-temperature incineration, these do not deal with the closing the loop, the end of life still remains the same. It is possibly more important for countries, where incineration is not the primal waste treatment method, so by sterilizing the waste, it can be safely landfilled. However, in the case of Erasmus MC, the sterilized waste is just as well incinerated.

Most methods combine a type of sterilization method with shredding, making the final mix of materials difficult to separate due to the small size of the pieces.
This is exactly why the current output of the Pharmafilter cannot be used for recycling, because it is claimed to be too difficult to separate. Therefore the explored solutions would only provide additional advantage if they can separate the materials to recyclable streams. The two systems which seem to be able to separate waste are the Ecosteryl and Curo. Still, in these two cases the exact separate categories are indistinct, and their recyclability is questionable. Additionally, they are very complex and require large installations on site. Next to the existing Pharmafilter system, finding place for them in the already limited space would be difficult. The replacement of the Pharmafilter system is not realistic or recommended after the initial investment in that system and the advantage which it can provide for wastewater management. Based on the assumed cost of such a system, it would be also not economically viable for the hospital to invest in a second similar solution only focusing on solid waste.

Based on these conclusions and the conclusions of , sterilization of infectious waste is eliminated as an option for the scope of this project and as a result, infectious waste recycling as well

Recommendation
However, a separate purchase of the Ecosteryl sorting machine could be explored, which could be used in combination with the solid waste output of the Pharmafilter. The conditions needed for this machine to separate the Pharmafilter solid fraction can be investigated, and the solid waste could be adapted to fit the requirements, such as larges size or completely dry stream.

Appendix C
Final graphical package

COLLECT HERE

RECYCLING FOLIE

draagtassen

folie om de flessen

folie om de bedden

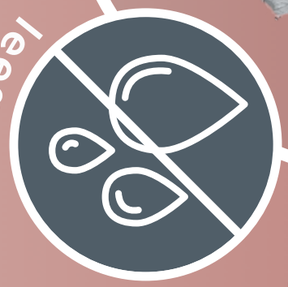
geen harde plastic!

Only the materials in the picture. If you are unsure, don't throw it here!

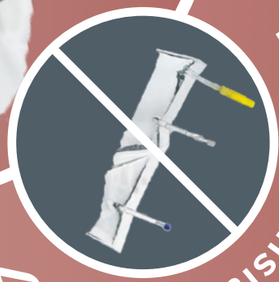
GEEN HARDE PLASTIC!
GEEN ANDERE PLASTIC!

dialyse zak

leeg



zonder aansluitpunten



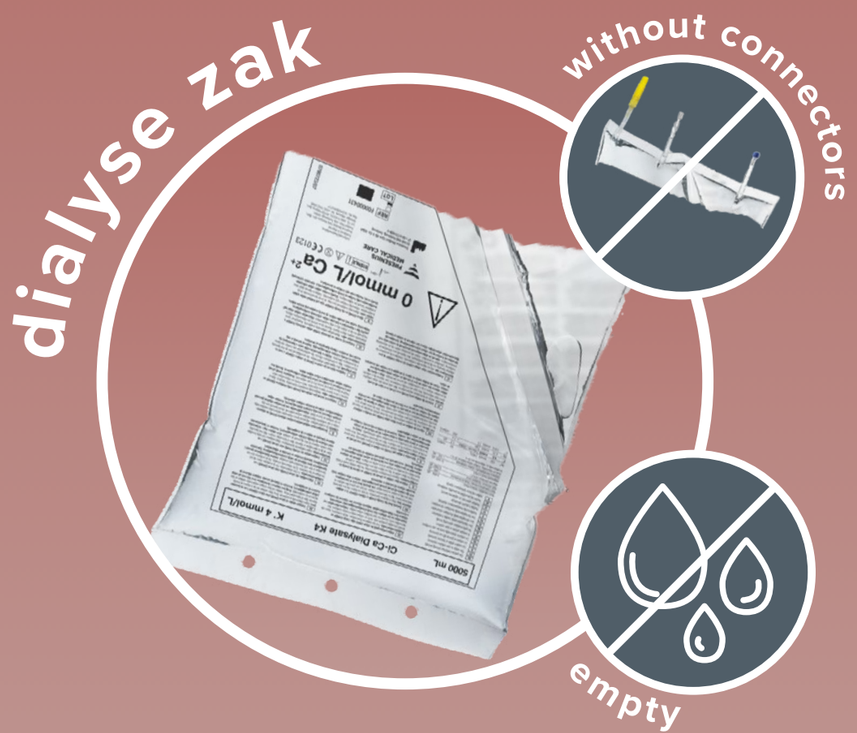
dialyse omzak

GEEN ANDERE INFUUS ZAK!
GEEN ANDERE PLASTIC!

COLLECT HERE

DIALYSE ZAK

Only the dialysaat zak in the picture. No other type of infusion bags! Cut the connectors and empty the bags first. If you are unsure, don't throw it here!

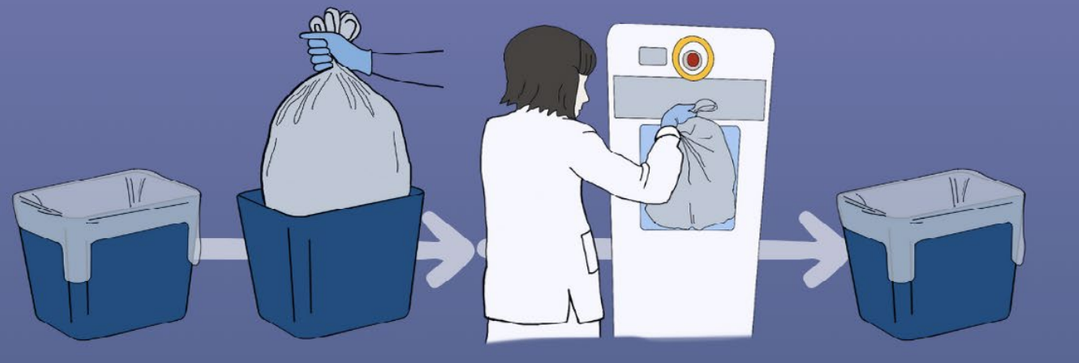


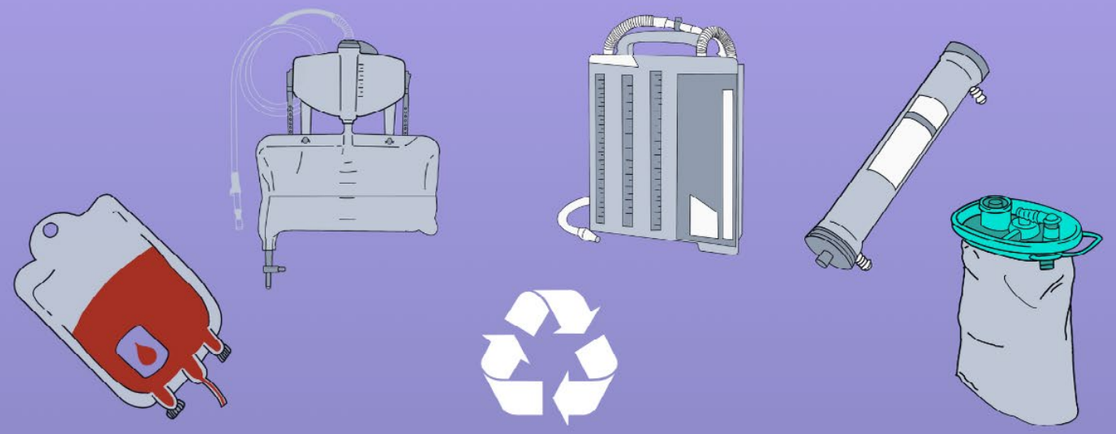
You can temporaily collect the empty bags here. You can throw them in the recycling bin in waste storage room when you collect the new fluids.

GEEN HARDE PLASTIC!
GEEN ANDERE PLASTIC!

This is a bag for collecting items for the Tonto

When you have an item for the Tonto, you can use this bag to collect your item, then dispose the whole bag in the Tonto and place a new bag in the bin. Putting items in the Tonto is better for the environment than using the WIVA gegs.





Are you sure it cannot go to the Tonto?

Before disposing an item in here, think about whether it could go to Tonto. It is always a better option for the environment and for the disposal costs. Items like drains, artificial kidneys, suction bags and blood bags can all be disposed in Tonto.

By minimizing the use of the WIVA kegs, we can save up to 4000 kg of C02 per year

BE MINDFUL OF YOUR ENVIRONMENTAL IMPACT.

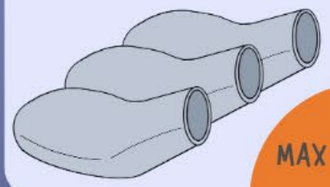
WHAT DOES THE TONTO DO?

It cleanes the waste from pathogens and medicines. Compared to disposing products in the WIVA kegs, it saves considerable CO2 emissions and costs. Unfortunately, recycling the mixed waste is not yet possible, so recyclables should be always disposed in the separate waste streams.

WHAT SHOULD GO INTO THE TONTO?

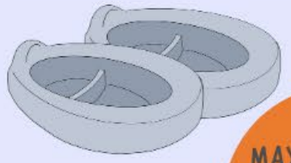
The highlighted items below should definitely be disposed in the Tonto insetad of the Wiva kegs. Apart from that, waste from isolation patients can be disposed in a bag, except from the forbidden materials. Where it is stated, the items need to be placed first in the special 40 L Tonto bag, then into the opening of the Tonto. Be mindful about the maximum number of products per time.

URINALS



MAX 3

BEDPANS

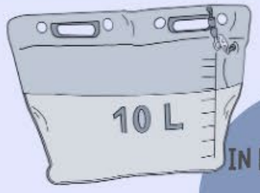


MAX 2

MEASURING JARS

MAX 1

FILTRATE BAGS



IN BAG

CYTOSTATICS

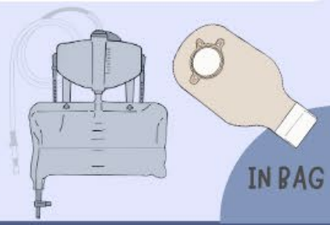
WASTE FROM ISOLATION PATIENT

Except from metals, glass, porcelain, electronics and syringes.

IN BAG

MAX 1

CATHETERS AND OSTOMY BAGS



IN BAG

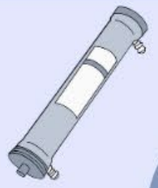
BLOOD AND BLOOD BAGS

IN BAG

SUCTION BAGS

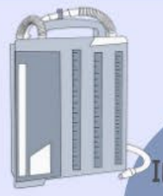
IN BAG

ARTIFICIAL KIDNEYS



IN BAG

REDON AND THORACIC DRAIN



IN BAG

WHAT CANNOT GO INTO TONTO?

The materials listed below should be **never** placed in Tonto to avoid breaking down.
Dispose them in the designated category.

NO METALS

NO PORCELAIN

NO GLASS

NO SYRINGES

NO BATTERIES

NO PAPER AND CARDBOARD

NO PRINTER CARTRIDGES

NO GMO WASTE

NO CAST

TIPS

Some items has loose parts, such as connectors or tubes, which can be stuck and break down Tonto.
Here is how you can avoid it:

Always put the loose parts and items with tubes or connectors into a bag

Tape the loose connectors to the bag

For more information send an email to: tonto@erasmusmc.nl In case of breakdown, press the reset button and/or call 44445 and brng your waste to the nearest Tonto.

restafval

linnen

Don't forget to recycle

Appendix D
Sensitizing booklets

ICU waste management

Sensitizing booklet

TU Delft

About me

Name:
.....
.....

Age:
.....
.....

Job/Functie:
.....
.....

About me

I sometimes throw the waste in the wrong bin.

○ totally disagree ○ disagree ○ neutral ○ agree ○ totally agree

I would like to contribute to recycling more from our waste in the IC.

○ totally disagree ○ disagree ○ neutral ○ agree ○ totally agree

I am open to changes in the process of waste disposal if it does not take any extra effort.

○ totally disagree ○ disagree ○ neutral ○ agree ○ totally agree

I am open to changes in the process of waste disposal even if it takes a small effort.

○ totally disagree ○ disagree ○ neutral ○ agree ○ totally agree

About the waste and your work

This is what I like about the waste disposal system/process in the ICU :

.....
.....
.....
.....

What gives you the most energy during your work?

.....
.....
.....
.....

This is what I **don't** like about the waste disposal system/process in the ICU :

.....
.....
.....
.....

Which moments do you find the most difficult during your work?

.....
.....
.....
.....

What can you imagine as a problem if we want to separate more waste?

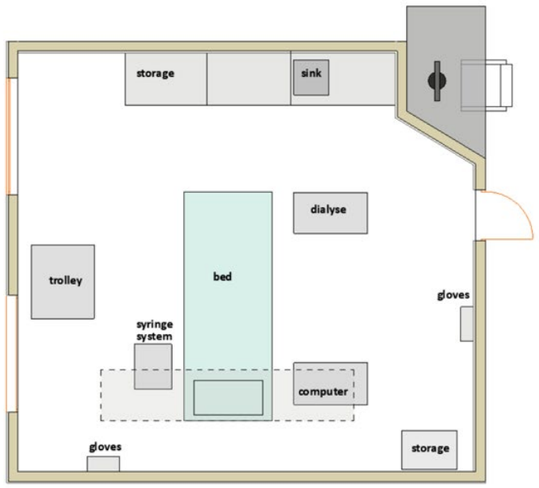
.....
.....
.....
.....

Do you have any ideas about waste management that you would like to share ?

.....
.....
.....
.....

The ICU Room

Below you see a floorplan of the ICU room. Please show the areas in the room where you think waste is produced. Then show where do you open packages and what are the main routes that you usually take. For each one, use a sign indicated on the right.



open packages

waste is generated

main routes

Waste types

Which waste type you would like to ideally recycle if it was possible ? Please choose only one.

○ plastic bottles

○ gloves

○ syringes

○ plastic packagings

○ aprons/jackets

○ IV bags

○ tubes and connectors

○ diapers

Thank you!

Thank you for helping me with my project by contributing to this research!
I might have some additional questions based on the results.
If you are open for a discussion later, please provide your contact detatils below. I would really appreciate it!

Mail:.....

Mobile:.....

If you have any other comments, please let me know below:

.....
.....
.....
.....
.....

Appendix E
Sensitizing booklets analysis

ANALYSIS

Analysis

Question	Theme	Quote
This is what I like about the waste disposal system/process in the ICU	Tonto system	The Tonto
		The Tonto
		That it's all in one in the tonto, it saves time
	Ease of use	it does not take effort
		it is easy
		that it is there. the garbage doesn't pile up at the front door
	progress is being made	it's being thought about
		that it has been thought about and action taken for a long time
		that there is now a Green Team who is committed to this
	separation of specific waste types	the sharp bin
		plastic is separated from all other waste. and all paper and cardboard are very good for the environment
This is what I don't like about the waste disposal system/process in the ICU	concerns about lack of separation system	we don't separate all the waste we can
		we don't separate plastic
		that we don't spearate the most simple things like gloves, dialyse bags/plastic etc
		everything in one -> not recycling
		plastic is not recycled enough
		that hardly any start has been made with separating or separating waste
	weight is too much	heavy trash
		the heavy boxes with fluid
	the amount generated	too many
		The amount of plastic everything is packed separately
	no problem	it's going well the way it's organized now

New table

Question	Theme	Quote
What gives you the most energy during your work?	patient	patients
		to make patients better and to guide
		the interaction with the patients and families
		patient
		transfer the patient
	professional achievements	achieved treatment
		...achieving treatment goals
		being useful
	social needs	the people around me
		my colleagues
		my colleagues....
		colleagues..
		colleaagues,,,
	physical needs	food
Which moments do you find the most difficult during your work?	helplessness	when I can't help severe situations
		that you can not cure everyone especially young people
	losing patients	grief at patients death
		bad news for patients
		if many patients die..
	high workload	when I am overworking
		time mangement?
	interaction with relatives	family
		guiding family
	waste	we throw away too much
Do you have any ideas about waste management that you would like to share ?	separation and recycling	recycle items
		recycling
		separate bins
		to separate more plastic
	plastic waste management	handle plastics more carefully more often the same aprons/jackets
		to separate more plastic
	organization	now the environmental stations belong to no one.it quickly becomes chaos

New table

Participant name	Age	Job	Q1: I sometimes throw the waste in the wrong bin.	Q2: would like to contribute to recycling more from our waste in the IC.	Q3: I am open to changes in the process of waste disposal if it does not take any extra effort.	Q4: I am open to changes in the process of waste disposal even if it takes a small effort.	This is what I like about the waste disposal system/process in the ICU	This is what I don't like about the waste disposal system/process in the ICU	What can you imagine as a problem if we want to separate more waste?	What gives you the most energy during your work?	Which moments do you find the most difficult during your work?	Do you have any ideas about waste management that you would like to share ?	Which waste type you would like to ideally recycle if it was possible ? Please choose only one.	Mail	Mobile
Esmée van Bregén	33	ICU nurse	totally disagree	agree	totally agree	agree	it does not take effort	we don't separate all the waste we can	space and more effort for nurses and more time	patients	-	-	plastic packagings		
Marcella Tuinman	31	(trainee) ICU nurse	totally disagree	totally agree	totally agree	totally agree	The Tonto	heavy trash	-	being useful	when I can't help severe situations	recycle items	plastic bottles gloves	m.tuinman@erasmusmc.nl	
Natalie	53	IC Nurse	disagree	agree	agree	agree	The Tonto	the heavy boxes with fluid	more trash cans	to make patients better and to guide	grief at patients death	handle plastics more carefully more often the same aprons/jackets	aprons	n.doove@erasmusmc.nl	
Jermaine	38	careassitant	totally disagree	neutral	agree	agree	plastic is separated from all other waste. and all paper and cardboard are very good for the environment	it's going well the way it's organized now	that there is not enough storage separation space	the people around me	bad news for patients	geen	plastic bottles IV bags	j.neral@eramusmc.nl	
Fleur	27	physician assistant student	agree	totally agree	totally agree	totally agree	the sharp bin is useful	we don't separate plastic	that they cannot process it	food	when I am overworking	separate bins	plasitc packaging (platic bottles aprons iv bags)		
Asia	35	ICU nurse	neutral	totally agree	totally agree	totally agree	That it's all in one in the tonto, it saves time	that we don't spearate the most simple things like gloves, dialyse bags/plastic etc	that we need more space for it than we have	the interaction with the patients and families	that you can not cure everyone especially young people	to separate more plastic	iv bags		
Sebastian	42	ICU nurse	totally agree	totally agree	totally agree	totally agree	it is easy	everything in one -> not recycling	behavior	patient	time mangement?	recycling	aprons	s.wagener@erasmusmc.nl	0619489885
Wim Nederlof	64	senior ICU nurse	agree	agree	agree	agree	it's being thought about	too many	it needs time	my colleagues	we throw away too much	-	gloves	w.nederlof@erasmusmc.nl	
Manuela	36	ICU nurse	disagree	agree	agree	neutral	that there is now a Green Team who is committed to this	The amount of plastic everything is packed separately	more work more time	my colleagues and achieving treatment goals	if many patients die family	-	syringes		
Janne	44	senior ICU nurse	agree	totally agree	totally agree	totally agree	that it has been thought about and action taken for a long time	not transparent enough -> that is also why I did not know that glass does not gets recycled	cost, discipline of staff members	collega's achieved treatment	-	-	aprons + added glass		
Jessica v.d.	32	ICU nurse	neutral	totally agree	totally agree	totally agree	-	plastic is not recycled enough	hard to read it (more time and ...to separate)	my colleagues transfer the patient	guiding family	-	gloves	hard to read	
Koerl	61	ICU nurse	disagree	totally agree	totally agree	totally agree	that it is there. the garbage doesn't pile up at the front door	that hardly any start has been made with separating or separating waste	it is so many!. If we start separating waste properly, it will become very complicated	not relevant	not relevant	now the environmental stations belong to no one.it quickly becomes chaos	plastic packaging		

What can you imagine as a problem if we want to separate more waste?	lack of space	space and more effort for nurses and more time
		that there is not enough storage separation space
		that we need more space for it than we have
		more trash cans
	lack of time	it needs time
		space and more effort for nurses and more time
		more work more time
		it is so many!. If we start separating waste properly, it will become very complicated
		that they cannot process it
	behaviour change	discipline of staff members
		behavior
	financial concern	cost..

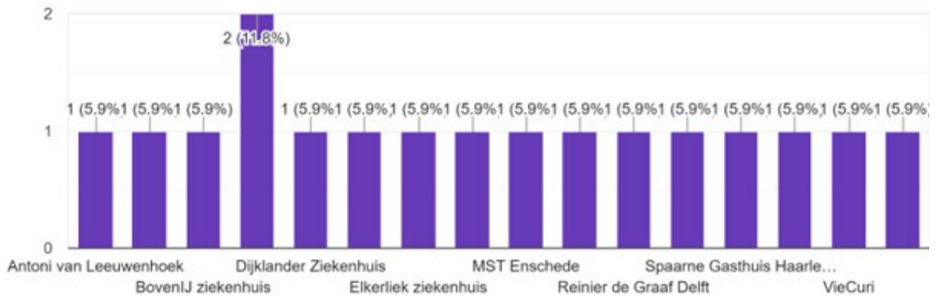
Appendix F
Questionnaire to hospitals - results

List of hospitals

Elkerliek ziekenhuis
Radboudumc
Reinier de Graaf Gasthuis
VieCuri
IC MMC Veldhoven
Reinier de Graaf Delft
Diakonessenhuis Utrecht
UMC Utrecht
Spaarne Gasthuis Haarlem/Hoofddorp
Beatrix Ziekenhuis
ETZ
MST Enschede
st Antonius
Dijklander Ziekenhuis
Antoni van Leeuwenhoek
BovenIJ ziekenhuis
art

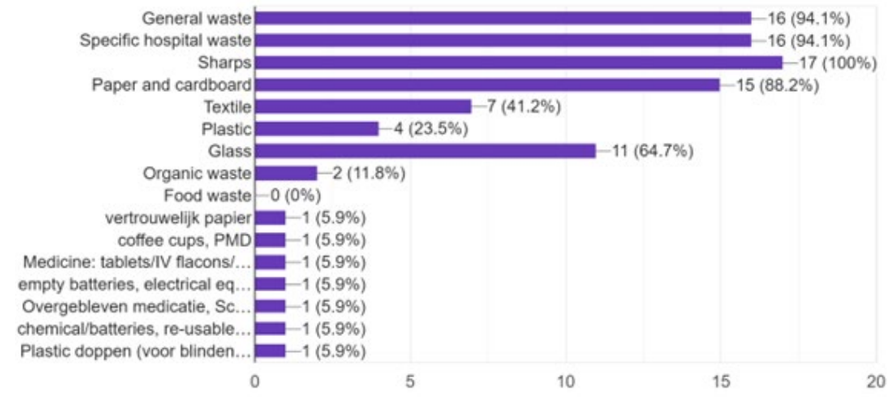
Which hospital's ICU do you represent?

17 responses



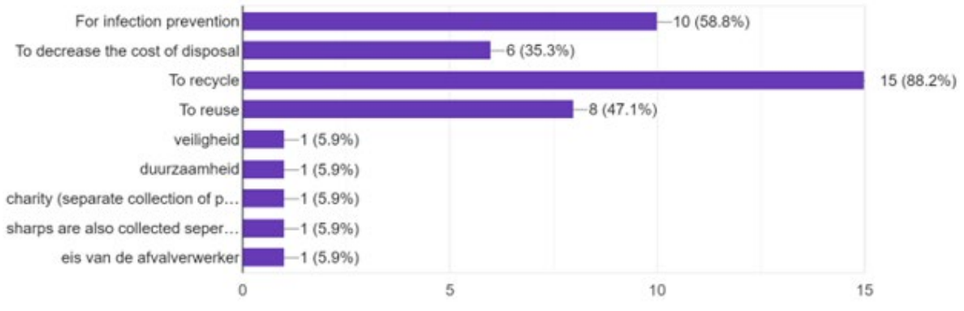
Which waste streams do you collect separately at the ICU? (please select all that apply)

17 responses



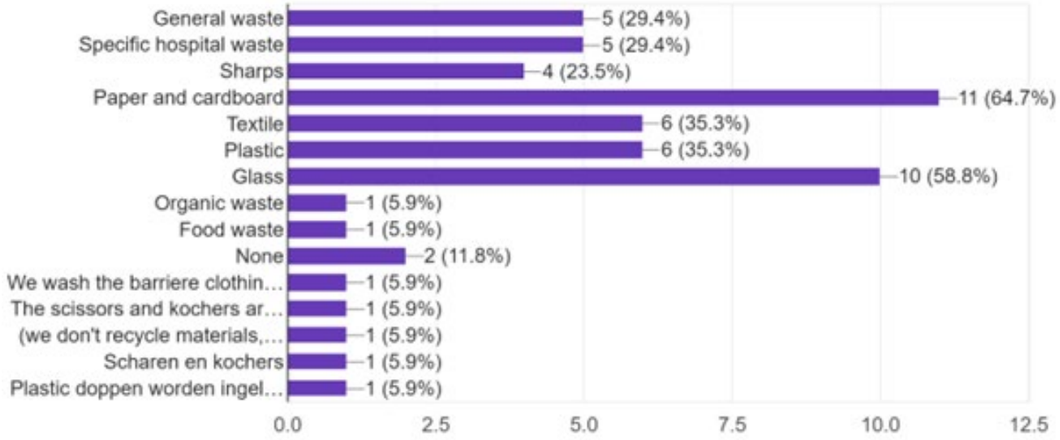
For which purpose do you separate the waste? (please select all that apply)

17 responses



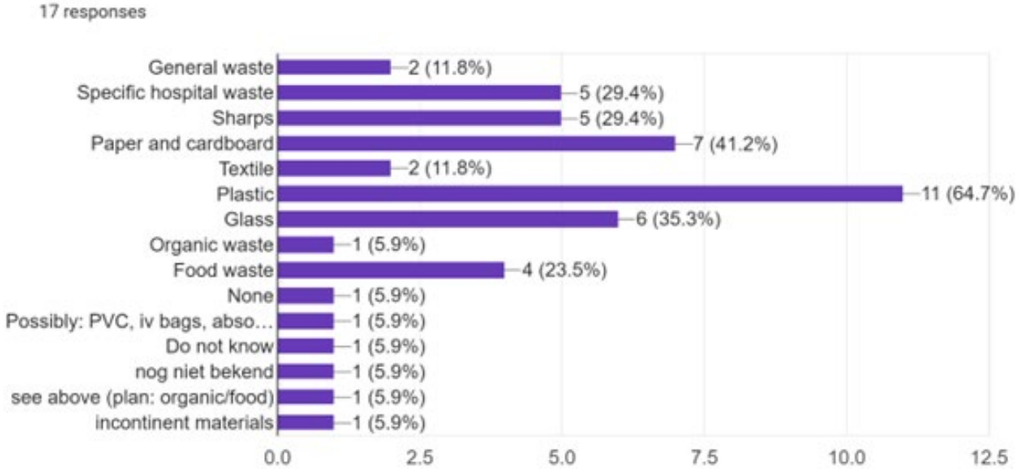
Which waste streams do you recycle from the ICU? (please select all that apply)

17 responses



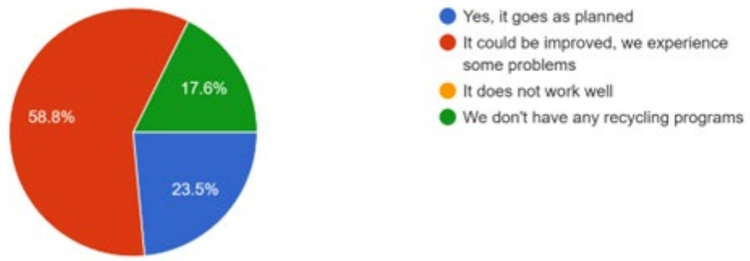
Which waste streams do you plan to recycle in the future (coming years)? (please select all that apply)

17 responses



Are the recycling programs already implemented operating smoothly?

17 responses



Recycling problems

What problems do you experience?

9 responses

niet iedereen doet goed mee, regelmatig verkeerde dingen in verkeerde bakken

Sometimes the waste is not offered properly. Many recycable waste is put with the general waste. The medicine waste is often still intact, for example in complete tablet strips, but the rules say we can't offer it back to the pharmacy.

The hospital is not very coöperative in the implementation of new recycle and/or waste disposal streams.

we want to seperate more paper en plastic in the patiënts rooms. But we are trying to find a way to implemted that.

not everyone is participating + new ambitions have to be implemented (time consuming)

commitment

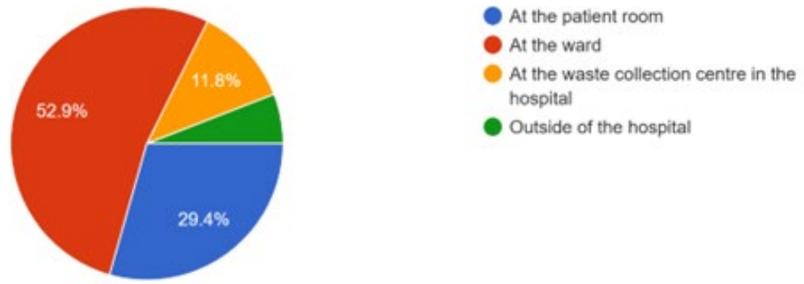
space (for storage/collection bins), costs to buy alternatives, mindset of employees, awareness among personal,, collaberation with other departments,

Papier bakken regelen lukt niet goed

voor het op vangen van te recyclen material is het wenselijk op elke kamer plastic en papier gescheiden te deponeren, nu moet er specifiek gelopen worden naar een centrale plastic bak en een centrale papierbak moet e

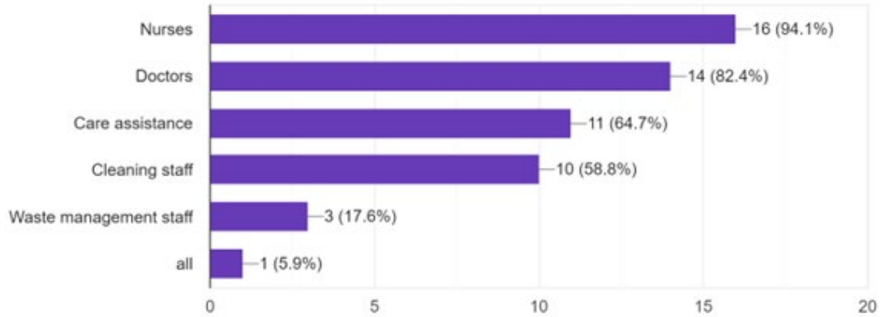
At which point is the waste collected?

17 responses



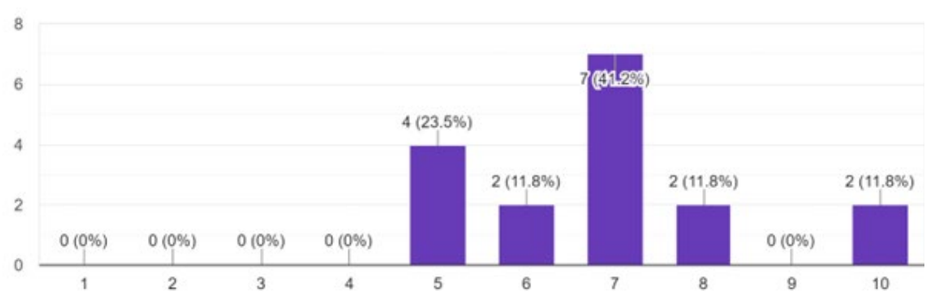
Who is responsible for the separation? (please select all that apply)

17 responses



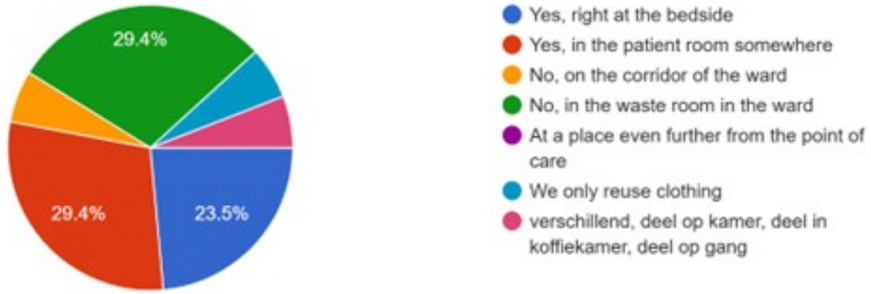
On a scale of 1 to 10, how knowledgeable these members are in correct waste separation?

17 responses



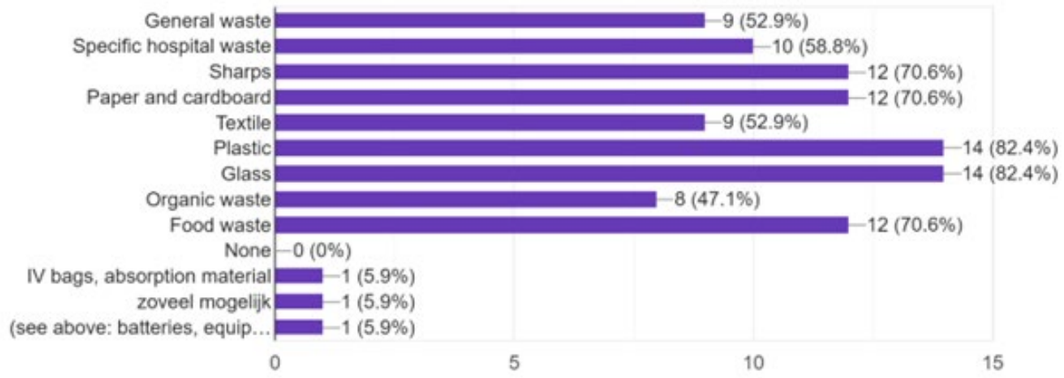
Do you have separating opportunities at the point of care/point of waste generation?

17 responses



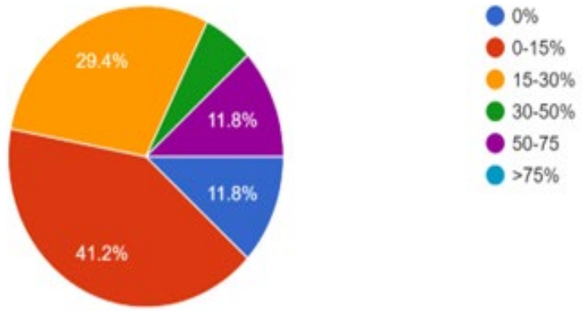
Which waste streams would you ideally separate if there was an opportunity? (please select all that apply)

17 responses



What percentage of your waste do you recycle?

17 responses

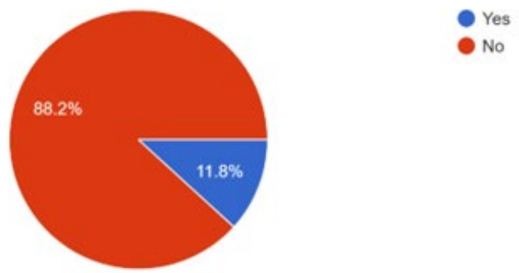


What is the greatest barrier in your hospital that can retain the ICU from recycling (more)?

17 responses

Is any sorting or segregation of material performed in the hospital (after the collection)?

17 responses



Sorting/segregation

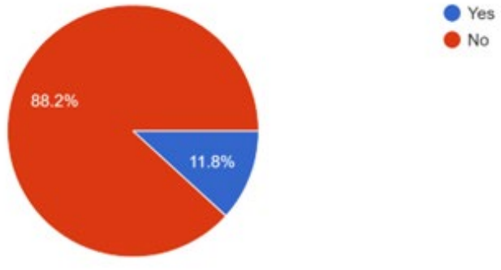
What do you sort out?

1 response

We have a special system called 'Pharmafilter'. All of our goes to this system, except paper and glass

Do you use a sterilisation method for treating the infectious waste?

17 responses



If yes, what kind of method is it?

4 responses

Not yet , is a pilot

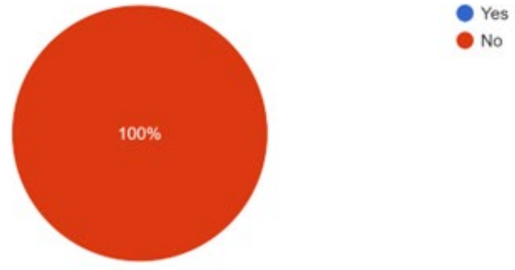
?

(I don't know, really)

dont know

Do you recycle any infectious waste after the sterilisation?

16 responses

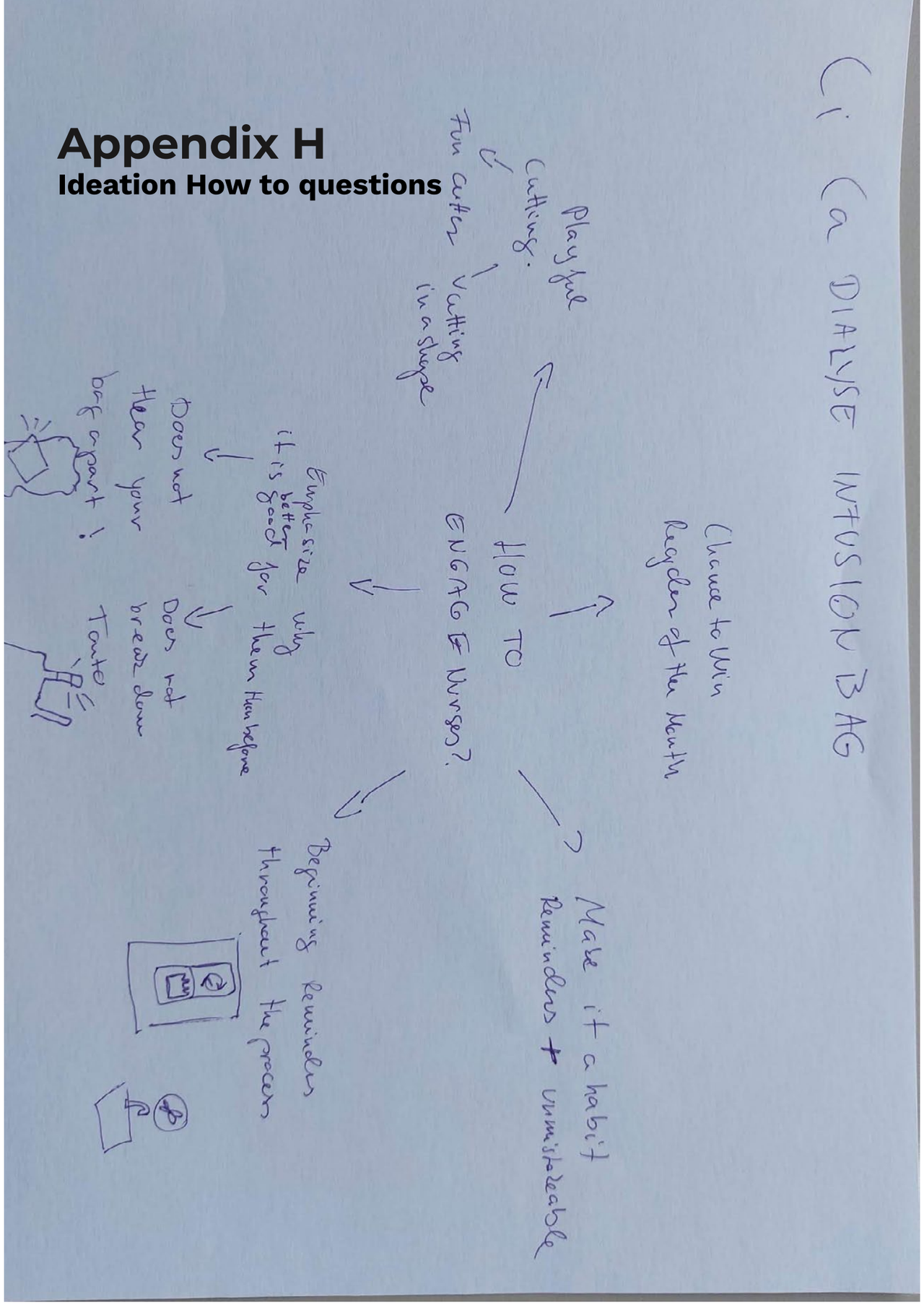


Appendix G
List of interviews and observations

New table

Type	Who	Aim
Interview	Prezero Zare waste manager	Understanding the waste streams in the hospital and recycling opportunities of identified waste types
Interview	Pharmafilter employee	Understanding the sterilization process of Pharmafilter and the problems which occured. Finding current aim of the system
Interview	Cardiac ICU Nurse at EMC	explanation of waste disposal processes, waste collection locations and Tonto usage
Observation	General ICU Nurse at EMC	Understanding the workflow of an ICU nurses around waste disposal
Observation	General ICU Nurse at EMC	Understanding the workflow of an ICU nurses around waste disposal with a differen type of patient.
Interview	Infection Prevention Team	General knowldege about infectioun prevention protocol and sepcific questions about ehy certain protocols are applied, explorign sterilization opportunities
Interview	Logistic Department	Understanding the concerns of logistic and the weaste streams in the hospital. understanding tonto usage and prices.

Appendix H
Ideation How to questions



TONTO RULES

HOW TO Make Tontos more desirable

- Reduce waiting time ↓ less individual products
- Accessible ↓ Remove tonto items in front of Tonto
- less breakdown ↓ Tips how to avoid it: Tape or BAG
- less breakdown ↓ Make forbidden items more pop
- Reduce waiting time ← Centralised disposal -> convenience helps

HOW TO make kegs less desirable

- Make them smaller
- Mental barrier (sign for asking to rethink)
- physical barrier in front of kegs
- Show impact of kegs.
- Place them in different location
- Make opening more effort

TONTO RULES

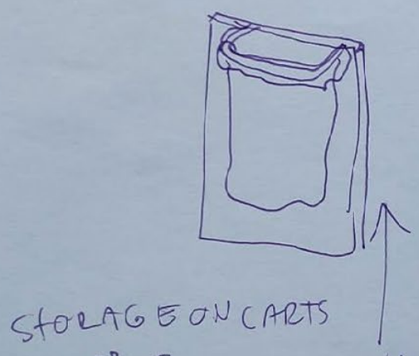
HOW TO provide space for bag in Patient room?

- on the wall
- in the binside
- frame, temporary space, closing
- Automatic dispenser for one hand
- Already bin equipped with Tonto bag

HOW TO make nurses aware of items should be disposed in tonto.

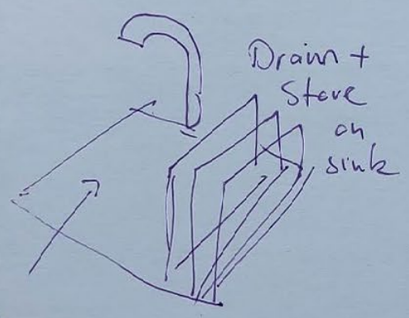
- 27 items ⇒ reduce list
- Visualise with picture -> quick decisions
- What can go? ⇒ What should go?
- Provide list in the room where waste is produced.
- List for WIVA kegs: only thing that breaks tonto
- Show purpose of tonto

Ci-Ca Dialyse bags

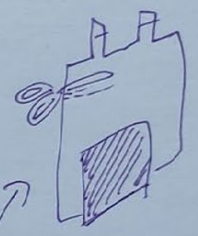


STORAGE ON CARTS

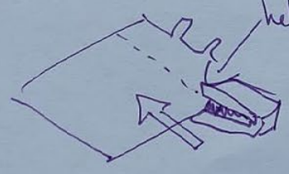
How to collect temporarily in room?

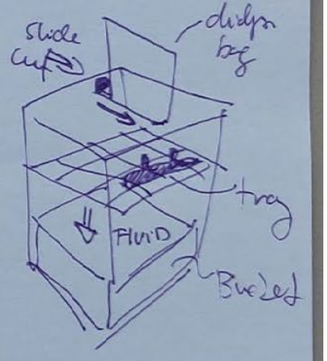


Holding Down the bags



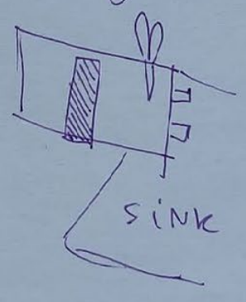
How to help in cutting? → Automatic Cutter



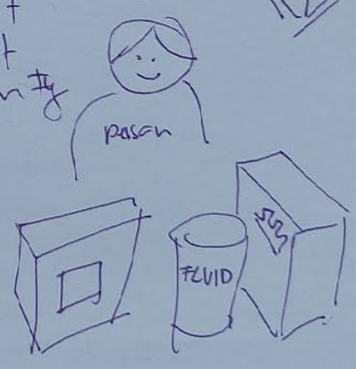


Hanging on Door

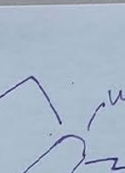
rolling mobile bin

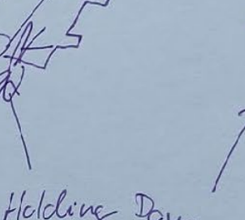


Night shift activity



Ci-Ca DIALYSE INFUSION BAG



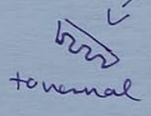


Reduce Thinking

Step by step guide

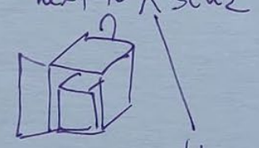
step 1 CUT

Step 2 EMPTY



to normal

to recycling



Location next to sink

Hangers in the room

How to

Reduce effort? → integrate into procedure

Automatic Cutter

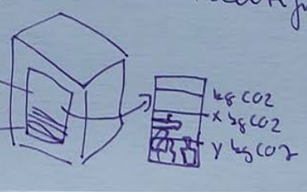
SINK → in the room → move bin

Outside (wash out)

Same as the pouch

How to Avoid mistake

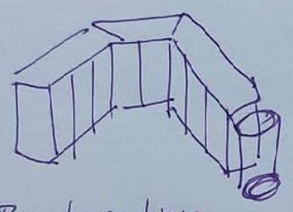
Show in transparent bin



Minimize number Identify types

Ci-Ca dialysis pouch

Location on the cart



Bin Location next to storage space

How TO Reduce effort?

Pre-opened bags every shift

~~Bin setting~~ Bin is placed on the wand in each unit.

Collection is done by care assistance every 4 hours or beginning of shifts

Exact size + shape only enough for 4 bags

Identify category

No other infusion bags

minimize type of products

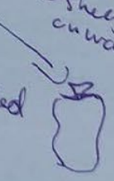
How TO Avoid mistakes?

Clear signs on each location

sheet on wall

color coded frames

color coded sign

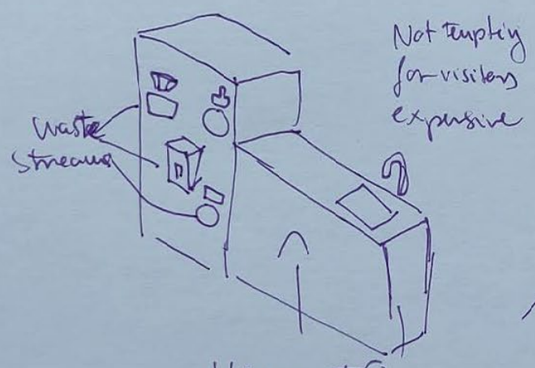


color coded bags

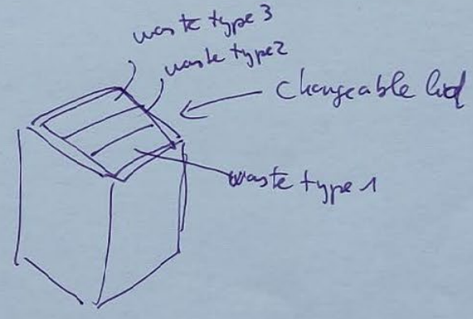
VISUAL CUES

proper training slides screens posters

WASTE WALL

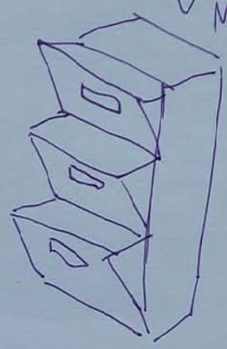


Not tempting for visitors expensive



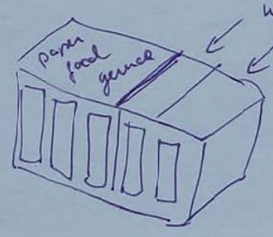
QR codes on products

HOW TO COLLECT MORE TYPE IN ONE → FUTURE

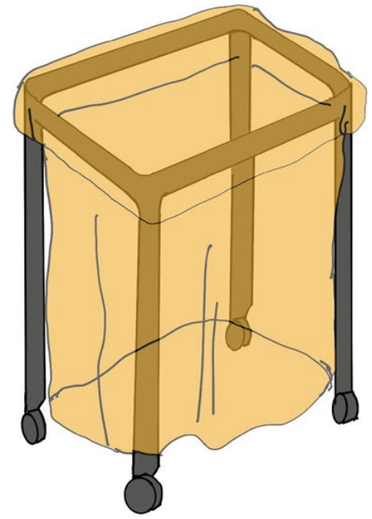


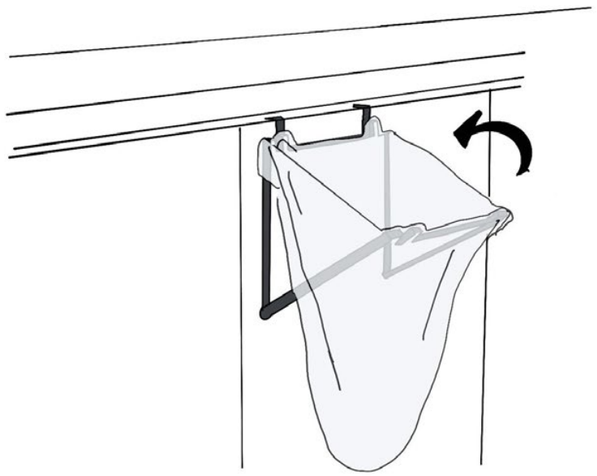
Modul in patient Rooms

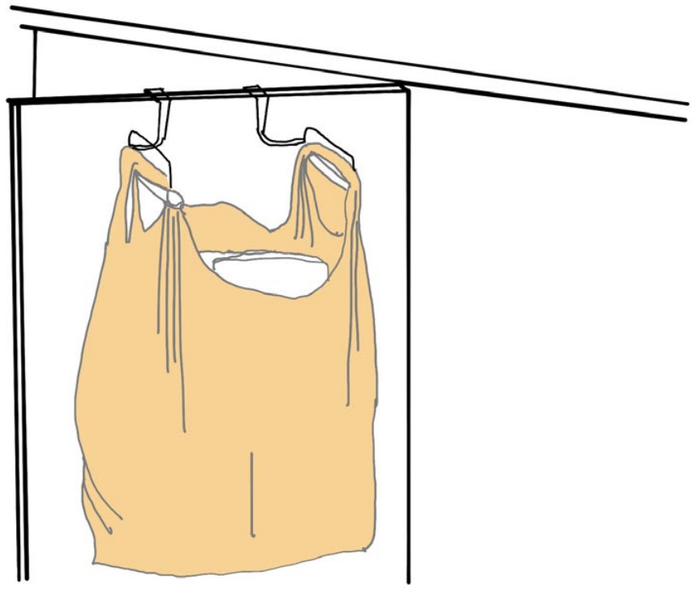
extendable modules

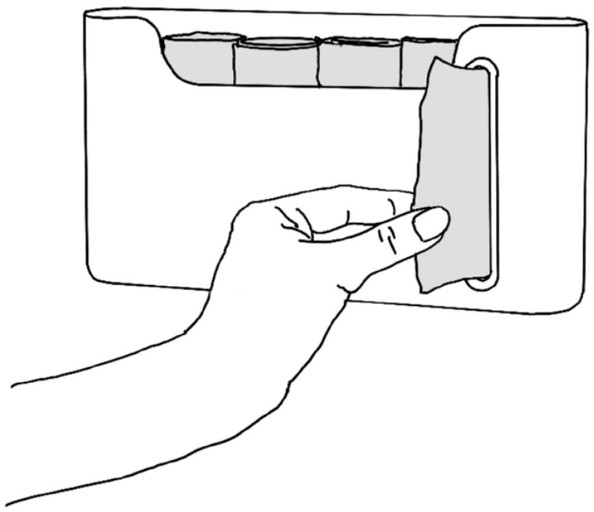


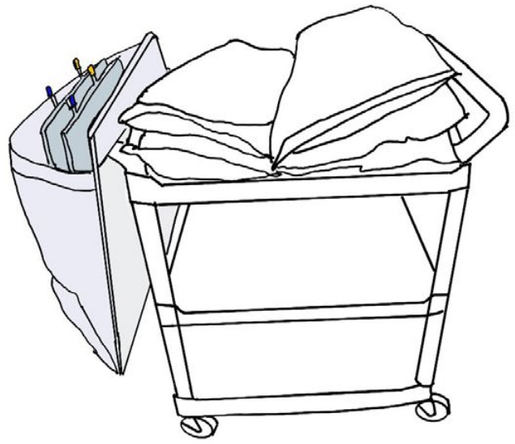
Appendix I
Ideation iteration

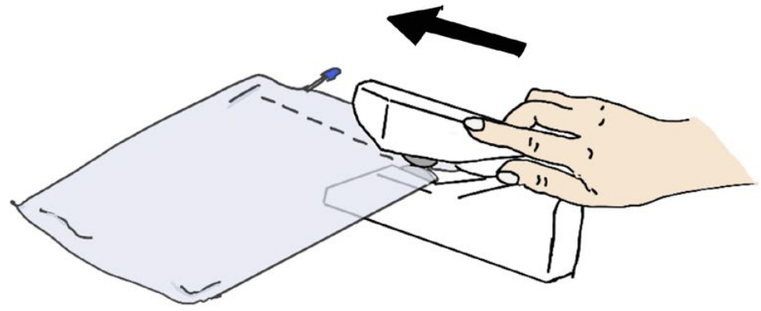


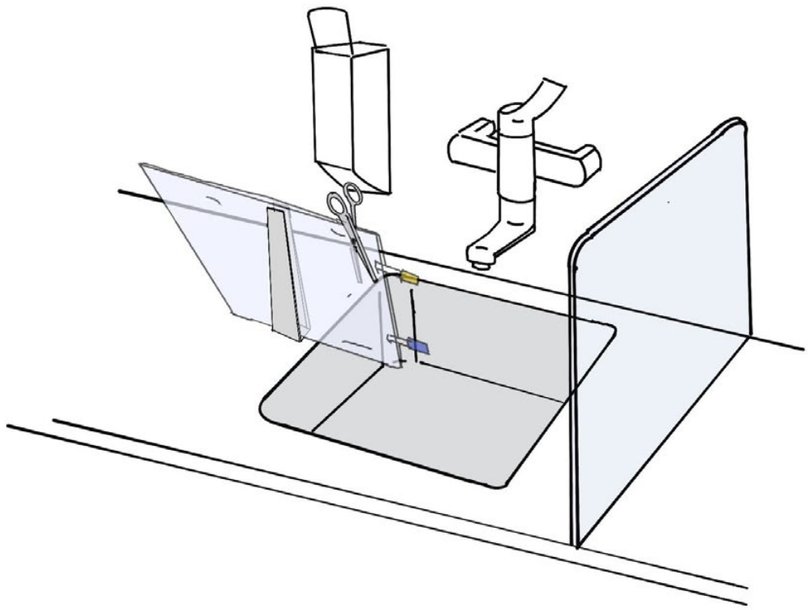


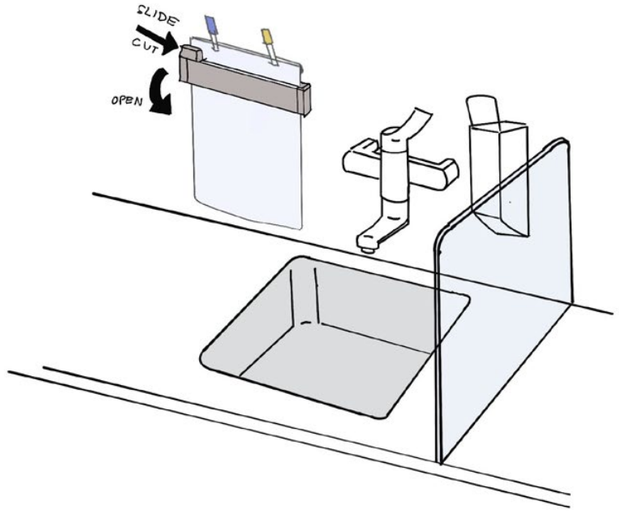


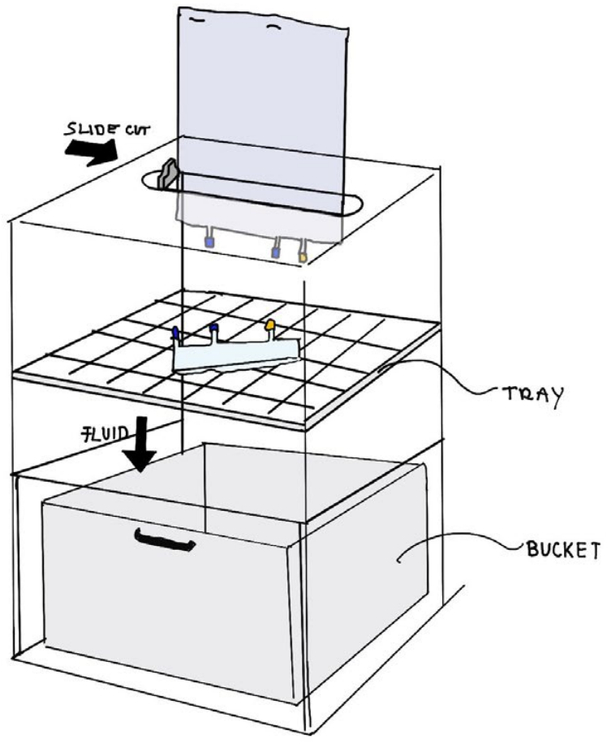


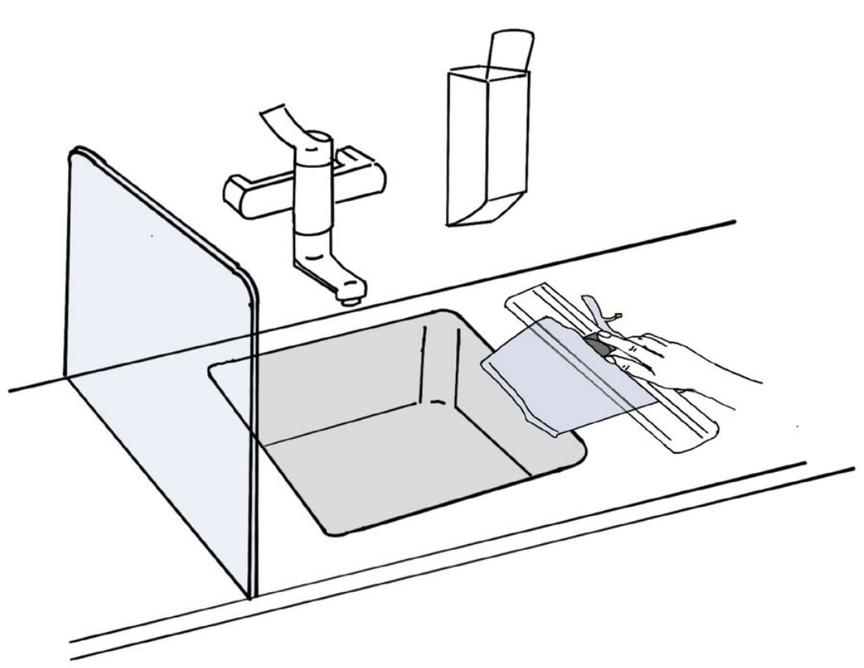


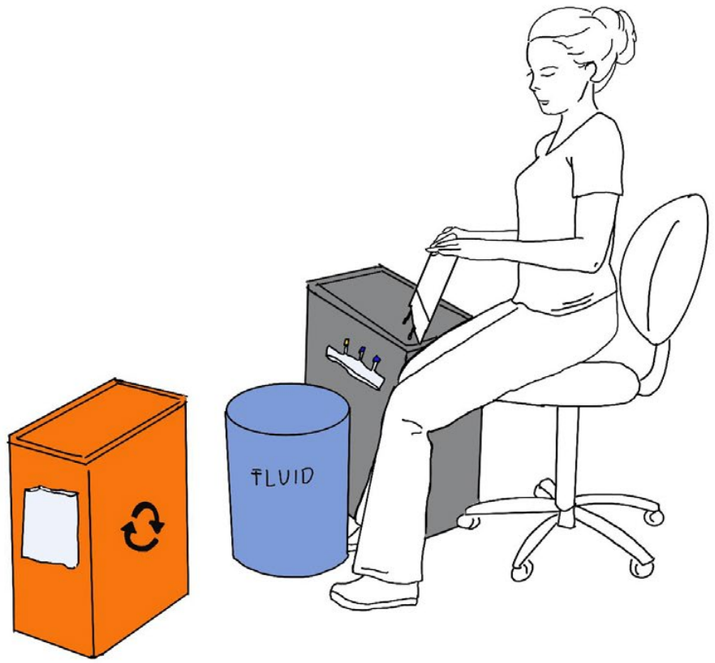


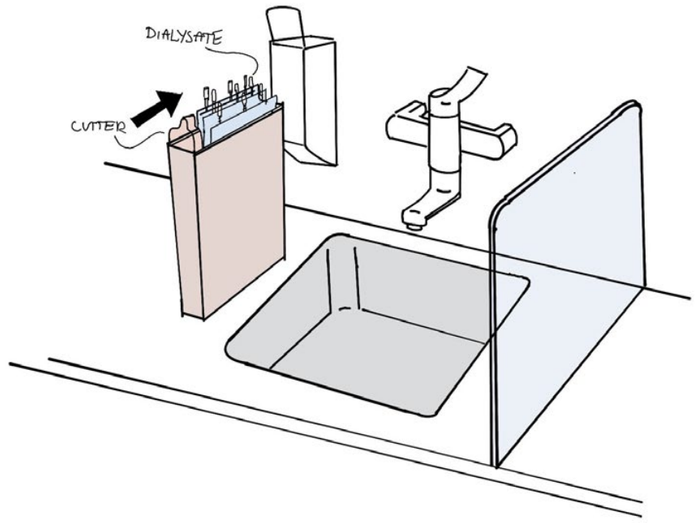


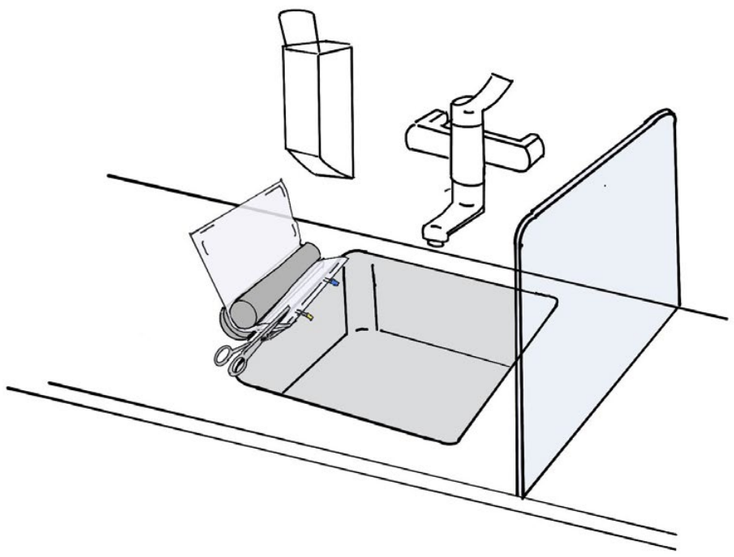

SLIDE
CUT
OPEN

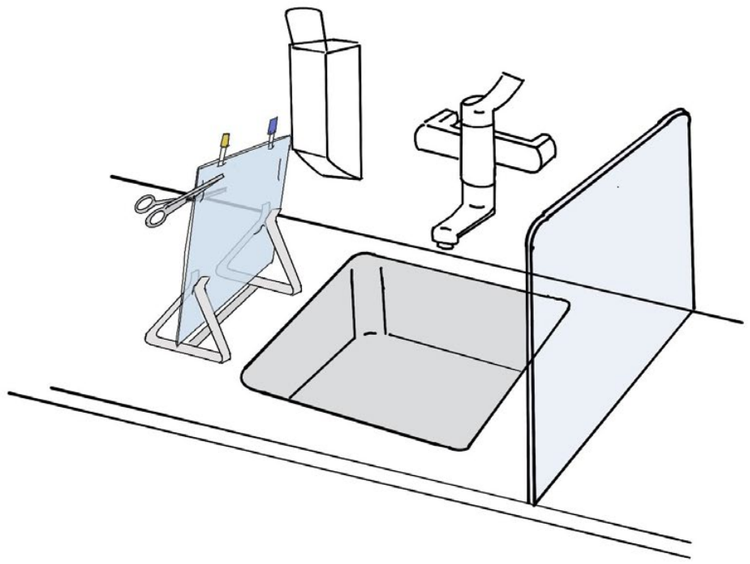

SLIDE CUT
TRAY
FLUID
BUCKET

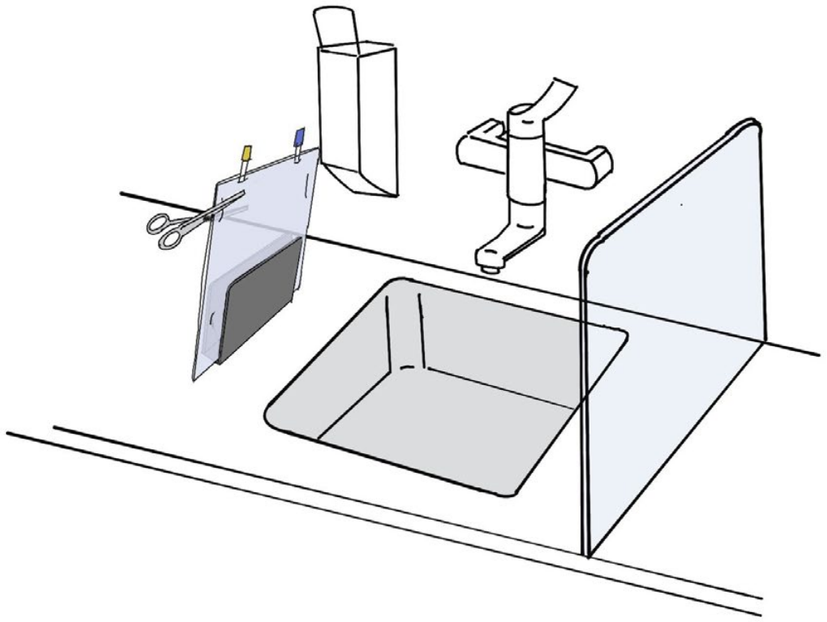



FLUID


DIALYSATE
CUTTER







Appendix J
List of Tonto rules

Current rules:
What can go in it?
- Garbage bags with residual waste
- SZA
- Excluding GMO waste
- Bedpan, urinal, measuring jar, disposable crockery and cutlery
- Aluminum splint (alu sín)
- Ventilation disposables
- Can of soda
- Blood and blood bags
- Glass ampoules
- Catheters and catheter bags
- Cytostatics
- Disposable clothing and masks
- Incontinence pads
- Isolation Aprons
- Plastic plaster
- artificial kidneys (long tube found in SZA)
- Needles as part of an infusion system
- Neck collar
- Paper and cardboard (small amount)
- Paper from research bank
- Plastic gloves and overshoes
- Redon drains and Thoracic drain (large plastic box)
- Stomach pumps or Sonders
- Splash goggles
- Spike IV System
- Chest drain (repeated)
- Tracheostomy cannula (picture)
- Heat blankets (also alu)

27 items

What can’t go in Tonto:
- Batteries
- cast (except for plastic)
- glass medicine bottles with leftovers
- needles
- needle container
- paper and carboard (large)
- printer cartridges
- scissors and tweezers
- Biopsies
- polypectomy string
- hemoclip
- suction ends
- GMO waste

13 items

Appendix K
Waste audit calculations

All calculations are made for the General Adult ICU

	container 1	comments	container 2	comments
number of bag	weight bag (g)		weight bag (g)	
1	841		838	transp
2	794		2 745	
3	1 389		3 336	
4	4 026		758	
5	4 017		682	
6	1 370		585	
7	2 753		3 116	
8	3 328		763	transp
9	3 699		675	
10	2 352		854	
11	1 820		2 223	
12	570	white	1 797	
13	1 824		827	
14	2 170		1 862	
15	734	white	360	transp
16	905	white	3 262	
17	2 939		4 960	
18	261	transp	717	
19	508		1 889	
20	2 386		2 083	
21	1 625		607	transp
22			1 446	
23			1 590	
24			1 769	
25			2 430	
plastic wraps	576		1 003	
sum cont. 1	**40 887**	**sum cont. 2**	**43 177**	
		waste from night shift	**85 643**	**g**
			85,60	**kg**
		average weight per bag	**1861,80**	**g**

	Amounts for half of the shift		
food related waste	7 095		food related waste
garbage bags	416		garbage bags
blood and other fluid container	1 329	wrong place	blood and other fluid container
textile	510		textile
protective eyeglass large	347		protective eyeglass large
protective eyeglass normal	760		
papersheets	1 650		papersheets
paper	1 042		paper
plastic packaging	676		plastic packaging, bottles, metal
hard plastic pieces	473		
bottles	841	with some liquid	
metal	56		
large plastic wraps	789,5		
masks	211		masks
tubes	1 379	with some liquid	tubes
syringes	4 103	with liquid	syringes
wipers	1 279		wipers
tissues	760		tissues
gloves	2 343		gloves
hybrid packaging(paper +plastic)	926		hybrid packaging(paper+plastic)
paper cups	234		paper cups
diapers	2 742		diapers
infusion bags	5 642		infusion bags
gowns	3 966		gowns
unsorted	1 059		unsorted
other	308		other
all	**40 937**	**g**	**all**

Appendix L
Proposal calculations

calculation of waste amounts yearly						
				per shift kg	**per day (3 shift) kg**	**per year kg**
	calulcation based on waste audit		**all general waste excluding food related**	70,192	256,8	93732
	calulcation from Metabolic		**all general waste excluding food related**			**59600**

		dialysis patients(40% of all)	weight of one bag g	number of bags per day per patient	per day weight g	per year	**per year kg**	**% of general waste**
from 13000 patient days in 365 days, average 35 patient per day	**dialysis packagings and dialysis fluid bags**	13	65	16	13520	4934800	**4934,8**	**8,224666667**
	from Focco (500.000 piece per year)	50000	100			5000000	5000	8,333333333

			per shift	per day	per year	**per year kg**	**% of general waste**
plastic packaging			1 352	4056	1480440	**1480,44**	**2,5**
						985	
from metabolic (not all is taken intoa ccount)	262	LDPE					
	307	LDPE					
	262	LDPE					
	121,5	LDPE					
	14	LDPE					
	19	LDPE					
	985,5						

			per shift	per day	per year	**per year kg**	**% of general waste**
diapers			5 484	16452	6004980	**6004,98**	**10,0083**
			3600	10800	3942000	3942	6,57
wipes							
			per shift	per day	per year	per year kg	% of general waste
			2 558	7674	2801010	2801,01	4,66835
			3600	10800	3942000	3942	6,57

			per shift	per day	per year	**per year kg**	**% of general waste**
plastic bottles			1 346	4036,8	1473432	**1473,432**	**2,45572**

calulation of environmental impact reduction from recycling

	Material	**type of recycling**	**kg CO2 reduction per kg of polymer (Schwarz et al., 2021)**	**kg per year**	**CO2 reduction per year**	
plastic bottles	PP, HDPE, PET	mechanical open loop	2,1	1500	**3150**	**kg CO2**
plastic packagin	LDPE	mechanical open loop	2,5	1500	**3750**	**kg CO2**
dialysis bags	PP	mechanical open loop	2,3	5000	**11500**	**kg CO2**

Impact unit: kg CO2 eq.
Uncertainty rubric: 10% for precise data & perfect database match, 30% for plausible substitution, 100%+ for wild guess

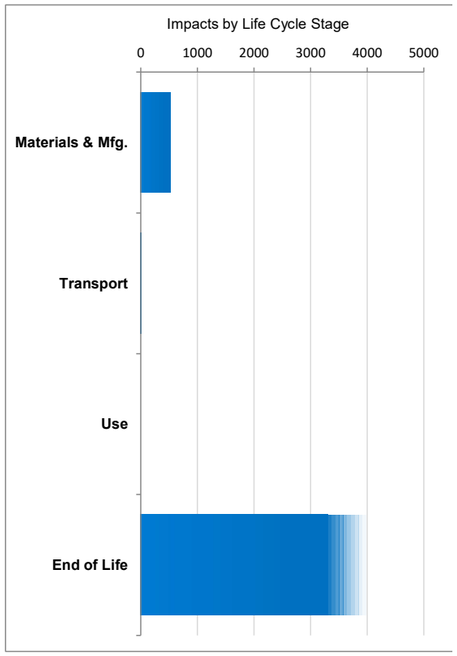
Design option:
SZA disposal 2 tons

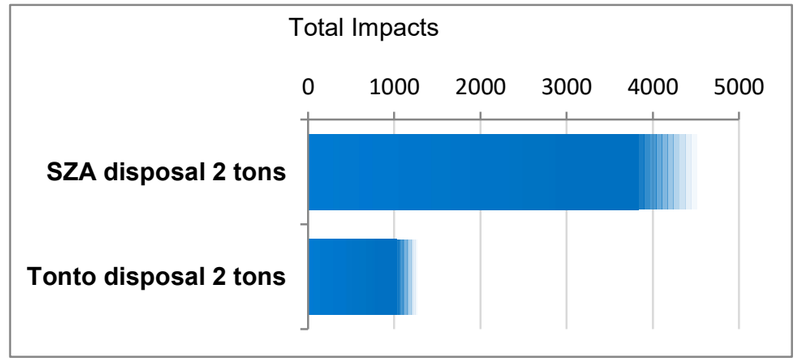
Manufacturing	Eco-intensity (impacts/kg)	Mass per item (kg)	Items per func.unit (#)	Uncertainty %	Notes	Calculated Impact
pp box material	1,63	200,000	1,00			326
pp box manufacture	0,972	200,000	1,00			194,465
						0
						0
						0
						0
						0
						0
						0

Transport	Eco-Intensity (impacts/ ton-km)	Mass per item (ton)	Distance per item (km)	Items per func.unit (#)	Uncertainty %	Notes	Calculated Impact
transport empty kegs to hospital	0,09	0,200	80,000	1,00	10%		1,36853
transport full kegs to incineration site	0,09	2,200	40,000	1,00	10%	fluids are included	7,52689
							0
							0

Use	Eco-Intensity (impacts/MJ or other)	Amount per item (MJ or other)	Items per func.unit (#)	Uncertainty %	Notes	Calculated Impact
						0
						0
						0

End of Life	Eco-Intensity (impacts/kg)	Mass per item (kg)	Items per func.unit (#)	Uncertainty %	Notes	Calculated Impact
incineration waste (high temprature) (PE)	1,70	2000,000	1,00	10%	fluids are included	3400
PP incineration with energy recovery	1,22	200,000	1,00			244,799
						0





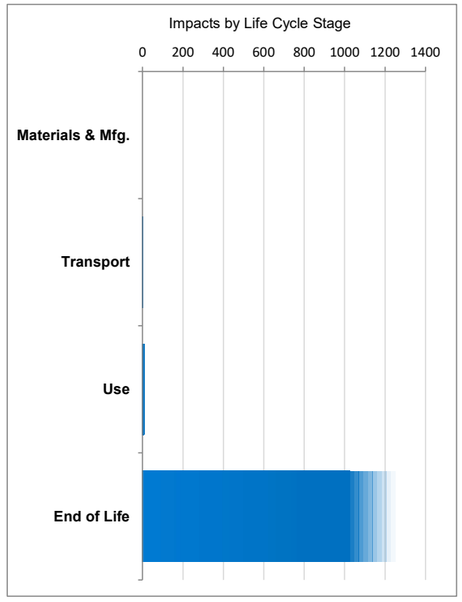
Design option:
Tonto disposal 2 tons

Manufacturing	Eco-intensity (impacts/kg)	Mass per item (kg)	Items per func.unit (#)	Uncertainty %	Notes	Calculated Impact
						0
						0
						0
						0
						0
						0
						0

Transport	Eco-Intensity (impacts/ ton-km)	Mass per item (ton)	Distance per item (km)	Items per func.unit (#)	Uncertainty %	Notes	Calculated Impact
transport pharmafilter solid waste to incineration	0,09	0,500	40,000	1,00			1,71066
							0
							0
							0

Use	Eco-Intensity (impacts/MJ or other)	Amount per item (MJ or other)	Items per func.unit (#)	Uncertainty %	Notes	Calculated Impact
electricity	0,15	30	2	30%		9,11193
						0
						0

End of Life	Eco-Intensity (impacts/kg)	Mass per item (kg)	Items per func.unit (#)	Uncertainty %	Notes	Calculated Impact
incineration with energy recovery(PE)	1,14	1000,000	1,00	10%	fluids are separated	1138,32
						0
						0



Appendix M
waste disposal costs

Total cost of disposal

New table

Waste stream	Processing		Transport	
	Cost	Unit	Cost	Unit
Not-specific hospital waste [Residual waste]	€ 157,78	€ per 1.000 kg	€ 182,01	€ per transport
Solid fraction Pharmafilter	€ 157,78	€ per 1.000 kg	€ 242,00	€ per transport
Specific hospital waste	€ 595,30	€ per 1.000 kg	€ 291,03	€ per transport
Paper/Carboard	€ 37,87-	€ per 1.000 kg	€ 126,00	€ per transport
Foils	€ -	€ per 1.000 kg	-	
Confidential paper	€ 7,66-	€ per 1.000 kg	€ 251,68	€ per transport
Large residual waste	€ 217,88	€ per 1.000 kg	€ 105,00	€ per transport
Wood	€ 70,69	€ per 1.000 kg	€ 105,00	€ per transport
Styrofoam (EPS)	€ 223,86-	€ per 1.000 kg	€ -	€ per transport
Elektronic waste	€ 254,09	€ per 1.000 kg	€ 168,00	€ per transport

Appendix N
waste types ICU

products disposed very frequently

apron

gown

plastic bottle

paper-plastic packaging

paper packaging

Ci-Ca infusion bag

wipe

infusion bags

ıbsorbent hygiene product

tubes

Ci-Ca pouch

Food contact waste

syringe

plastic packaging

bandages

protective glasses

tissue

gloves

paper cup

face mask

products disposed every 72 hours

apron

gown

plastic bottle

paper-plastic packaging

paper packaging

Ci-Ca infusion bag

wipe

infusion bags

bent hygiene product

tubes

Ci-Ca pouch

Food contact waste

syringe

plastic packaging

bandages

protective glasses

tissue

gloves

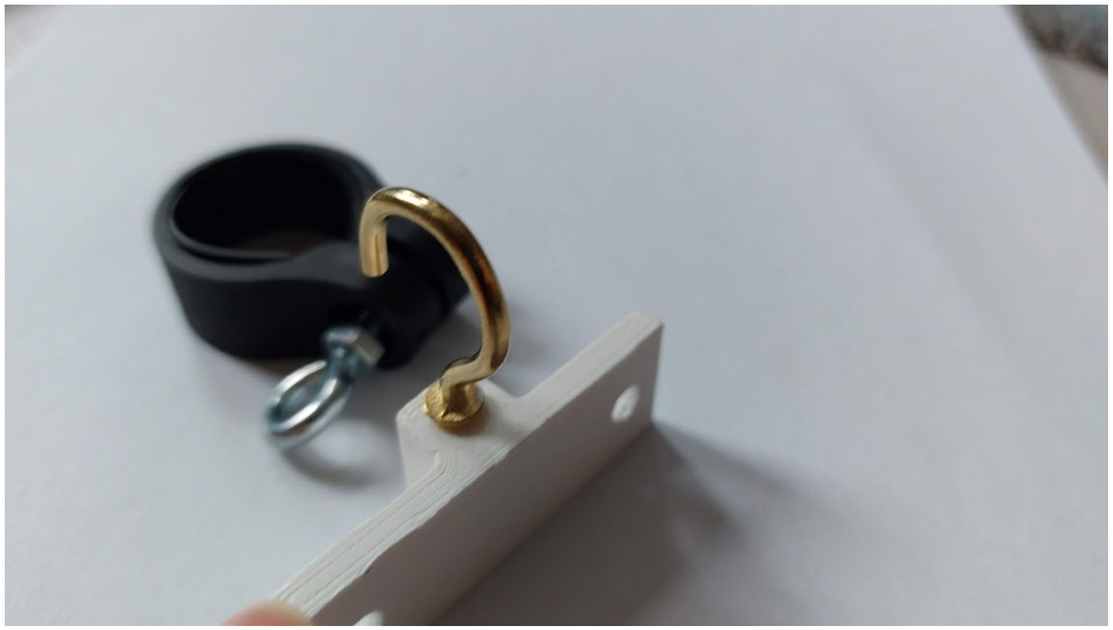
paper cup

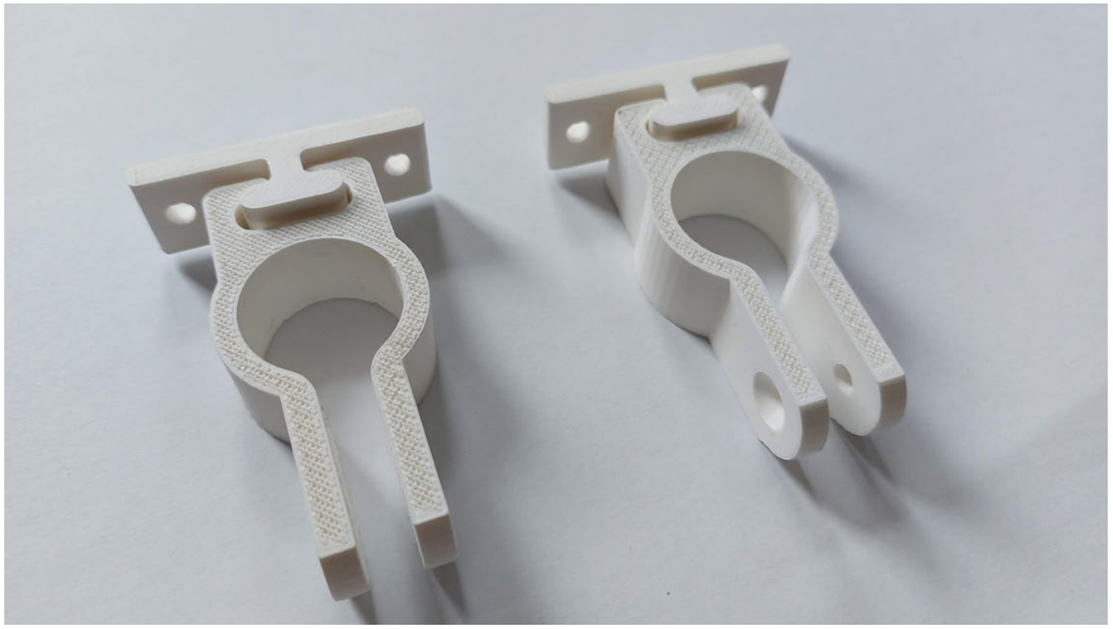
face mask

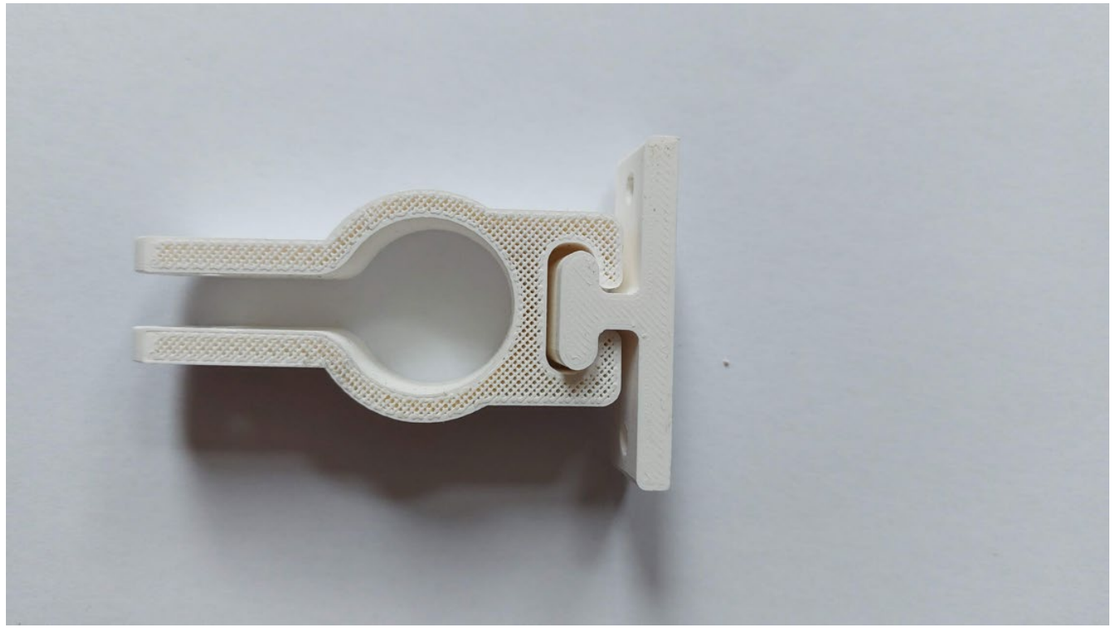
products disposed very frequently (not all patient)

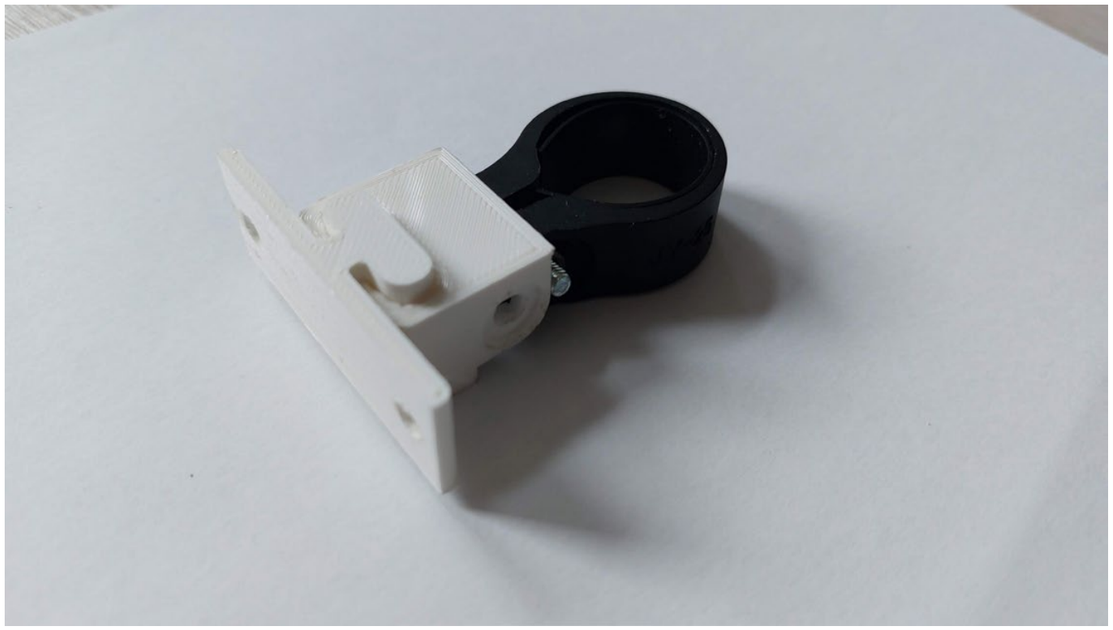
products disposed every 24 hours

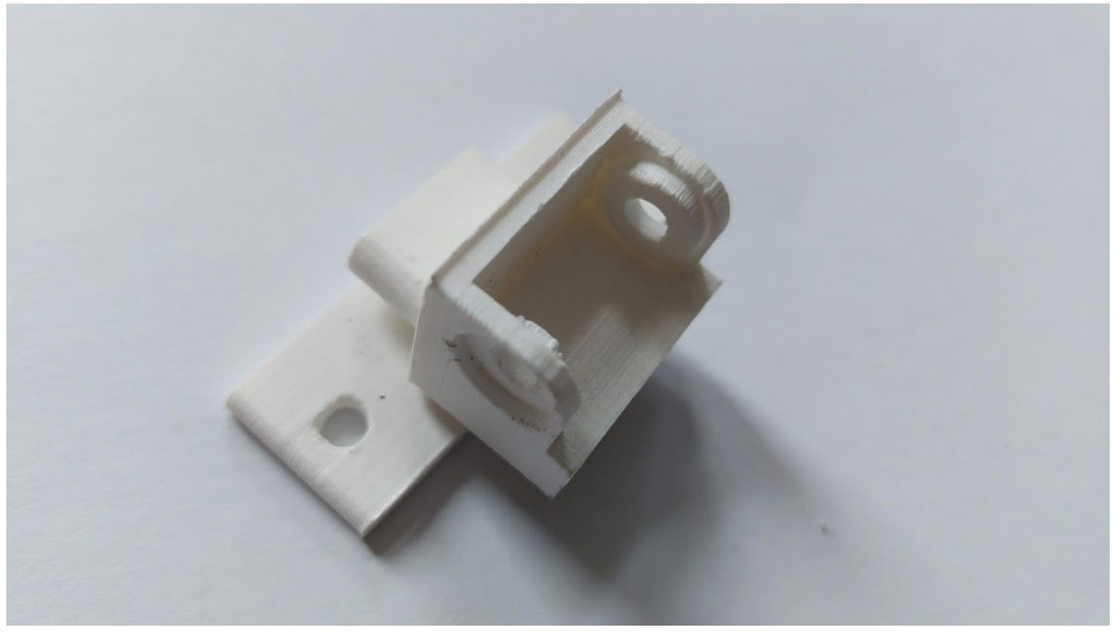
Appendix O
connection iterations











Appendix P
Final user evaluation form

Evaluation form

Product usability evaluation

My name is Júlia Pongrátz and I am an Integrated Product Design master student from TU Delft.
For my graduation project I am investigating the waste separation and recycling opportunities in the Intensive Care unit.
As you may know, the overall produced waste is 7 bags for each patient every day!

In my final design, I am proposing solutions for the collection of the dialysate fluid bags and their outer packaging for their recycling.
To help the process of separate collection, physical and graphical solutions were designed.
In order to recycle the dialysate bags, the connectors need to be cut first. To make this less effort, a cutting device is proposed (figure 1). To help in the collection, I designed a special bin that can be attached to the carts used for the dialysis patients (Figure 2).
The purpose of this study is to evaluate the final design and gain insights about is desirability. After a short explanation, I will ask you to go through the process of cutting and collecting and think out loud while you are doing it.
After that, I will ask some short questions about your experience. It is good to note, that there are no right and wrong answers, it's about your own experience.
The evaluation is anonym, but I ask you to give permission of using the collected answers in my project.
Thank you for your participation!

I consent voluntarily to participate in this study and give permission to voice- record and use my answers for the graduation project of Júlia Pongrátz for the Master Integrated Product Design.

◯ Yes ◯ No

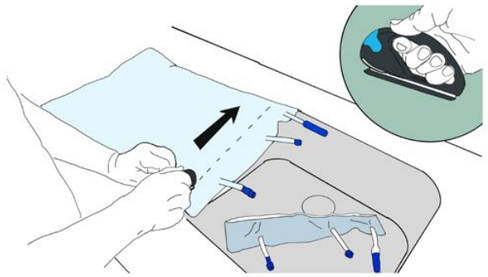


Figure 1. Cutting the connectors with the safety cutter

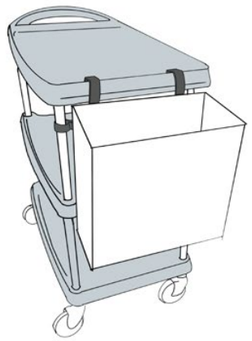
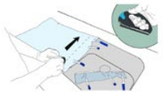


Figure 2. Bin attached to the cart

Evaluation form

Cutting the devices



The location of the cutting device in the room is convenient.

◯ totally disagree ◯ disagree ◯ neutral ◯ agree ◯ totally agree

Cutting the device with the safety cutter makes the process easier.

◯ totally disagree ◯ disagree ◯ neutral ◯ agree ◯ totally agree

Collection bin

It is easy to place the dialysate fluid bags in the collection bin

◯ totally disagree ◯ disagree ◯ neutral ◯ agree ◯ totally agree

It is easy to remove the dialysate fluid bags from the collection bin

◯ totally disagree ◯ disagree ◯ neutral ◯ agree ◯ totally agree

The size of the bin is convenient to use

◯ totally disagree ◯ disagree ◯ neutral ◯ agree ◯ totally agree

Walking with the cart while the bin is attached to it does not cause any problem.

◯ totally disagree ◯ disagree ◯ neutral ◯ agree ◯ totally agree

The attachment of the bin to the cart is easy to use.

◯ totally disagree ◯ disagree ◯ neutral ◯ agree ◯ totally agree

The proposed solutions make the separate collection of the dialysis fluid bags easier.

◯ totally disagree ◯ disagree ◯ neutral ◯ agree ◯ totally agree

I would like to see this implemented.

◯ totally disagree ◯ disagree ◯ neutral ◯ agree ◯ totally agree

Signs on the waste storage in patient room

The sign helps me to reframe the waste category to "not all waste"

◯ totally disagree ◯ disagree ◯ neutral ◯ agree ◯ totally agree

The sign help me to not dispose the dialysaat fluid bags in the main waste stream.

◯ totally disagree ◯ disagree ◯ neutral ◯ agree ◯ totally agree

Sign on the mobile bin

The sign on the bin provides clear information.

◯ totally disagree ◯ disagree ◯ neutral ◯ agree ◯ totally agree

Reminder on the dialysis device

The small reminder could help to dispose the fluid bags correctly when removed from the device.

◯ totally disagree ◯ disagree ◯ neutral ◯ agree ◯ totally agree

Graphic in the waste storage room

The graphic provides clear information about what should be collected here.

◯ totally disagree ◯ disagree ◯ neutral ◯ agree ◯ totally agree

The graphic provides enough information about what should be collected here.

◯ totally disagree ◯ disagree ◯ neutral ◯ agree ◯ totally agree

Ihe graphic helps to engage more in separate collection

◯ totally disagree ◯ disagree ◯ neutral ◯ agree ◯ totally agree

Evaluation form -Tonto usage

Sticker on the Tonto

It communicates the pupose of the Tonto clearly

◯ totally disagree ◯ disagree ◯ neutral ◯ agree ◯ totally agree

It helps me in the correct usage of Tonto

◯ totally disagree ◯ disagree ◯ neutral ◯ agree ◯ totally agree

It helps me to decide easier which items should I throw into the Tonto

◯ totally disagree ◯ disagree ◯ neutral ◯ agree ◯ totally agree

It helps me to decide easier which items should I not throw into the Tonto

◯ totally disagree ◯ disagree ◯ neutral ◯ agree ◯ totally agree

The tips help me to know how can I reduce the risk of breakdown.

◯ totally disagree ◯ disagree ◯ neutral ◯ agree ◯ totally agree

Sign over the Tonto bin

It helps me to know I can use this bin for items belonging to the Tonto.

◯ totally disagree ◯ disagree ◯ neutral ◯ agree ◯ totally agree

Sign over the WIVA kegs

It helps me to consider placing something to Tonto instead of the Wiva kegs.

◯ totally disagree ◯ disagree ◯ neutral ◯ agree ◯ totally agree

Tonto bag dispenser

I would find it useful to have a Tonto bag dispenser in the patient room.

◯ totally disagree ◯ disagree ◯ neutral ◯ agree ◯ totally agree

Appendix Q
Materials on Biofine PP

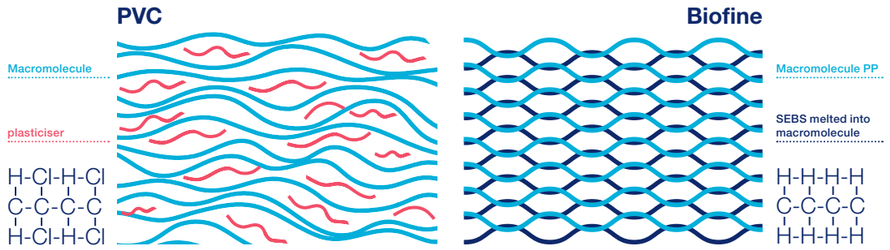
FRESENIUS MEDICAL CARE

Biofine
PVC-free material used in Peritoneal Dialysis

What is Biofine?

Biofine is a material developed by Fresenius Medical Care in 1996. Biofine consists of polymers constructed from hydrogen and carbon atoms extruded into a multilayer material.

The various properties of the material such as flexibility, transparency and impact resistance are achieved by an intelligent and smart mixture of different polymers and an adapted production technology. It does not contain any halogenated polymers. **Biofine is PVC-free** and does not need plasticisers such as phthalates (e.g. DEHP).



- **Biofine is a barrier to water vapour.** Therefore, we can ensure consistent quality of the solution over the entire shelf life.

- **Biofine can help to reduce waste from disposables compared to PVC products.** A comparison between Biofine-based products vs. PVC-based products showed that ~88 kg/year for a CAPD patient and ~29 kg/year for an APD can be saved.*

- **Biofine foil transparency allows patients to inspect their outflow bags carefully.** Cloudy effluent may be detected by patients more quickly.

Biofine contains no chlorine and incinerates to carbon dioxide and water during ideal combustion.

*https://academic.oup.com/ndt/article/34/Supplement_1/gfz106.FP573/5515732 (last accessed on 16/05/2022)

FRESENIUS MEDICAL CARE

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www.freseniusmedicalcare.com

How can Biofine be recycled?

Biofine films consist mainly of polyolefins such as polypropylene (PP). Thus, no critical property is known for these materials that needs to be considered during its disposal. Biofine can be used as a feedstock for material recycling, which has been demonstrated by internal material streams.

However, options and conditions of material recycling are strongly dependent on specific local or individual circumstances, including existing recycling infrastructure, the legal framework, contamination during handling, use or by product residues etc.

In case of more ambitious national recycling schemes, additional requirements regarding a waste product / packaging might be defined with specific materials or material combinations unsuitable for high-quality (mechanical) recycling. For pure Biofine, such limitations are currently not known.

Example of waste recycling

In our Fresenius Medical Care production plant in St. Wendel, generated Biofine waste material is collected and recycled by waste companies to produce other plastic products.

Granulated material to produce Biofine

Production of Biofine via extrusion

Recycling of production waste

Repalletised and mixed with different granulates to produce new materials
(e.g. waste bins for bio-waste, park benches)

Post-industrial recycling circle

Appendix R

Cost estimations dialysis collection final design

Cost estimation					
Part number	**Name of part**	**Quantity**	**Price per unit**	**Price**	**Comment**
1	Basket	1	8,50 €	8,50 €	cost of material, labour and mold
2	Attachment Part Box	2	0,45 €	0,90 €	cost of material
3	Attachment Part Post	2	0,28 €	0,56 €	cost of material
4	rubber seal	2	0,01 €	0,02 €	bought in 100 piece batch
5	Screw	2	0,04 €	0,08 €	bought in 100 piece batch
6	Screw	4	0,03 €	0,14 €	bought in 100 piece batch
7	Nut	6	0,02 €	0,14 €	bought in 100 piece batch
			Total basket	10,34 €	
	Cutter	1	5,50 €	5,50 €	https://www.logistiekconcurrent.nl/martor-secumax-snitty-veiligheidsmes
	posters	1	1,50 €	1,50 €	printing and laminating
	stickers	4	0,30 €	1,20 €	printing

Total price per unit	**18,54 €**	
Total price	**370,80 €**	for 20 unit

Appendix S
Bill of materials dialysis collection final design

Bill of material					
Part number	**Name of part**	**Quantity**	**Size (mm)**	**Availabiliy**	**Material**
1	Basket	1	430x350x180	custom made	PP
2	Attachment Part Box	2	55x33x20	custom made	ABS
3	Attachment Part Post	2	44x17x18	custom made	ABS
4	rubber seal	2	D250 mm	commercial	steel
5	Screw	2	M4x20 mm	commercial	steel
6	Screw	4	M4x10 mm	commercial	steel
7	Nut	6	M4	commercial	steel

Appendix T
Stakeholder analysis

New table

Stakeholder name	Interest?	Influence over the project?	What is important for them?	How could the stakeholder contribute to the project?
Erasmus MC	high	high	Cost reduction meeting targets for Green deal media attention	facilitating collaboration, implement suggested measures, invest in solutions change protocols
Nurses	high	high	Safe working environment hassle-free work patients health clear rules	help investigating problems /opportunities co-creation long-term engagement/use of system
Doctors	low	high	Safe working environment hassle-free work patients health	help investigating problems /opportunities long-term engagement/use of system
Care assitance	high	high	Safe working environment hassle-free work patients health clear rules	help investigating problems /opportunities co-creation long-term engagement/use of system
Cleaning staff	low	high	Safe working environment low workload clear rules	help investigating problems /opportunities long-term engagement/use of system
Hospital waste management	high	high	managable waste process clear communication	help investigating problems /opportunities
Prezero (waste management company)	high	high	Income generation reducing cost	provide information offering solutions for recycling/transporting
Hospital Logistic department	high	high	managable waste process	help in organizing the system within and outside erasmus mc
Patients	low	low	high-quality care	not involved
Pharmafilter	low	high	income generation, waste through their system	help in making their system more user-friendly
Other hospital waste processor companies	high	low	the investment in their system	provide good solutions
Zavin (SZA waste processor)	high	low	generate income (more sza waste)	-
European Union	low	high	countries to meet sustainability goals. hospital to comply with regulations	create regulations that promote recycling

Material supplier	low	high	sell more material cost optimization	provide information about material qualities - take part in uisng recycling materials
Medical equipment supplier	low	high	sell more equipment,cost optimization	using easy to separate materials/design/mono-materials
Tu Delft	high	low	successful project, future collaborations with Erasmus MC	insights and support from supervisor team
Hospital Green Team	high	high	increase recycling engage staff	create awareness and engage staff help forward plan to management
Ministry of health, Welfare and sport	low	high	compy with regulation	provide information about regulations
Rijkswaterstraat Ministry of Infrastructure and water management	low	high	compy with regulation	provide information about regulations
Ministry of Economic Affairs and climate policy	low	high	compy with regulation	provide information about regulations
Citizens	high	low	healthy environment/recuded air pollution, high quality of care	support projects
Dutch Green Deal Sustainable Care	high	low	decrease env. impact of healthcare	cooperation with other hospitals engaging industry partners
Cleaning company	low	low	maintaining contract with Erasmus MC Making profit by their service	providing necessary waste bags
Other dutch hospitals	high	low	learn from the developments in other departments	collaborate to make changes faster, induce regulatory change by common force
Hospital management	low	high	Safe and smooth operation of the ICU	cover necessary costs, set-up proposed solution