From Insight to Impact:

Towards a More Sustainable Reinier de Graaf

by

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Abstract

This research investigates the implementation of sustainable alternatives to reduce the use of disposable absorbent pads in hospital care, focusing on the Obstetrics and Endoscopy departments of Reinier de Graaf Hospital. A mixed-methods approach was applied, combining literature review, stakeholder interviews, pilot studies, and clinically oriented absorption tests. Results from the absorption tests show that reusable products, such as washable pads and towels, can provide comparable performance to disposables when applied in a task- and context-specific manner. Pilot studies emphasized that successful implementation requires not only technically adequate and more sustainable alternatives, but also logistical integration, clear communication, and bottom-up staff involvement.

The application of the COM-B model demonstrated that psychological capability is a major barrier, as healthcare staff had limited knowledge of sustainability. Physical opportunity also played a role, with high workload limiting the time available for behavioural change. The Behaviour Change Wheel indicated that these barriers can be addressed through education and environmental restructuring, increasing awareness and supporting adaptation via integration into existing logistical workflows. The Consolidated Framework for Implementation Research highlighted the role of opinion leaders and implementation facilitators in bridging the gap between Green Teams and the sustainability coordinator.

Overall, this study concludes that reducing disposable absorbent pad use is both feasible and desirable, provided that product performance, workflow integration, and organisational support are combined with behavioural interventions and hospital-wide awareness. These findings contribute to the development of practical strategies for sustainable healthcare implementation.

Foreword

This thesis marks the conclusion of my master's research project, which I could not have completed without the support and guidance of many people. I would like to take this opportunity to express my gratitude to all those who contributed to this journey.

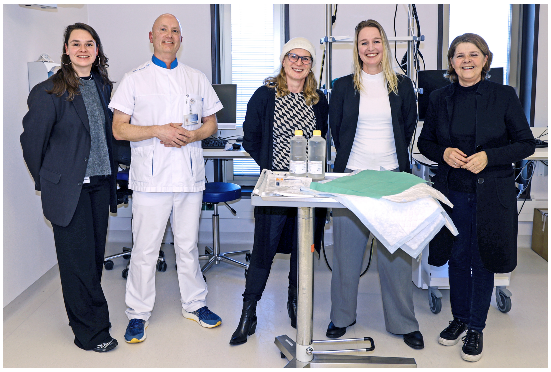
First, I would like to sincerely thank Alie Rozendal for her continuous support and guidance throughout the entire project. She not only encouraged me to become more aware of sustainability, but also helped me to appreciate the challenges of transitioning from a linear to a circular economy. She pushed me out of my comfort zone and provided me with unique opportunities, such as meeting the mayor of Delft. She also made it possible for me to stay closely connected to the hospital setting, where I experienced both the importance of this work and the joy it can bring.

I am grateful to Jenny Dankelman for her valuable feedback and the dedicated time she invested in supervising my thesis. Her insights greatly improved the quality of this work.

A special thanks goes to my friends and family, who always believed in me and supported me throughout this challenging process.

I would also like to thank the Thesis Lab organisation and my fellow students. The in-depth discussions and shared perspectives with this group gave me a deeper understanding of the complex sustainability challenges we are collectively facing in healthcare.

Finally, I want to express my gratitude to the Obstetrics and Endoscopy departments of Reinier de Graaf Hospital, and in particular to Patrick Ruijtenbeek, Kitty Kapiteijn, and Roos Langbein. They helped me translate this project into clinical practice, guided me in understanding the realities of healthcare workflows, and supported me in making this project both feasible and successful.



Contents

1 Introduction

Climate change is widely recognized as one of the greatest global threats to human health. The World Health Organization projects that between 2030 and 2050, climate change will cause approximately 250,000 additional deaths per year due to malnutrition, malaria, diarrhea, and heat stress alone [1]. Beyond these alarming predictions, climate change is already contributing to more frequent extreme weather events, shifting infectious disease patterns, and worsening air quality, all of which have immediate and long-term health consequences. In response, international agreements such as the Paris Agreement have set ambitious targets to limit global warming, underscoring the need for all sectors to drastically reduce greenhouse gas emissions [2].

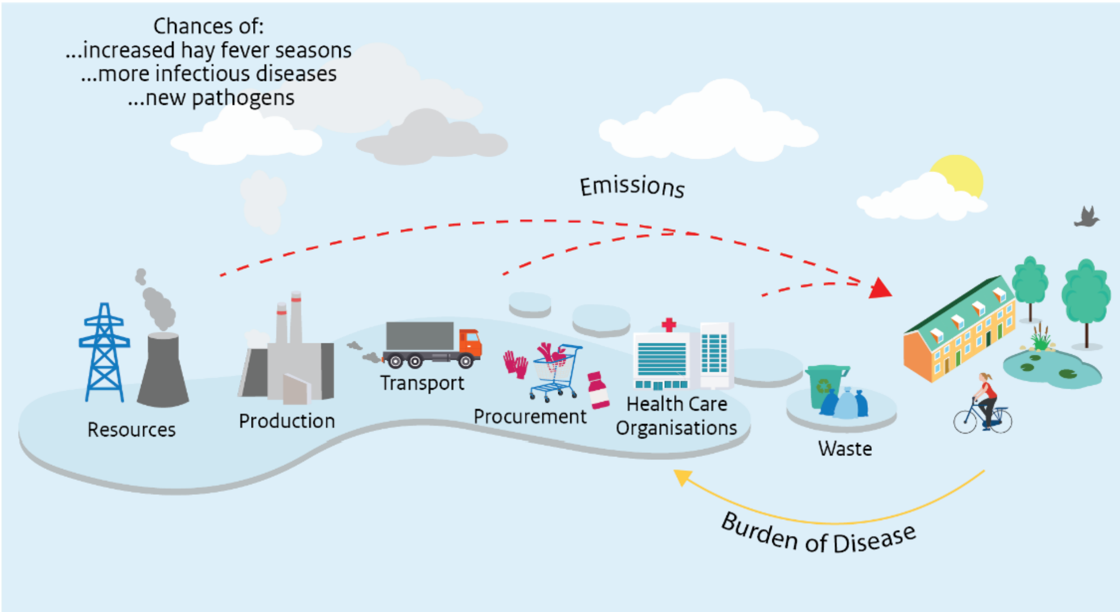


Figure 1: Diagram of the Environmental footprint of the healthcare chain and its reinforcing effects on public health. Increased greenhouse gas emissions and particulates contribute to climate change, leading to heat stress, longer hay fever seasons, and emerging diseases [3].

These global challenges are also evident at the national level, particularly within the Dutch healthcare sector. The Dutch healthcare sector accounts for an estimated 7% of the country's total greenhouse gas emissions, 13% of primary resource use, and 4% of all waste production [3]. Emissions from energy use, medical equipment production, and incineration of medical waste contribute to air and water pollution, climate change, and associated health risks. Healthcare faces a paradox: it safeguards health but also drives environmental degradation through intensive resource use and waste generation, ultimately contributing to future disease burdens (see Figure 1).

To address this, efforts are being made across the sector, ranging from hospital energy efficiency programs to sustainable procurement policies. The Green Deal Duurzame Zorg (GDDZ) framework has mobilized hundreds of organizations to align with the Paris Agreement by committing to measurable sustainability targets. The latest GGDZ version 3.0 sets out goals including 55% reduction in healthcare CO_2 emissions by 2030 (relative to 2018 levels) and a 50% reduction in primary raw material use by 2030 (relative to 2016 levels), on the path to climate-neutral and circular healthcare in 2050 [4].

Achieving the ambitious sustainability objectives outlined in the GGDZ requires a fundamental reconsideration of the reliance on single-use medical products. Modern hospitals rely heavily on medical disposables and single-use items like gloves, gowns, syringes, packaging, and incontinence pads, to maintain hygienic and efficient care. However, this convenience comes at a cost: disposables generate enormous amounts of waste and incur significant carbon emissions through their manufacture and incineration after disposal. It is estimated that approximately 80% of the healthcare sector's carbon footprint stems from the production, transportation, use, and disposal of medical supplies, reflecting the structural dependence on a linear model of disposability [5].

One disposable product that has received growing attention is the disposable absorbent pad, commonly referred to in Dutch hospitals as *celstofmatje*. These single-use pads are employed to absorb bodily fluids during medical procedures or routine patient care. Although they serve an important role in maintaining hygiene and infection prevention, their application is frequently excessive, and they are sometimes used in situations where this is not strictly necessary [6]. National consumption is substantial, with an estimated 23 million disposable absorbent pads used annually in the Netherlands [7]. Their significance has also been recognized at the organizational level: a benchmark by the Netherlands Federation of University Medical Centres (NFU) identified disposable absorbent pads among the 22 most impactful disposables, ranking 13th in both use and environmental burden [8].

At Reinier de Graaf Hospital, the setting of this research, the scale of disposable absorbent pad use is considerable. Internal procurement records show that more than 200,000 pads were consumed in 2024. Recognizing the need for change, Reinier de Graaf has set a goal to reduce the use of disposable absorbent pads by 20% in 2025, measured against 2024 procurement levels. To support this institutional ambition, this research aims to develop an evidence-based strategy to reduce waste from disposable absorbent pads. The project focuses on minimizing unnecessary use and evaluating sustainable alternatives, with the overarching goal of achieving waste reduction while safeguarding infection prevention, cost-effectiveness, and logistical feasibility.

1.1 Research Questions

This study aims to address the following main research question:

Main Research Question:
How can a hospital-wide implementation strategy for reducing the use of single-use products be designed, while ensuring cost-effectiveness, infection prevention, logistical feasibility, and usability, based on a case study of disposable absorbent pads in the Obstetrics and Endoscopy departments?

To answer this question, the following sub-research questions are formulated:

1. What are the current usage patterns and drivers of disposable absorbent pad use in the Obstetrics and Endoscopy departments?
2. Which behavioural, procedural, and organisational factors influence the reduction or substitution of single-use products in clinical settings?
3. What sustainable alternatives exist for disposable absorbent pads, and how do they perform in terms of functionality, environmental impact, and staff acceptance?
4. How can sustainable alternatives be integrated into existing workflows and hospital logistics without compromising cost-effectiveness and infection prevention?

2 Theoretical Framework

The transition towards sustainable healthcare requires more than technical solutions; it necessitates systemic change in how hospitals operate, make decisions, and influence behaviour. This chapter introduces complementary perspectives that together provide the foundation for interpreting the study's findings.

First, circular healthcare is discussed, applying circular economy principles to the healthcare sector. Tools such as the R-Ladder and Value Hill model are outlined, together with policy frameworks like the Green Deal Duurzame Zorg and the Milieuthermometer Zorg, which guide sustainability efforts in Dutch hospitals.

Second, the COM-B model and the Behaviour Change Wheel are presented to conceptualise the behavioural dimension of change, offering a lens to understand conditions that may support or hinder sustainable practices.

Finally, the Consolidated Framework for Implementation Research (CFIR) is introduced to address organisational and contextual factors that influence implementation processes.

2.1 Circular healthcare

The healthcare sector is increasingly recognized as both a protector of and a contributor to public health challenges, particularly in relation to environmental sustainability. Although its primary mission is to safeguard health and well-being, the sector also produces substantial carbon emissions, material waste, and resource consumption. These environmental impacts paradoxically undermine the long-term health outcomes it seeks to promote [9]. Recent evaluations highlight the urgent need to embed sustainability within healthcare system resilience strategies [10].

A promising framework to address these challenges is the circular economy (CE). CE is defined as an economic system that replaces the traditional "end-of-life" model with strategies of reduction, reuse, recycling, and recovery across production, distribution, and consumption processes. It operates at multiple levels: micro (products, companies, consumers), meso (eco-industrial parks), and macro (cities, regions, nations), with the overarching aim of fostering environmental quality, economic prosperity, and social equity [11].

In the healthcare sector, the application of CE principles is particularly urgent. Globally, healthcare has been estimated to rank as the fifth largest emitter of greenhouse gases if considered a country [12]. Hospitals, as major contributors to this footprint, are among the most resource-intensive institutions due to their reliance on single-use products and energy-intensive processes required for strict hygiene and infection prevention. This dependency drives high material consumption, substantial environmental impacts, and rising operational costs.

Within healthcare, this approach is referred to as circular healthcare (CH). CH explores safe and effective ways to reduce reliance on disposables through reprocessing, reuse, and substitution with sustainable alternatives. Circular strategies in healthcare aim to extend product life cycles where clinically safe and economically feasible. Examples include the reprocessing of surgical instruments, refurbishment of medical equipment, and adoption of reusable textiles such as gowns and drapes [13]. Furthermore, some hospitals are experimenting with product-service systems, in which manufacturers retain responsibility for maintenance and end-of-life recovery of devices. This model aligns economic incentives with environmental goals and encourages systemic change.

The relevance of circular healthcare lies in its capacity to reduce environmental impact, enhance operational efficiency, and strengthen the long-term resilience of healthcare systems. To facilitate this transition, several conceptual tools have been introduced, including the Value Hill model and the R-ladder, which provide structured approaches for identifying and prioritizing circular strategies across the product life cycle.

Complementary to these models, sector-specific policy instruments and frameworks have been established to support sustainable implementation. Examples include the Green Deal Duurzame Zorg and the environmental certification scheme Milieuthermometer Zorg, which aim to lower the ecological footprint of healthcare while safeguarding the quality of care.

2.1.1 Value Hill Model and R-ladder

The 10R Value Hill model offers a structured framework for visualizing how medical products gain, retain, and lose value throughout their lifecycle [14]. It demonstrates that the greatest sustainability gains can be achieved through upstream strategies in the pre-use and use phases, such as Refuse (R0), Rethink (R1), and Reduce (R2), which minimize unnecessary consumption and extend product lifespans. In the post-use phase, value can be retained through higher-order strategies such as Reuse (R3), Repair (R4), Refurbish (R5), and Remanufacture (R6), before resorting to lower-value options like Recycling (R8) or Recovery (R9). Applied to hospital settings, the model underscores that prevention and early-stage interventions preserve substantially more value than downstream waste management approaches. This makes it a valuable tool for structuring both behavioural interventions and process redesigns in the context of medical consumables (see Figure 2).

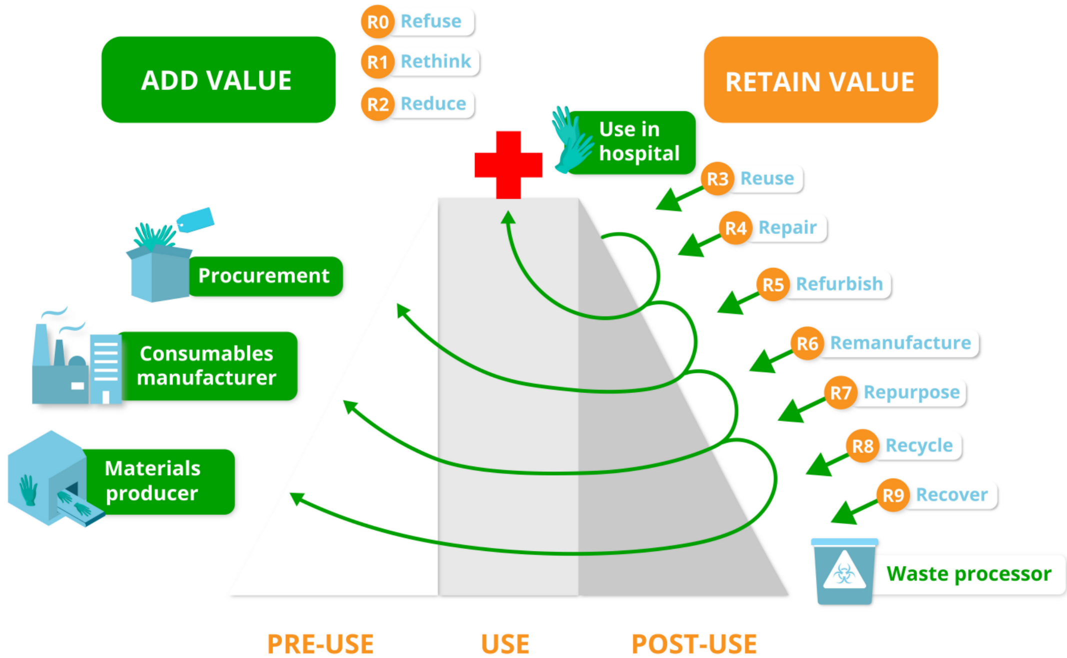


Figure 2: Combined visualization of the R-Ladder (10R hierarchy) and the Value Hill model in the healthcare context. The figure illustrates how early-stage strategies such as Refuse (R0), Rethink (R1), and Reduce (R2) preserve the most value across the hospital product lifecycle. Prioritizing these upstream interventions in procurement and design yields greater sustainability gains than downstream end-of-life strategies like Recycle (R8) or Recover (R9) [14].

In hospitals, applying the upper levels of the R-ladder requires reconsidering procurement norms and clinical practices. This may involve refusing products that are not medically necessary or redesigning workflows to limit disposable use. Where product use remains essential, opting for reusable alternatives or enhancing recycling systems can extend material value. Such measures must be adapted to healthcare-specific requirements, including sterility, safety, regulatory compliance, and staff workload.

2.1.2 Green Deal Duurzame Zorg

The Green Deal framework was introduced in the Netherlands in 2011 to accelerate sustainability initiatives across various sectors. A healthcare-specific version, the GDDZ, was first launched in 2015. Since then, the framework has evolved through successive versions, with GDDZ 3.0 currently setting goals for the period 2023–2026 [4].

The GGDZ has been signed by over 300 organizations, effectively mobilizing the healthcare sector to pursue concrete sustainability targets in line with the Paris Agreement. The latest GGDZ version 3.0 (2023–2026) outlines several ambitious sustainability targets for the Dutch healthcare sector. These include a 55% reduction in direct healthcare-related

CO_2 emissions by 2030, relative to 2018 levels, and a 50% reduction in primary raw material use by 2030, relative to 2016 levels. These goals contribute to the broader objective of achieving climate-neutral and circular healthcare by 2050.

While the GDDZ 3.0 applies broadly to the entire healthcare sector, it allows for sector-specific elaboration through route maps and implementation tools. For hospitals, the agreement highlights priority areas such as sustainable procurement, reduction of material waste, and a shift from disposable to reusable medical products, where feasible.

The GDDZ 3.0 outlines five strategic themes designed to transform the Dutch healthcare system into a sustainable, climate-neutral sector by 2050. These themes reflect a systemic approach to sustainability that encompasses prevention, education, emissions reduction, circular resource use, and pharmaceutical responsibility. Each theme is accompanied by concrete actions that healthcare institutions are expected to implement. Table 1 provides an overview of these five themes with examples relevant to operational and clinical practice.

Table 1: The five strategic themes of the Green Deal Duurzame Zorg 3.0 with hospital-specific example actions

No.	Theme	Example Actions
1	Health promotion for patients, clients, and healthcare workers	Provide healthy, varied, more plant-based, and sustainable food options; apply new knowledge and experience regarding health promotion.
2	Increasing awareness and knowledge of the impact of healthcare on climate, and vice versa	Embed sustainable healthcare and Planetary Health into all healthcare education programs; contribute to public debate on the relation between human behaviour, climate change, environmental pollution, lifestyle, and health.
3	Reducing CO_2 emissions by 55% in 2030 and achieving climate neutrality by 2050	Reducing electricity consumption in existing hospital buildings; including CO_2 emissions from production and embedded CO_2 in construction materials for new buildings; stimulating staff to use sustainable commuting options.
4	Reducing primary raw material use by 50% and reducing residual waste by 75% in 2030	Prioritizing reuse over disposables; Sustainable procurement criteria for medical devices; Promoting healthy and sustainable nutrition in hospitals.
5	Reducing the environmental burden of pharmaceuticals	Appropriate prescribing by physicians; appropriate dispensing by pharmacists; sustainable procurement by health insurers.

2.1.3 Milieuthermometer Zorg

The Milieuthermometer Zorg (MTZ) is a widely used sustainability certification system for Dutch healthcare institutions, developed by the Milieuplatform Zorgsector and Stichting Milieukeur (SMK). It supports organizations in embedding environmental sustainability into daily operations, with sector-specific criteria in areas such as energy consumption, procurement, waste management, mobility, and sustainable care delivery [15].

The certification consists of three levels: Bronze, Silver, and Gold. Since version 7, the Silver level has been fully aligned with the targets of the Green Deal Duurzame Zorg 3.0, meaning that organizations signing the Green Deal can demonstrate compliance through MTZ Silver certification. Gold certification goes beyond these requirements, including stricter obligations across all themes, increased external communication and transparency, and at least 30% procurement of green electricity [15].

In the latest version of the MTZ, the reduction of disposable absorbent pads and the adoption of reusable alternatives are explicitly included as sustainability criteria.

Milieuaspect/ onderwerp	Omschrijving	Inspectiemethode	Type	Afwijking	<30 bed	Zeer klein
7 Wasbare onderlegger	Doel: Het verminderen van de milieu-impact van onderleggers Eis: De organisatie maakt gebruik van wasbare onderlegger.	Visuele en/of administratieve controle.	Extra	Zie 4.2 (indien van toepassing)		
6 Minder onnodig gebruik celstofmatjes/onderleggers	Doel: Het voorkomen van onnodig en onjuist gebruik van celstofmatjes/onderleggers. Eis: Er is aantoonbaar beleid op het juist gebruik van celstofmatjes/onderleggers. Hiervoor is duidelijk onderscheid in wanneer celstofmatjes/onderleggers wel en wanneer niet gebruikt worden en dit is opgenomen in de relevante protocollen/werkwijzen.	Visuele en/of administratieve controle.	Extra, verplicht voor goud	Major voor goud. Voor zilver en brons: zie 4.2 (indien van toepassing)		

Figure 3: Criteria from the Milieuthermometer Zorg 7 (MTZ7) specifically addressing absorbent pads. The framework requires both a demonstrable policy to reduce unnecessary use of disposable absorbent pads and the adoption of washable underpads [15].

The framework requires hospitals to demonstrate policies that prevent unnecessary and incorrect use of disposable absorbent pads by clearly distinguishing in protocols when their use is justified and when it is not. In addition, MTZ introduces an explicit requirement for the use of washable underpads (see Figure 3). By embedding these criteria, the MTZ strengthens alignment with the Green Deal Duurzame Zorg 3.0 and supports hospitals in transitioning from single-use to reusable products, thereby lowering material consumption and environmental impact in daily care delivery.

2.2 Implementing change in healthcare

To understand the barriers and facilitators to sustainable practices, it is necessary to apply a theoretical lens that considers both individual behaviour and the broader institutional context. This section introduces a set of behavioural and implementation science frameworks that are particularly relevant for healthcare. The COM-B model (Capability, Opportunity, Motivation–Behaviour) serves as a foundation by identifying the core conditions required for behaviour change [16]. Building on this, the Behaviour Change Wheel (BCW) links intervention functions and policy categories to the COM-B components, offering a systematic guide for designing change strategies [16]. The Consolidated Framework for Implementation Research (CFIR) adds a multi-level perspective, highlighting contextual determinants at the individual, organisational, and system level that influence implementation outcomes [17]. Taken together, these frameworks provide complementary insights into the dynamics of change in healthcare and offer practical guidance for designing interventions to promote sustainable practices.

2.2.1 COM-B model and the Behaviour Change Wheel

The COM-B model (Capability, Opportunity, Motivation – Behaviour) provides a foundational framework for understanding the conditions that influence behaviour change [16]. According to this model, three interdependent components must be present for a specific behaviour to occur (see Figure 4).

First, **capability** refers to an individual's *psychological* and *physical* capacity to engage in the behaviour, including relevant knowledge, skills, and decision-making ability. Second, **opportunity** encompasses all external factors in the *physical* and *social* environment that either enable or constrain the behaviour. This includes access to resources, time availability, institutional infrastructure, and social influences from colleagues or leadership. Third, **motivation** involves the internal processes that energise and direct behaviour. This includes both *reflective* elements such as beliefs, intentions, and values, and *automatic* processes like emotional responses and habitual patterns.

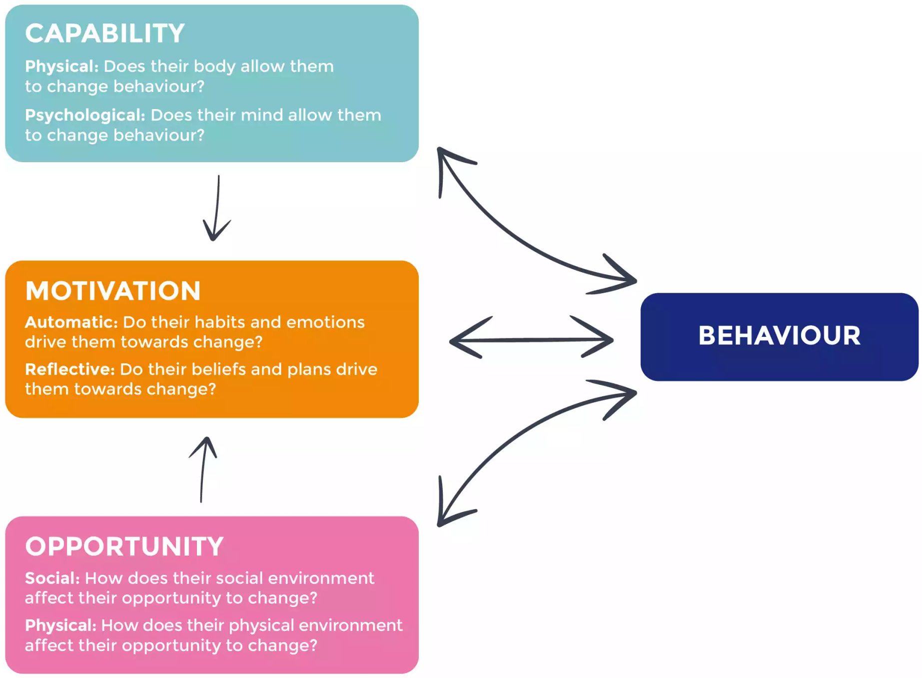


Figure 4: The COM-B model illustrates how behaviour is influenced by three interacting components: capability, opportunity, and motivation [18].

In clinical environments, barriers to adopting new or more sustainable practices frequently emerge when one or more of these components are lacking. For example, healthcare staff may not have the necessary information or training to adopt new routines, and many are unaware of the environmental impact of their daily practices, resulting in a low prioritisation of green initiatives (capability) [20][21]. Second, staff often work in systems that are not structured to support different behaviours, reinforced by fragmented institutional strategies and a lack of leadership commitment (opportunity) [22]. Last, resistance to change is common, particularly when sustainable alternatives are perceived as requiring additional effort, disrupting established workflows, or when competing clinical priorities overshadow environmental goals [23]. Understanding how these factors interact is essential for designing interventions that are not only technically feasible, but also likely to be adopted and sustained in real-world practice.

The Behaviour Change Wheel (BCW, see Figure 5) builds upon the COM-B model by offering a systematic method for designing interventions that support behaviour change [16]. At the core of the BCW lies the COM-B system, which identifies capability, opportunity, and motivation as the three essential conditions for behaviour to occur. Surrounding this core are nine distinct **intervention functions**, such as *education*, *persuasion* and *training*. These functions represent broad categories of activities that can be employed to influence one or more components of the COM-B model.

The outermost layer of the wheel outlines seven **policy categories** that can be used to support or implement these intervention functions. These include *guidelines*, *communication and marketing*, and *fiscal measures*. Each policy category acts as an enabling mechanism for intervention delivery, helping to translate behavioural goals into practical, system-level

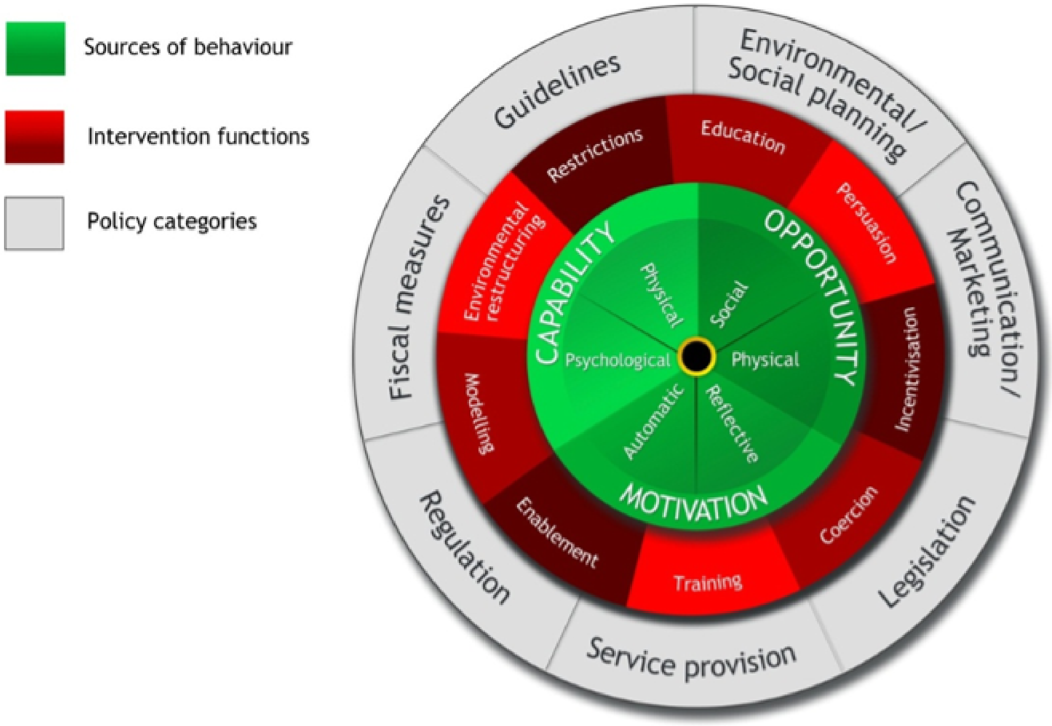


Figure 5: The Behaviour Change Wheel (BCW) integrates the COM-B model (centre) with nine intervention functions (middle ring) and seven policy categories (outer ring) [16].

strategies.

This makes the COM-B and BCW framework particularly useful for designing targeted strategies to address barriers to sustainable behaviour in clinical settings. For example, if capability is lacking, interventions could include sustainability-focused education and integration into existing staff training programmes. If motivation is low, persuasive communication, peer-to-peer role modelling, or performance feedback may help reinforce the perceived value of sustainable practices. When opportunity is limited, structural adjustments such as making reusable materials more accessible or embedding sustainability into institutional protocols could enable behaviour change.

2.2.2 Consolidated Framework for Implementation Research

While the COM-B and BCW frameworks focus primarily on individual behaviour, institutional and systemic barriers also play a critical role in determining the success of sustainability initiatives. To capture these broader determinants, the Consolidated Framework for Implementation Research (CFIR) provides a comprehensive lens [17]. CFIR structures the implementation process into five interrelated domains: the characteristics of the innovation itself, the outer setting, the inner setting, the individuals involved, and the implementation process (see Figure 6). Together, these domains enable a systematic analysis of how organisational, policy, and environmental factors influence the adoption of sustainable practices.

The **innovation** domain refers to the features of the intervention being implemented. Key factors include the *perceived advantage* over current practices, *adaptability* to local conditions, *complexity*, and the strength of *supporting evidence*. In a hospital setting, for example, introducing reusable absorbent materials may be seen as advantageous due to waste reduction, but also perceived as complex because of hygiene concerns or workflow adjustments.

The **outer setting** encompasses the broader institutional and policy context that influences implementation. This includes *local attitudes* towards sustainability, *external regulations* and *funding opportunities*, and *pressure* from patients, insurers, or society. National climate agreements and hospital-wide sustainability targets can generate external momentum for adopting circular practices.

The **inner setting** focuses on the characteristics of the implementing organisation itself. This includes *cultural alignment* with the innovation, the degree of *leadership engagement*, internal *communication quality*, and the *availability of resources* such as time, training, or infrastructure. Organisational readiness and the prioritisation of sustainability internally are critical for successful integration into clinical routines.

The **individuals** domain highlights the roles, capabilities, and motivations of those involved in or affected by the implementation. Effective change requires not only *skilled staff* but also individuals who *perceive sustainability as meaningful* and aligned with their professional identity. Clinical champions or influential staff members can act as key facilitators in encouraging adoption among peers.

Finally, the **imlementation process** domain refers to the way interventions are introduced and embedded over time. This includes *planning*, *stakeholder engagement*, *execution*, and ongoing *evaluation*. Adaptive strategies that respond to local barriers and facilitators, combined with feedback loops, are essential for long-term success.

These dimensions are visually summarised in Figure 6, which illustrates the interaction between setting-, individual-, intervention-, and process-level factors within the CFIR framework. Taken together, these domains provide a structured lens to analyse why implementation efforts succeed or fail. They also offer practical guidance for designing interventions that are not only technically feasible, but also contextually appropriate and sustainable in the long term.

2.2.3 Combining behavioural and organisational frameworks

An effective implementation strategy in healthcare must address both individual behaviour and the organisational context in which that behaviour occurs. Integrating the COM-B model and BCW with the CFIR enables such a multi-level perspective. COM-B/BCW provides a lens for understanding and influencing behaviour through capability, opportunity, and motivation, while CFIR captures organisational and system-level determinants such as leadership, resources, and policy context. Together, these frameworks offer a structured basis for identifying barriers and enablers and for designing interventions that are contextually appropriate and sustainable, which makes them particularly relevant for this thesis on the adoption of sustainable practices in clinical settings.

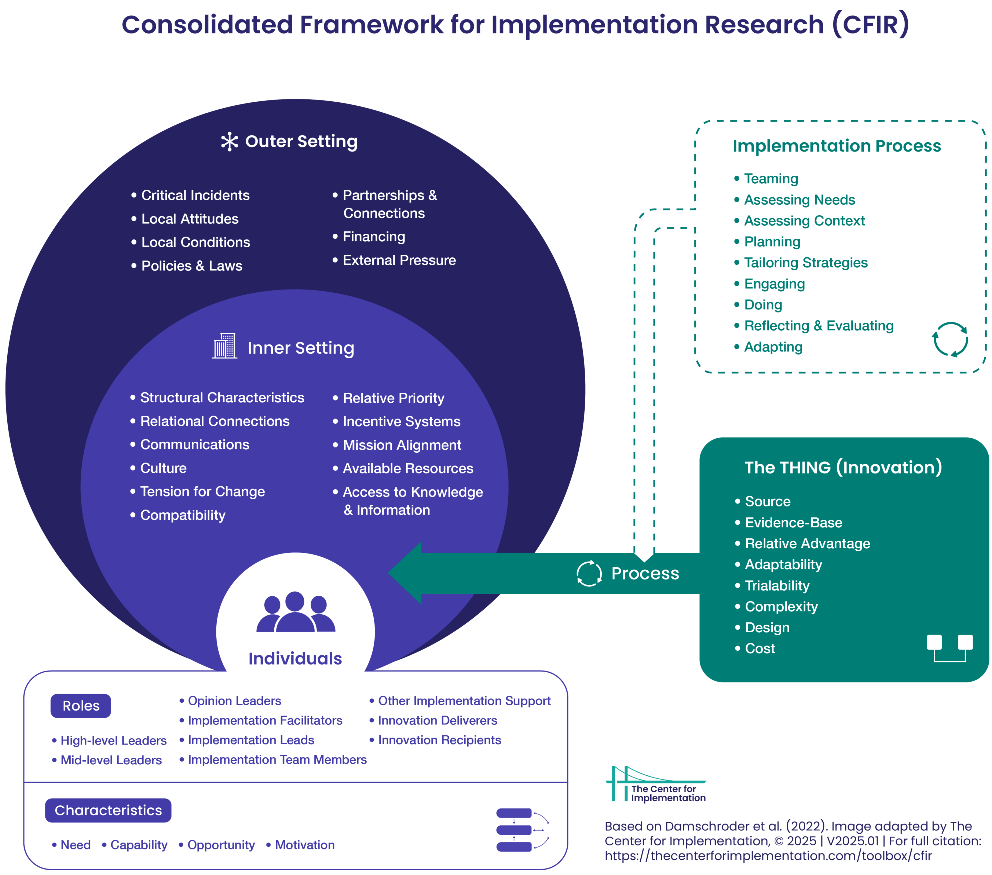


Figure 6: The Consolidated Framework for Implementation Research (CFIR) 2.0 provides a comprehensive structure for analysing the factors that influence implementation success. It includes five domains: intervention characteristics, inner setting, outer setting, characteristics of individuals involved, and the implementation process [19].

3 Disposable absorbent pads

Improving sustainability in healthcare requires a clear understanding of products and practices that contribute most to environmental burden. Among the many single-use items in clinical care, disposable absorbent pads represent a significant source of medical waste (see Figure 7). They are used across nearly all hospital departments, particularly in high-throughput areas such as obstetrics and endoscopy, to absorb bodily fluids and maintain hygienic conditions during procedures. Although designed for single use and valued for infection prevention and convenience, their application often extends beyond necessity, leading to routine overuse and avoidable material consumption [6].

A 2022 project by the Nederlandse Federatie van Universitair Medische Centra (NFU), conducted under the Green Deal Duurzame Zorg, assessed the environmental impact of disposables across six university medical centres. Disposable absorbent pads ranked 13th among 22 high-impact products, with procurement data indicating 1.8 million pads purchased in that year, corresponding to an estimated environmental impact of 263,000 kg CO_2-eq [8]. On a national scale, annual use is estimated at approximately 23 million pads [7].

This chapter provides background information on disposable absorbent pads to contextualise their sustainability challenges. It first examines their material composition, functional properties, and absorption and leakage performance. The R-ladder framework is then applied to identify opportunities for reduction, reuse, and rethinking, supplemented by documented initiatives from other hospitals. Alternative product solutions are subsequently evaluated, and the chapter concludes with a comparative environmental analysis quantifying the potential benefits of transitioning to more sustainable options.

Figure 7: A standard disposable absorbent pad used in clinical settings. These single-use pads are designed to absorb bodily fluids and protect surfaces such as examination tables and patient beds.

3.1 Materials and composition

Disposable absorbent pads used in healthcare settings fall under the broader category of absorbent hygiene products (AHPs), which also includes diapers, incontinence briefs, menstrual pads, and absorbent bed sheets. These products vary in shape, size, and additional features such as straps or tapes, yet they all share a common multilayered structure designed to ensure fluid uptake, retention, and leakage prevention. A standard pad typically consists of four functional layers: a top sheet, an acquisition and distribution layer, an absorbent core (soaker), and a bottom sheet [24], as illustrated in Figure 8.

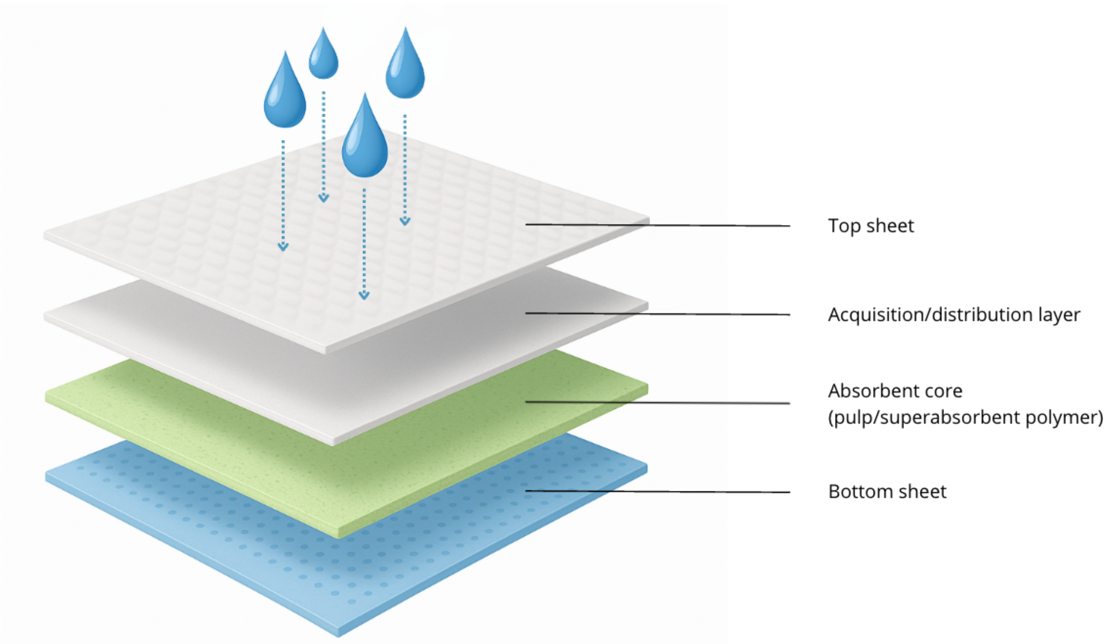


Figure 8: Functional layers of a disposable absorbent pad. The structure consists of a top sheet for initial fluid contact, an acquisition/distribution layer to spread and channel the liquid, an absorbent core made of pulp and superabsorbent polymer for retention, and a bottom sheet that acts as a waterproof barrier to prevent leakage (adapted from [24]).

The top sheet forms the interface with the patient's skin and is usually made of a hydrophilic nonwoven fabric such as polypropylene or polyester. It enables rapid fluid transfer to the inner layers while maintaining a relatively dry surface, thereby protecting the skin from overhydration and irritation. In some products, the top sheet is treated with emollients or antimicrobial coatings to minimise dermatological risks [25].

Beneath the top sheet lies an acquisition and distribution layer (ADL), which channels and disperses fluid across the absorbent surface, reducing the risk of local saturation and improving the efficiency of the core [26]. The absorbent core is the functional centre of the pad and typically consists of a mixture of fluff pulp and superabsorbent polymers (SAPs). SAPs, such as sodium polyacrylate, are crosslinked hydrophilic polymers capable of absorbing and retaining fluid many times their own mass, even under mechanical pressure [27]. Their combination with cellulose-based fluff pulp provides both high absorption capacity and fluid immobilisation.

The bottom sheet functions as the waterproof barrier and is generally composed of polyethylene (PE) or a similar plastic film laminated to the underside of the core. Its role is to prevent leakage and protect medical surfaces such as beds or examination tables [28].

3.2 Absorption and leakage performance

Incontinence products, both body-worn and non-body-worn underpads, are typically evaluated using standardized laboratory tests that measure fluid absorption and leakage performance. The ISO 11948-1 standard, also known as the Rothwell method, is the most widely applied procedure to determine maximum absorption capacity [29]. Pads are weighed dry, submerged in saline for 30 minutes, drained for 5 minutes, and reweighed (see Figure 9). The absorbed volume is calculated as the difference between dry and wet weights. To ensure uniform saturation, features such as cuffs or backings are neutralized. Results are expressed on the Rothwell scale (1–22+), which is commonly used in European procurement. The procedure is repeated for at least five pads, after which the mean and standard deviation of the results are calculated.

Although widely used, the Rothwell method was originally developed for large body-worn disposable pads and does not perform well for modern products. Contemporary incontinence pads often have more complex multilayered structures and a higher proportion of superabsorbent polymers, which limit the applicability of the test in predicting real-world performance [30]. Furthermore, studies evaluating the method's reliability demonstrated good repeatability, but poor reproducibility between laboratories. This suggests that while the test can achieve adequate precision under controlled conditions, ambiguities in the standard's instructions for constructing and operating the test apparatus leave too much room for variation in practice [31].

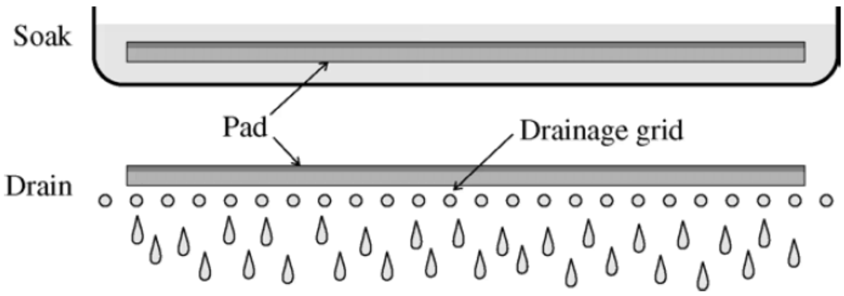


Figure 9: The apparatus used to measure the total absorption capacity of incontinence pads using international standard ISO 11948-1 (Cottenden et al., 2003).

Retention under pressure describes how well a pad holds liquid when compressed, simulating situations such as sitting or repositioning. The ISO 11948-2 standard [31] was originally developed for small body-worn pads for lightly incontinent women and prescribes applying 25 ml of saline to the pad, followed by placing a standardized filter paper and a 1.5 kPa weight for one minute (see Figure 10). The increase in filter paper mass represents the rewet value, and the procedure is repeated for at least five pads to calculate mean and standard deviation [30].

However, several issues have been identified with the method. Judging the exact moment of liquid absorption is difficult, and even short delays in applying the filter paper can substantially alter the results. This variability undermines reproducibility across laboratories. Moreover, product innovations have significantly improved rewet performance over the past decades, narrowing the differences between pad types and further reducing the discriminatory power of the test [30]. As a result, ISO 11948-2 demonstrated both poor repeatability and weak correlation with clinical performance, and it has since been officially withdrawn as an international standard.

Absorption rate, or acquisition speed, measures how quickly a product can absorb

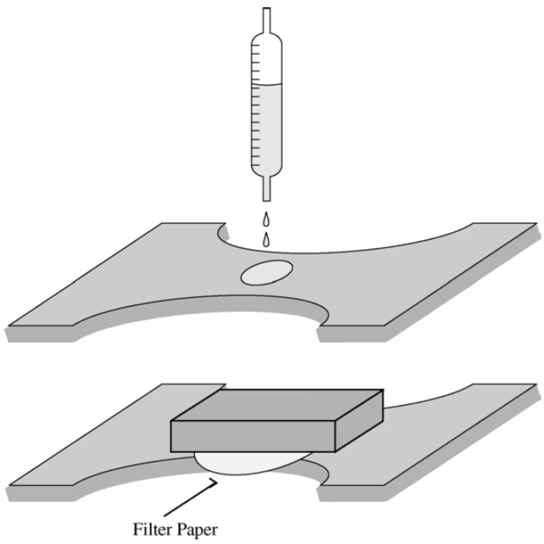


Figure 10: The apparatus used to measure the rewet mass for incontinence pads using international standard ISO 11948-2 (Cottenden et al., 2003).

fluid. This parameter is particularly important during heavy voids, where delayed uptake may result in pooling and leakage. The NWSP 70.9 Rate of Acquisition and Re-Wet test [32] evaluates both the time needed for a fixed saline volume to penetrate the product (rate of acquisition) and the amount of liquid resurfacing under pressure (rewet). In this procedure, a specified quantity of 0.9% saline is discharged at a controlled rate onto the test specimen, and the time to full penetration through the nonwoven cover is recorded. A pre-weighed filter paper is then placed on the surface, followed by a standardized weight, and the increase in filter paper mass represents the rewet value.

Compared to ISO 11948-2, NWSP 70.9 provides more reproducible results and better reflects in-use performance under load and pressure. This makes it especially relevant for flat, non-body-worn products such as underpads, which rely heavily on rapid absorption and surface dryness, as they cannot benefit from anatomical fit to guide fluid flow.

3.3 Comparative environmental impact

Only a limited number of life cycle assessments (LCA) directly compare reusable and disposable absorbent pads. Geene (2023) evaluated 1,000 uses of disposable versus reusable pads, comparing 1,000 single-use disposables (see Figure 11) to ten reusable pads washed 100 times each (see Figure 12). The study reported that reusables emitted 49.4 kg CO_2-eq, compared to 117 kg CO_2-eq for disposables, corresponding to a 58% reduction in climate impact [28].

To enable fair comparison across environmental categories, the LCA study also used a "single score" expressed in milli-points (mPt), where 1 mPt represents one-thousandth of the average annual environmental footprint of a European citizen. The mPt scale aggregates multiple environmental impact categories into one unit based on severity, including: (1) climate change, (2) acidification, (3) particulate matter formation, (4) land use, (5) fossil resource use, and (6) water use. In this scoring system, reusable pads scored 3.7 mPt, compared to 8.1 mPt for disposable pads, confirming their lower footprint (see Figure 13) [28].

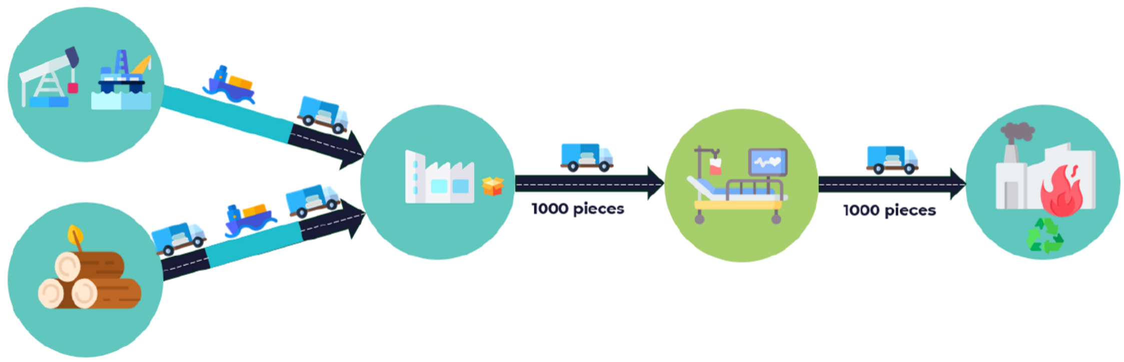


Figure 11: Schematic representation of the life cycle use pattern of disposable absorbent pads as analyzed in the LCA by Geene (2023) [28].

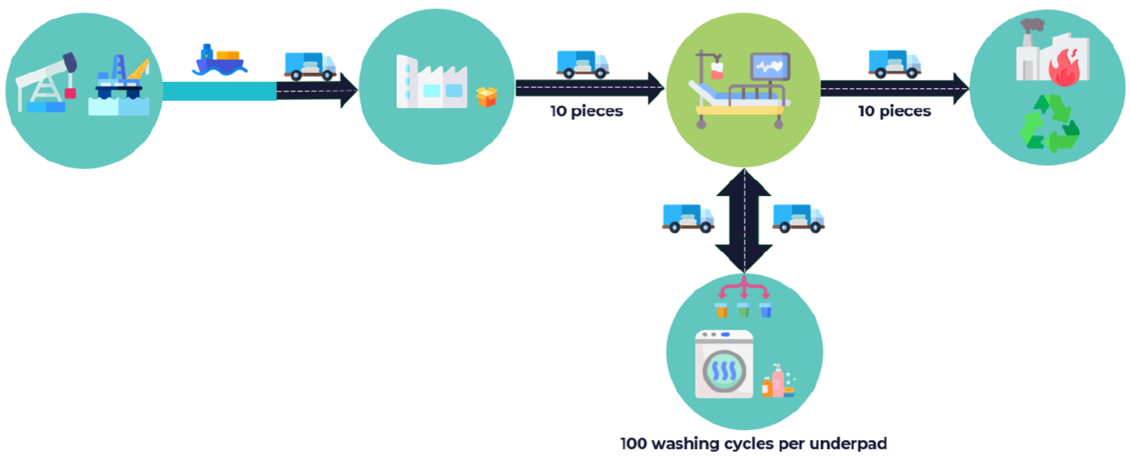


Figure 12: Schematic representation of the life cycle use pattern of reusable absorbent pads as analyzed in the LCA by Geene (2023) [28].

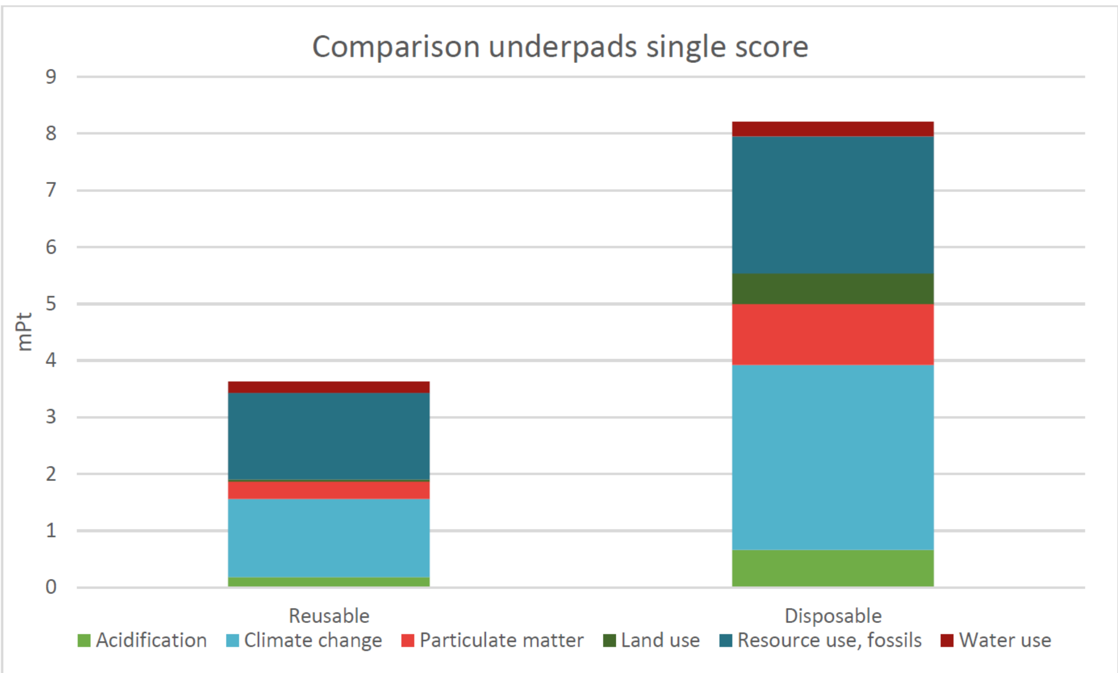


Figure 13: Single-score environmental impact (in mPt) of disposable vs. reusable absorbent pads across six categories: climate change, acidification, particulate matter, land use, fossil resource use, and water use [28].

Blank (2023) corroborated these findings in an LCA of three disposable products (A–C) and one reusable pad. Using ReCiPe midpoint categories, the reusable option performed better in 15 of 18 environmental metrics, with overall impacts 33–64% lower than the best-performing disposable. Contribution analysis revealed that disposables are dominated by upstream material production and manufacturing, while reusables are dominated by the use phase (laundering and transport) (see Figure 14) [24].

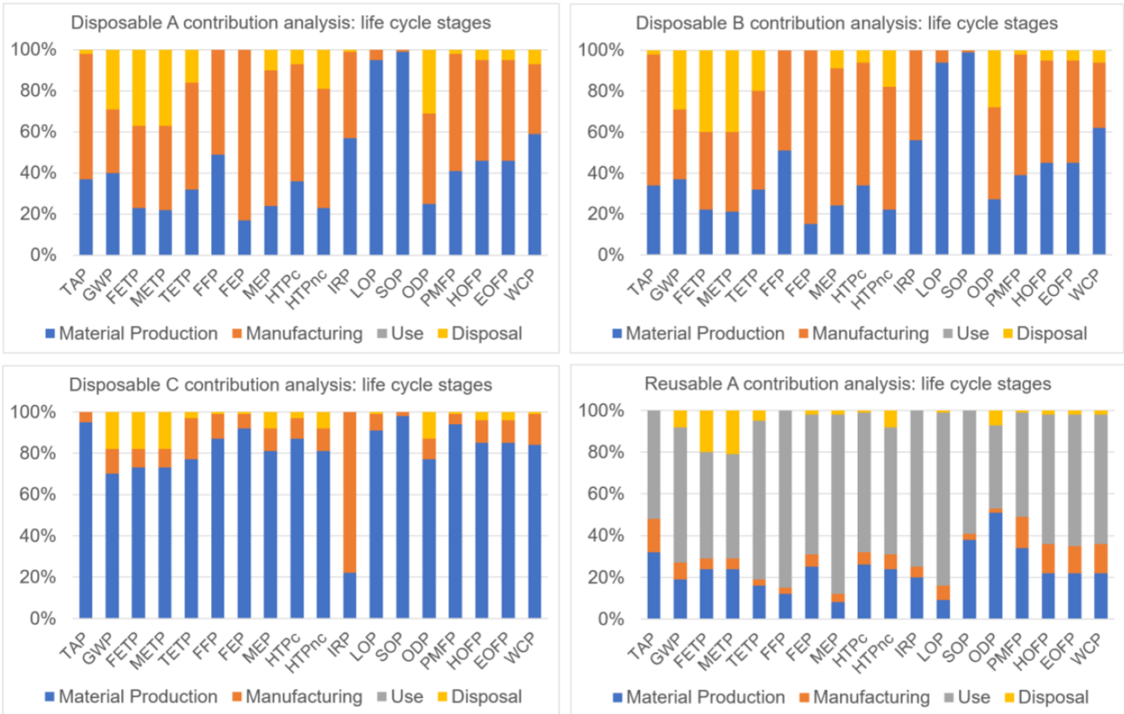


Figure 14: Life cycle stage contributions to total environmental impact: manufacturing dominates for disposables, while the use phase (laundering) dominates for reusables [24].

Griffing and Overcash (2023) compared 1,000 disposables to 1,000 washing cycles of reusables across six environmental metrics: natural resource energy combusted, natural resource energy materials, total natural resource energy, global warming potential (kg CO_2-eq), blue water consumption, and solid waste generated. They found that reusables had 52–97% lower impacts, with disposables dominated by production and supply chain activities, and reusables by laundry energy demand [27].

Collectively, these studies consistently demonstrate that reusable absorbent pads have a substantially lower environmental impact than disposables (see Table 2). The exact magnitude of benefit depends on methodological scope and assumptions, particularly regarding laundering practices. While disposables are dominated by upstream production impacts, the use phase is the critical driver for reusables. Nevertheless, reusables remain environmentally favorable under most scenarios.

3.4 Sustainability approaches

Given the significant environmental burden associated with single-use absorbent pads, hospitals are increasingly seeking alternatives that align with waste reduction goals and circular healthcare principles. This section outlines strategies to minimise the environmental impact of absorbent materials in clinical practice. It introduces the application of the R-ladder framework to assess the potential sustainability value of various interventions

Table 2: Comparative overview of LCAs on disposable vs. reusable absorbent pads

Study	Functional unit	Impact categories	Main findings	Key drivers
Griffing & Overcash (2023)	1000 disposables vs. 1000 wash cycles reusables	6 metrics: energy (materials, combustion, total), GWP, blue water, solid waste	Reusables 52–97% lower impact across all metrics	Disposables: manufacturing & supply chain; Reusables: laundry (electricity, drying)
Blank (2023)	1000 pads (60×60 cm), 3 disposables (A–C) vs. 1 reusable	ReCiPe midpoint (18 categories)	Reusable 33–64% lower than best disposable; better in 15/18 categories	Disposables: material production & manufacturing; Reusables: use phase (laundering, transport)
Geene (2023)	1000 disposables vs. 10 reusables (100 uses each)	6 categories: climate change, acidification, particulate matter, land use, fossil resources, water	Reusables 58% lower GWP (117 vs. 49.4 kg CO_2e); 3.7 vs. 8.1 mPt single score	Disposables: fluff pulp, polyethylene, polypropylene; Reusables: soap, gas, electricity during washing

and reviews documented implementation efforts in other hospitals.

3.4.1 Application of the R-ladder framework

The R-ladder of circularity (10R hierarchy) ranks strategies from most to least preferred in terms of resource value retention (see Figure 2). It provides a structured approach to evaluate the sustainability potential of interventions aimed at reducing disposable absorbent pad waste. Each strategy is introduced in general terms and then directly applied to the context of this thesis.

R0 – Refuse: This strategy aims to avoid the use of a product entirely, thereby preventing resource consumption and waste generation from the outset. It is the most effective approach in terms of resource value retention, as it eliminates the need for production, distribution, and disposal. For disposable absorbent pads, this involves critically assessing whether a pad is required for each procedure. If no bodily fluids are expected or protective surfaces are already in place, staff can omit pad use altogether. This requires a culture shift away from routine practices.

R1 – Rethink: Rethink focuses on re-evaluating product design, workflows, and business models to enable more sustainable practices. This can involve integrating alternative products, redesigning processes, and making sustainable options the default. In healthcare, this may include substituting disposable absorbent pads with certified reusable, washable alternatives, supported by adapted storage, ordering systems, and staff training. Structural nudges, such as limiting access to disposables or adding environmental impact labels, can further promote this transition.

R2 – Reduce: This strategy aims to use fewer resources while maintaining product functionality. Reduction can be achieved through improved efficiency, smaller product sizes, or reduced material thickness. Hospitals can reduce pad use by decreasing the number of pads per procedure, selecting smaller pad sizes, or using thinner designs. Success depends on staff engagement, awareness, and clear protocols that support efficient material use.

R3 – Reuse: Reuse involves using the same product multiple times in its original form, thereby extending its lifespan and reducing demand for new production. For single-use absorbent pads, reuse is generally not feasible due to contamination risks and their single-use designation. Limited reuse could be possible in low-risk settings if pads remain visibly clean and uncontaminated, but this must comply with infection prevention policies.

Table 3: Applicability of R-ladder strategies to disposable absorbent pads in healthcare settings

R-strategy	Description	Applicability in healthcare
R0 – Refuse	Avoid use entirely	Feasible when no fluids are expected or alternative protective surfaces are already in place. Requires culture shift and staff awareness.
R1 – Rethink	Redesign workflows, integrate sustainable defaults	Includes the substitution of disposable pads with certified reusable, washable alternatives, supported by adapted storage, ordering systems, and behavioural nudges.
R2 – Reduce	Use fewer resources without losing function	Reduce number of pads per procedure, use thinner designs, or select smaller formats where feasible. Requires staff engagement and clear protocols.
R3 – Reuse	Use multiple times in original form	Applicable only to reusable pads in low-risk settings with proper laundering protocols. Not feasible for disposable pads due to contamination and single-use designation.
R4–R6 – Repair, Refurbish, Remanufacture	Restore to working condition	Not applicable to disposable pads due to contamination and design limitations.
R7 – Repurpose	New function without processing	Limited to non-clinical uses (training), not scalable due to contamination risks.
R8 – Recycle	Process into new materials	Currently unfeasible due to mixed materials (polypropylene, cellulose, SAPs, polyethylene), gel formation after use, and contamination with bodily fluids. Classified as hazardous medical waste (EURAL code 18 01 03*; LAP3 Sector Plan 19).
R9 – Recover	Energy recovery via incineration	Standard end-of-life route in the Netherlands. Legally required due to hazardous waste status. Avoids landfill but results in permanent material loss and emissions.

R4–R6 – Repair, Refurbish, Remanufacture: These strategies restore a product to working condition through repair, refurbishment, or remanufacturing, and are particularly relevant for durable goods and technical equipment. They are not applicable to disposable absorbent pads due to the product's material composition, contamination risk, and design for single use, which prevents disassembly or hygienic restoration.

R7 – Repurpose: Repurposing involves assigning a product a new function without processing it into raw materials, typically after it has served its original purpose. This can extend the usefulness of items beyond their intended application. In theory, disposable pads could be repurposed for non-clinical uses such as training demonstrations or surface protection during equipment cleaning. However, contamination risks and their classification as hazardous medical waste make this option highly restricted and generally not feasible as a scalable strategy.

R8 – Recycle: Recycling converts waste materials into new products or raw materials, reducing the need for newly extracted, primary resources. For disposable absorbent pads, recycling is currently not feasible. Their multilayered composite design (polypropylene, cellulose, SAPs, polyethylene) prevents effective material separation, and SAPs form an irreversible gel when wet. In addition, contamination with blood, amniotic fluid, and other bodily substances classifies them as hazardous medical waste [34][35], legally excluding them from recycling streams.

R9 – Recover: Recovery involves extracting energy or other value from waste materials that cannot be reused or recycled, most commonly through incineration or waste-to-energy processes. For disposable absorbent pads, incineration is the standard end-of-life route in the Netherlands. While it prevents landfill disposal, it results in permanent material loss, requires high energy input, and generates emissions (see Section 3.3).

3.4.2 Documented sustainability interventions

Several Dutch hospitals have piloted or implemented measures to reduce disposable pad consumption. These interventions can be grouped into three main strategies:

1. **Reusable textile-based pads** (washable absorbent mats)
2. **Behavioural change and awareness campaigns** to reduce unnecessary pad use
3. **Replacement with alternative products** such as towels or non-absorbent mats

Examples include pilots at UMCG, Noordwest Ziekenhuisgroep, and LUMC, where reusable absorbent pads were introduced in departments such as surgery, obstetrics, and intensive care. Reported outcomes ranged from 40–74% reductions in disposable pad use to substantial CO_2 savings (up to 86%), often accompanied by positive feedback from staff and patients. Other hospitals, including St. Antonius, Erasmus MC, and Haaglanden MC, have focused on behavioural strategies, using targeted communication, staff engagement, and department-specific awareness tools to achieve reductions of 42–50%.

Common challenges include logistical constraints (limited laundry capacity for reusables, storage space limitations), product suitability issues (not functional for all clinical procedures), and the need for continuous reinforcement of behavioural change. Pilots vary from short-term departmental trials to multi-year programmes, with some eventually integrated into routine practice. A complete overview of documented initiatives is provided in Appendix Table A1.

3.5 Conclusion

This chapter has examined the environmental burden of disposable absorbent pads in clinical practice and introduced the R-ladder framework as a structured approach for evaluating potential sustainability strategies. Higher-tier strategies such as *Refuse*, *Rethink*, and *Reduce* emerged as the most promising for reducing environmental impact within the current context, while *Reuse* is generally not feasible for disposable pads. Lower-tier strategies such as recycling and recovery offer limited value due to material composition, contamination, and legal restrictions. Consequently, the focus of this thesis is on implementing and evaluating *Refuse*, *Rethink*, and *Reduce* strategies, alongside the substitution of disposables with certified reusable alternatives where applicable.

Documented initiatives in Dutch hospitals demonstrate that substantial reductions in disposable pad use are achievable, often accompanied by significant CO_2 savings and high levels of staff and patient satisfaction. These interventions include the introduction of reusable pads, behavioural change campaigns, and substitution with other washable textiles. However, replication is not straightforward: feasibility and impact depend on logistical infrastructure, infection control protocols, available storage, staff workflows, organizational support, and the capacity of hospital laundry facilities to process reusable pads.

These findings highlight that sustainability strategies must be tailored to the operational, regulatory, and cultural conditions of the implementation setting. Lessons from other hospitals inform the selection of interventions for this thesis, but their applicability depends on the specific characteristics of the target departments. The next chapter describes the research setting in detail, providing the contextual basis for assessing and implementing sustainable alternatives to disposable absorbent pads.

4 Research setting: Reinier de Graaf

The Reinier de Graaf Gasthuis is the oldest hospital in the Netherlands and a top clinical teaching hospital (STZ) with its main location in Delft and two outpatient clinics in Voorburg and Naaldwijk. It serves a catchment population of approximately 450,000 inhabitants in the surrounding region. In 2024, the hospital employed 2,652 staff members, including over 256 medical specialists across 33 clinical disciplines, and operated with a capacity of 492 beds [36].

That year, Reinier de Graaf recorded 105,115 initial outpatient visits, 44,018 emergency department consultations, 21,313 inpatient admissions, and 20,507 day treatments. In total, 106,485 inpatient days were registered, with an average length of stay of five days. Surgical activity comprised 32,680 operative procedures, while the Obstetrics Department oversaw 3,245 deliveries, of which 707 were caesarean sections [36].

This chapter provides the contextual background for the sustainability intervention studied in this thesis, moving from hospital-wide strategies to the operational setting of the selected departments. It begins by outlining the hospital's sustainability ambitions and ongoing initiatives, followed by a description of current waste management practices. The use of disposable absorbent pads is then examined to establish the rationale for focusing on Obstetrics and Endoscopy as pilot departments. The chapter continues with a mapping of the key stakeholders involved in procurement, infection prevention, logistics, waste handling, and frontline use. Finally, the organisational structure and workflow of the Obstetrics and Endoscopy departments are described.

4.1 Sustainability goals and initiatives

Reinier de Graaf Hospital has embedded sustainability within its organisational strategy, formalised in the 2024–2026 sustainability policy. The hospital is a signatory of the Green Deal Duurzame Zorg 3.0 and has achieved a Bronze level certification under the Milieuthermometer Zorg 6, committing to circular working practices, reduction of CO_2 emissions, and minimisation of pharmaceutical residues in the environment.

A central policy objective is the target to replace 20% of disposable products with more sustainable alternatives by 2026, while reducing overall waste by 15% (Reinier de Graaf, 2024). Achieving these goals is supported by the hospital's circular procurement strategy and the integration of sustainability criteria into departmental processes. The policy also prioritises staff engagement, aiming for 85% of employees to be aware of the link between climate, environment, and health, and for 70% to be actively working to make their own professional behaviour more sustainable. Responsibility for sustainability is distributed throughout the organisation, with a sustainability coordinator and an environmental coordinator providing central support. Departmental Green Teams, consisting of staff from the same ward or specialty, are tasked with identifying and implementing local sustainability initiatives [37].

These organisational ambitions are particularly relevant to this thesis, which examines how awareness and change management can support the transition towards more sustainable clinical practices. The emphasis on increasing staff knowledge about the link between climate, environment, and health, combined with the aim for behavioural change among a majority of employees, provides a supportive context for exploring strategies to reduce reliance on disposable products. The existing structure of Green Teams and a sustainability coordinator offers potential channels for engaging stakeholders and embedding changes within routine workflows.

As waste reduction targets form an integral part of the hospital's sustainability agenda and disposable absorbent pads contribute directly to the hospital's total waste stream, it is necessary to examine how waste is currently processed and managed. The next section therefore examines existing waste management systems at Reinier de Graaf, providing context for identifying opportunities and challenges in implementing sustainability initiatives.

4.2 Waste management

Effective waste management is a critical component of sustainable hospital operations. Healthcare facilities generate a wide range of waste types, each with distinct implications for safety, environmental impact, and regulatory compliance. Internationally, healthcare waste is commonly classified into two main categories: hazardous waste, primarily consisting of infectious or potentially infectious materials, and non-hazardous waste, which resembles municipal solid waste in composition. Non-hazardous waste streams typically account for up to 80% of the total volume of healthcare waste generated [38].

At Reinier de Graaf Hospital (RDGG), waste streams are similarly divided into *general business waste* (non-hazardous waste) and *Specifiek Ziekenhuisafval* (SZA; hazardous waste), in accordance with the Dutch Landelijk Afvalbeheerplan (LAP3) Sectorplan 19 on healthcare waste with infection or specific risks [36]. General business waste includes materials that pose no infection risk and can be processed alongside municipal waste. In contrast, SZA encompasses hazardous materials such as infectious waste, sharps, human tissue, and

Figure 15: The Pharmafilter installation on the premises of Reinier de Graaf Hospital. The system is currently in partial operation, focusing on wastewater treatment to remove pharmaceutical residues and other contaminants, with the treated water being reused within the hospital.

cytotoxic or cytostatic waste, which require specialised containment, licensed transport in compliance with ADR regulations [39], and final treatment through high-temperature incineration at authorised facilities, as stipulated in Dutch healthcare waste legislation.

Pharmafilter system

Over the past decade, RDGG has implemented and trialled various technological and organisational measures to reduce the environmental impact of its waste management processes. Two of the most significant initiatives were the Tonto and Pharmafilter systems, both designed to make hospital waste handling more sustainable [40].

The Tonto system functioned as an in-hospital waste grinder, installed in designated departmental waste rooms. It enabled healthcare staff to dispose of a wide range of contaminated waste, including disposable absorbent pads, food leftovers, and bedpans, by grinding them on site. The resulting slurry was transported via dedicated underground pipelines to the external Pharmafilter installation (see Figure 15), located adjacent to the hospital. This method was highly convenient for staff and therefore contributed to an increase reliance on the use of disposable products.

The Pharmafilter installation was originally designed as a closed-loop system that separated solid waste for appropriate treatment and purified wastewater to remove pharmaceutical residues, microplastics, and other contaminants. The treated water reportedly met or exceeded drinking water quality standards and could be reused within the hospital [40]. This model represented a substantial innovation in reducing the environmental footprint of hospital operations.

After the company operating the system went bankrupt, the installation at RDGG was taken offline. The hospital has recently reactivated the system in a modified capacity. It no longer functions as a grinding-based waste processing system for disposables. Instead, it focuses solely on wastewater treatment, filtering out pharmaceutical residues, microplastics, and other contaminants. The treated water is reused within the hospital, which reduces both water consumption and environmental contamination. The system is still in the process of scaling up to full operational capacity, with ongoing technical adjustments to optimise filtration performance.

The partial reactivation of the Pharmafilter system aligns with RDGG's broader sustainability goals, particularly in addressing pharmaceutical residue emissions and promoting water reuse. The period during which the Tonto system was in operation established a pattern of convenience-driven reliance on disposable products, which continues to pose challenges for reducing single-use consumption.

General waste

General business waste at RDGG is collected in compactor containers and processed externally. It consists of non-hazardous materials that pose no infection risk, such as packaging, paper, and food waste from administrative areas, waiting rooms, and cafeterias. In specific cases, disposable absorbent pads may also be classified as general waste, provided they are unused or not visibly soiled with blood or bodily fluids and therefore present no infection risk.

On average, each compactor collected at RDGG contains 5,087 kilograms of general waste. Processing costs are approximately €0.16 per kilogram, excluding transport (€0.017 per kilogram) and monthly container rental (€87.57). Due to its low-risk nature, general waste does not require specialised treatment, making it comparatively inexpensive to manage. However, correct segregation remains essential to ensure that potentially infectious materials are not misclassified into this stream.

In 2024, monthly volumes of non-hazardous medical waste at RDGG ranged from 41,020 kilograms in January to 50,580 kilograms in December (see Figure 16). Disposal costs followed a similar pattern, reflecting fluctuations in volume, with peaks in months of higher waste generation (see Table 4).

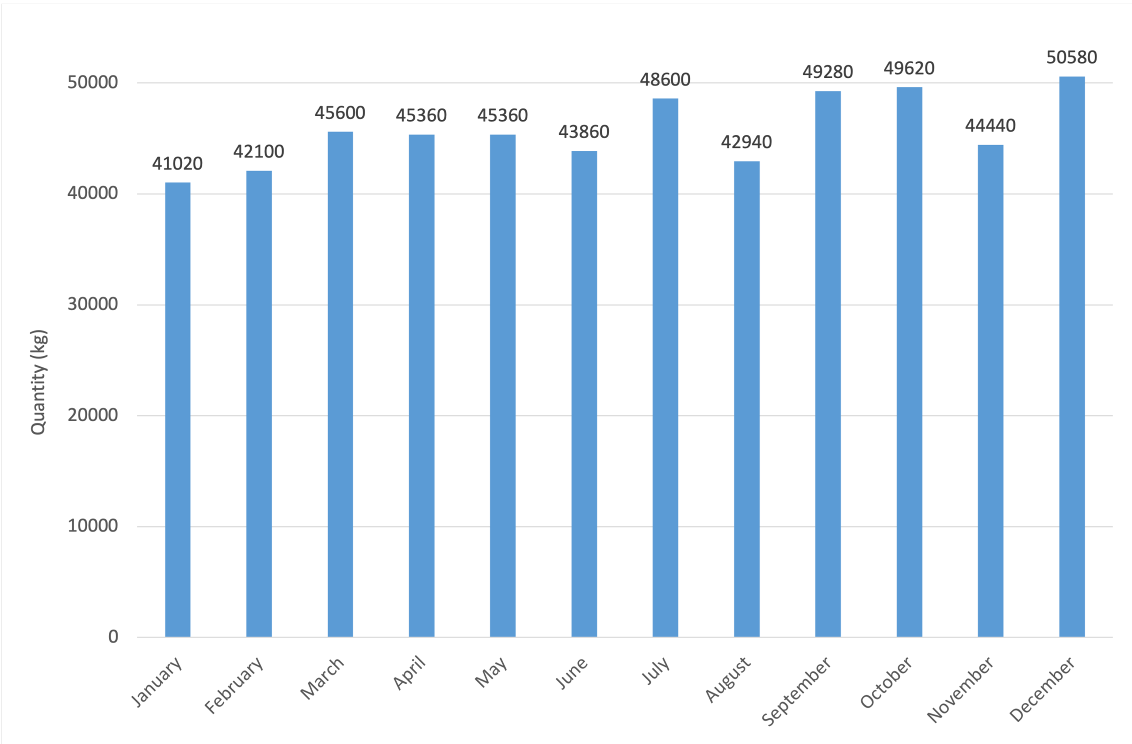


Figure 16: Monthly disposal of non-hazardous medical waste at Reinier de Graaf Hospital in 2024, measured in kilograms.

Table 4: Monthly cost of hazardous and non-hazardous medical waste disposal in 2024

Month	Hazardous waste (€)	Non-hazardous waste (€)
January	2761.05	7383.60
February	1919.70	7578.00
March	4139.60	8208.00
April	8978.35	8164.80
May	7722.25	8164.80
June	5530.00	7894.80
July	6805.85	8748.00
August	4700.50	7729.20
September	6478.00	8870.40
October	5537.90	8931.60
November	4838.75	7999.20
December	5917.10	9104.40

Hazardous waste

Hazardous waste at RDGG is collected in sealed cassettes and transported to certified processors for high-temperature incineration. In healthcare, hazardous waste refers to materials that pose a potential risk to human health or the environment due to their infectious, chemical, or physical properties. This waste must be segregated from general waste streams to prevent exposure hazards and ensure compliance with legal requirements. In the Netherlands, hazardous medical waste is regulated under the *Landelijk Afvalbeheerplan* (LAP3) [36], with updates forthcoming in LAP4. Typical examples include blood-contaminated gauze, sharp instruments, and cytotoxic agents.

Disposable absorbent pads also contribute to this waste stream. While unused or dry pads may be disposed of with general waste, pads that are visibly soiled with blood or other bodily fluids, particularly those originating from isolation rooms or infectious patients, must be classified as hazardous medical waste. At RDGG, such pads are collected in sealed, leak-proof grey containers and transported to certified processors for high-temperature incineration, in accordance with LAP3 regulations and infection prevention protocols.

On average, each cassette contains 582 kilograms of hazardous waste. Processing costs are approximately €0.64 per kilogram, excluding transport costs (€0.15 per kilogram) and monthly cassette rental (€88.00). Figure 17 shows the monthly hazardous waste volumes at RDGG in 2024. The amounts range from a low of 2,430 kg in February to a peak of 11,365 kg in April. The pronounced peak in April coincides with the shutdown of both the Tonto and Pharmafilter systems, which temporarily increased the share of clinical waste requiring external processing. Table 4 presents the associated monthly disposal costs for both hazardous and non-hazardous waste, showing that hazardous waste costs closely follow volume fluctuations, with the highest cost in April (€8,978.35) and the lowest in February (€1,919.70).

After collection, hazardous waste is transported to ZAVIN, a certified incineration facility in Dordrecht. ZAVIN holds ISO 14001 environmental management certification, underscoring its adherence to structured process control and sustainable operational standards. Hazardous medical waste is incinerated at temperatures exceeding 1000°C in a two-stage process: initial thermal treatment in a primary furnace, followed by complete combustion of the resulting gases in a secondary chamber. This method ensures the de-

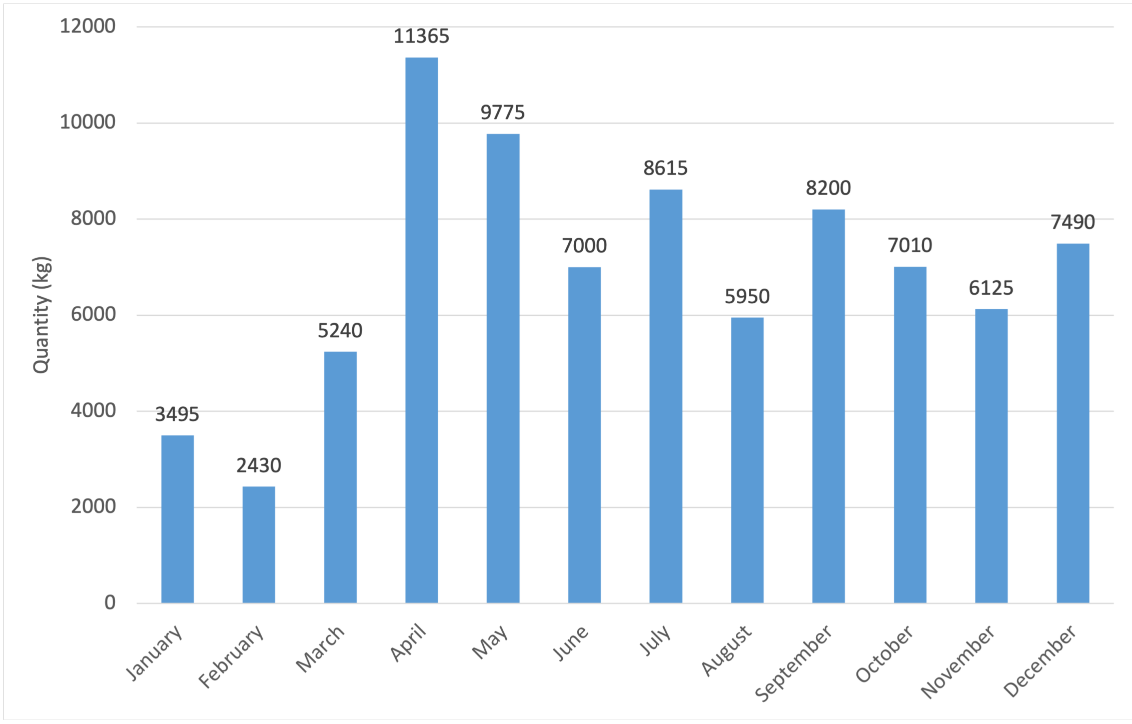


Figure 17: Monthly disposal of hazardous medical waste (SZA) at Reinier de Graaf Hospital in 2024, measured in kilograms.

struction of infectious and chemical hazards, but it also carries a significant environmental footprint due to CO_2 emissions and the absence of material recovery or reuse [41].

Correct segregation of hazardous waste, particularly absorbent materials such as disposable absorbent pads, is crucial for safety, regulatory compliance, and cost efficiency. National guidelines emphasise the use of visual aids, staff training, and colour-coded containers to support correct disposal practices. As hazardous waste is significantly more expensive to process than general waste (approximately €0.79/kg vs. €0.177/kg), preventing unnecessary classification of materials as hazardous and reducing the use of these products is both a financial and environmental priority.

4.3 Use of disposable absorbent pads

Internal procurement data from 2024 indicate that Reinier de Graaf used more than 200,000 disposable absorbent pads across all departments. These products are supplied through Zorgservice XL, with TENA as the main provider. Three pad types are currently in use, differing in size and absorbency rating: TENA Bed Plus (60 × 40 cm), TENA Bed Normal (60 × 60 cm), and TENA Bed Normal (60 × 90 cm). Table 5 outlines their technical specifications, including Rothwell rating, unit weight, and unit cost. Table 6 presents the 2024 data on annual consumption, associated environmental impact, and costs, categorised by pad size.

To estimate the climate impact of disposable absorbent pads at RDGG, a reference value of 117 kg CO_2-eq per 1000 units was applied for the 60 × 60 cm pad type (Tena Bed Plus 60x60 cm), as reported in a recent Dutch life cycle analysis study on disposable absorbent pads [28]. Since impact data for the 40 × 60 cm and 60 × 90 cm formats were not available, a proportional scaling approach was applied based on pad surface area. The 40 × 60 cm pad (0.24 m^2) was estimated to have 0.67 times the impact of a 60 × 60 cm pad

(0.36 m^2), while the 60 × 90 cm pad (0.54 m^2) was estimated at 1.5 times the reference value.

The 149,040 units of 40 × 60 cm pads consumed in 2024 accounted for an estimated 11,625 kg CO_2-eq. The 28,480 units of 60 × 60 cm pads contributed 3,332 kg CO_2-eq, while the 22,575 units of 60 × 90 cm pads added 3,962 kg CO_2-eq. Together, these pad types resulted in a total estimated footprint of 18,919 kg CO_2-eq in 2024.

This estimate should be interpreted with caution, as it assumes that the environmental burden of each product scales linearly with surface area. In reality, differences in material composition (absorbent core thickness, superabsorbent polymer content) and product category ("Normal" vs. "Plus") may alter the impact per unit weight. Nevertheless, the calculation provides a conservative order-of-magnitude estimate that situates disposable absorbent pads as a non-negligible contributor to the hospital's total footprint.

Table 5: Specifications of disposable absorbent pads used at Reinier de Graaf hospital in 2024, including product codes, sizes, Rothwell ratings, unit weights, and unit costs.

Article code	**Product name**	**Size (cm)**	**Rothwell (ml)**	**Weight (g)**	**Cost (€)**
770132	TENA Bed Plus	60 × 40	700	32	0.11
770044	TENA Bed Normal	60 × 60	900	42	0.14
770046	TENA Bed Normal	60 × 90	1200	61	0.20

Table 6: Annual use, costs, and estimated environmental impact of disposable absorbent pads at Reinier de Graaf hospital in 2024, categorised by pad size. Calculations are based on internal procurement data.

Pad Size (cm)	**Units Used**	**Total Weight (kg)**	**CO_2-eq Emissions (kg)**	**Total Cost (€)**
40 × 60	149,040	4,769	11,625	16,394
60 × 60	28,480	1,196	3,332	3,987
60 × 90	22,575	1,377	3,962	4,515
Total	**200,095**	**7,342**	**18,919**	**24,896**

To narrow the scope of this research, an internal analysis of procurement records was conducted to identify departments with both high potential impact and practical feasibility for reducing disposable absorbent pad use. The aim was to select case studies that would allow an in-depth examination of what is needed and what is possible to achieve meaningful reductions.

The analysis identified Obstetrics & Maternity, Operating Room, Dialysis, and Endoscopy as the highest consumers (see Figure 18). Obstetrics & Maternity recorded the highest usage and demonstrated clear motivation to address the issue, with a medical specialist expressing concern over disposable volumes and interest in exploring alternatives. The Operating Room ranked second; two days of observation and discussions with a Green Team representative indicated that pad use was generally aligned with clinical necessity, although sustainability practices there were still in an early phase. Dialysis also ranked high but lacked an active Green Team or clear internal contacts, presenting barriers to initiating a project. In contrast, Endoscopy showed high consumption alongside an established Green Team and prior willingness to engage in sustainability initiatives.

Based on these findings, Obstetrics & Maternity Care and Endoscopy were selected as pilot departments for testing sustainable alternatives. Selection was based on four criteria: (1) high consumption volumes, (2) demonstrated motivation and willingness to participate,

(3) operational diversity, with Endoscopy representing a small, high-throughput outpatient unit without linen infrastructure and Obstetrics a large inpatient setting with reusable logistics already in place, and (4) potential for cross-departmental learning and scalability of successful interventions.

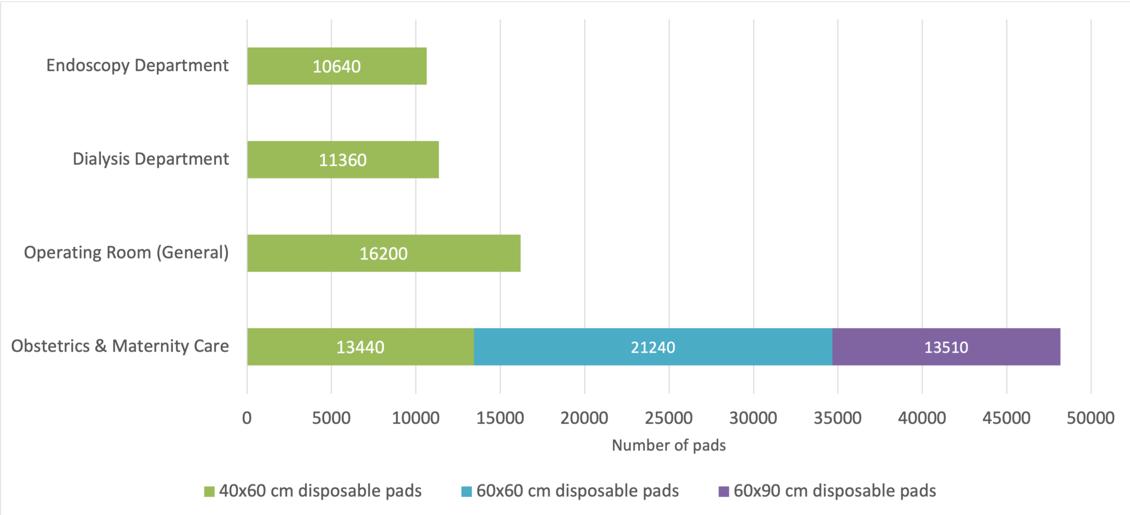


Figure 18: Total annual use of disposable absorbent pads by size (40 × 60 cm, 60 × 60 cm, 60 × 90 cm) in the four highest-using hospital departments in 2024.

Understanding how disposable absorbent pads are integrated into daily operations requires insight into the stakeholders who influence their procurement, use, and disposal. These stakeholders shape not only the current consumption patterns but also the opportunities and constraints for change. The next section presents a stakeholder analysis that identifies and maps these actors, their levels of interest, and their influence in relation to the transition toward more sustainable absorbent material use.

4.4 Stakeholder analysis

A stakeholder analysis was undertaken to identify, classify, and map all actors involved in the use, procurement, handling, and disposal of disposable absorbent pads. This type of analysis provides insight into the organisational context and supports the implementation of sustainability interventions in complex healthcare settings. Following the approach of Reed et al. (2009), stakeholders were systematically categorised according to their level of interest and power [42]. In this framework, *interest* refers to the extent to which stakeholders are affected by or concerned with the intervention, while *power* refers to their ability to shape, enable, or obstruct outcomes. The resulting classification provided the foundation for developing tailored engagement and communication strategies throughout the project.

Purchasing and logistics department

The Procurement and Logistics Department played a central role in the acquisition and internal handling of both disposable and reusable materials. This department provided data on purchasing volumes, unit costs, and monthly consumption per department. It also contributed to mapping current disposable and linen product journeys (see Figures A1 and A2 in the Appendix) and identifying potential integration points for reusable products.

In the power–interest grid, this department was classified as *high power, low interest*. Their high power stemmed from their authority to approve and procure materials, mean-

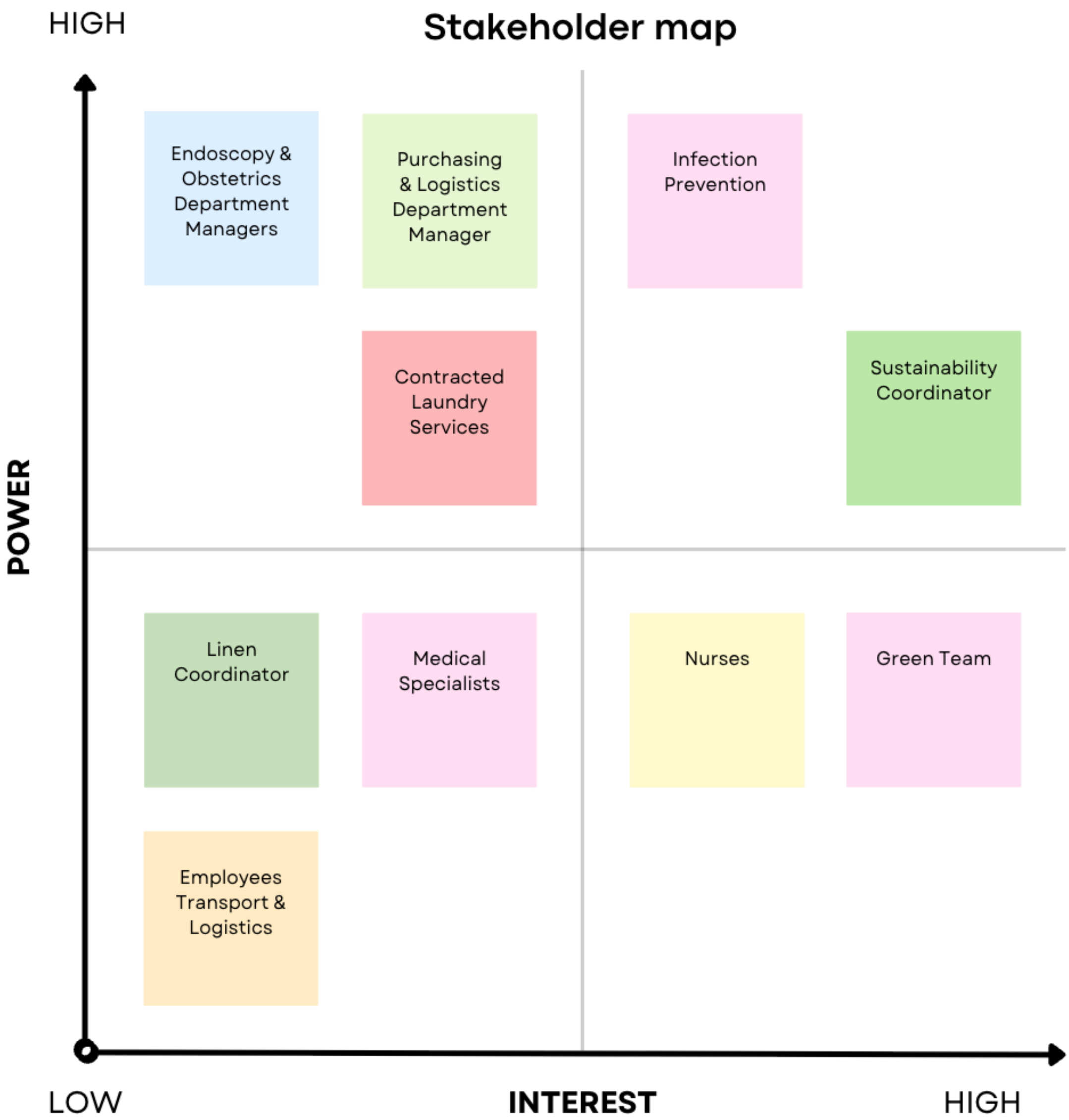


Figure 19: Stakeholder power–interest grid for the implementation of reusable absorbent materials at Reinier de Graaf hospital.

ing any product change had to receive their consent. Their low interest reflected their limited direct involvement in the clinical use or handling of absorbent pads, as well as in sustainability initiatives.

Linen coordinator

Reporting to the Procurement and Logistics Department Manager, the linen coordinator acted as the operational link between hospital departments and the external laundry provider. This role was consulted for contacts at the external laundry provider, advised on feasible reusable product options, and evaluated logistical constraints such as delivery, storage capacity, and collection procedures. The linen coordinator also contributed to mapping how linen products were handled within the hospital, from arrival to departure.

In the power–interest grid, this role was classified as *medium power, low interest*. The linen coordinator had medium power through their operational influence on integrating reusable products into existing linen flows, but limited direct involvement in the clinical use of absorbent pads or sustainability initiatives.

Infection Prevention

The Infection Prevention Department held a decisive role in approving any new material for clinical use. For potential reusable alternatives, their assessment was guided by national guidelines, particularly the WIP linen and bedding protocol [43], which remained in force until fully replaced by SRI standards [44]. Key requirements included microbiological quality control, light-coloured linen for contamination visibility, separation of clean and dirty storage, sealed transport of contaminated linen, daily removal of full laundry bags, and adherence to first-in–first-out storage principles.

In the power–interest grid, this department was classified as *high power, medium interest*. Their high power reflected their authority to approve or reject the introduction of any new material into clinical workflows. Their medium interest reflected their indirect involvement in daily pad use and handling, as their primary focus lay on ensuring regulatory compliance rather than operational management or sustainability initiatives.

Department managers

Department managers of specific hospital specialisms, such as Endoscopy or Obstetrics, were identified as *high power, low interest* stakeholders. Their high power derived from their authority to approve projects within their departments and to allocate resources or facilitate changes to workflows. However, their interest in the operational details of absorbent pad usage was relatively low, as their focus was primarily on managing overall departmental performance rather than small-scale sustainability initiatives.

For this project, department managers were approached for formal approval to conduct the case study in their departments and for strategic-level input. They were also consulted on the most effective ways to engage healthcare personnel within their teams to ensure cooperation and participation.

Sustainability coordinator

The hospital's sustainability coordinator, acting as the internal project supervisor, was classified as a *high interest, medium power* stakeholder. Their high interest reflected their direct involvement in promoting and advancing sustainability initiatives across the organisation, while their medium power stemmed from their ability to align departmental projects with the hospital's overarching sustainability strategy and to facilitate institutional support, rather than directly approving or rejecting operational changes.

In this project, the sustainability coordinator played a key role in facilitating connections to relevant contacts, ensuring that the intervention aligned with institutional sustainability objectives, and linking the case study to ongoing hospital-wide sustainability programmes. Regular update meetings were held to discuss project progress, address barriers, and ensure consistency with broader sustainability targets.

Contracted laundry services

Nedlin, the hospital's external laundry provider, was classified as a *medium power, low interest* stakeholder. Their medium power stemmed from their operational control over available reusable product options and reprocessing standards, while their low interest reflected their limited direct involvement in the hospital's daily workflows or sustainability projects beyond service provision.

This stakeholder was consulted to provide information on the sustainability of their operational practices and to offer insights into potential alternative products. Their facility has achieved a BREEAM Outstanding certification, reflecting the highest standards of environmental performance in industrial operations [44]. At present, they supply a washable and reusable absorbent pad, the full product specifications of which are presented in the appendix (see Figure A3).

Nurses

Nurses were classified as *high interest, medium power* stakeholders. Their high interest reflected their role as primary end-users of absorbent pads and the fact that any changes in product type or workflow would directly affect their daily practice. Their medium power stemmed from their influence on the practical adoption of new materials, although they did not hold formal authority to approve or reject such changes.

As the main operators in the use of absorbent pads, nurses were engaged through interviews to gather detailed insights into current usage patterns, workflow integration, and practical concerns regarding more sustainable alternatives. Their feedback was essential for ensuring that proposed interventions would be compatible with clinical routines and operational realities.

Green teams

Green Team members were classified as *high interest, medium power*. Their high interest reflected their informal role in promoting sustainability within their departments, often as nurses, medical specialists, or support staff who volunteered for the Green Team. Their official power was limited, as they did not have direct decision-making authority over product procurement or implementation, but they could play a crucial role in fostering engagement among other departmental staff.

In this project, Green Team members were contacted for information on departmental structures, other ongoing sustainability initiatives, and the general way of working within their departments. Engagement levels varied considerably: while some members were highly involved and proactive, others did not respond to contact attempts.

Medical specialists

Medical specialists were classified as *medium power, medium interest*. While they held significant authority within clinical decision-making, their direct involvement in the use or handling of disposable absorbent pads was minimal. In most cases, nurses were responsible for the preparation and clean-up in procedure rooms, meaning that implementation of reusable alternatives would have limited direct impact on the specialists' workflows. Their interest was therefore moderate, as the intervention aligned with broader sustainability goals but did not materially influence their daily practice.

Employees transport and logistics

Employees in the hospital's transport and logistics team were classified as *low power, low interest*. Their primary responsibility was the internal movement of materials between storage areas, departments, and disposal points. The introduction of new reusable materials required only minor adjustments to their workflow, primarily related to handling and routing. While operationally relevant, their involvement in decision-making was minimal, and their interest was limited, as the project did not significantly affect their core responsibilities.

They were consulted and observed for their handling of both disposable and linen products, in order to identify where and how these materials were transported, stored, and transferred within the hospital.

Stakeholder engagement strategy

The engagement strategy was directly informed by the positions of stakeholders within the power–interest grid. Stakeholders with high interest and moderate to high power, such as nurses and Green Team members, were prioritised for in-depth interviews to capture detailed operational insights and attitudes toward change. High-power stakeholders with lower day-to-day involvement, including the Infection Prevention department and the hospital's sustainability coordinator, were engaged through targeted meetings to ensure regulatory compliance and alignment with institutional sustainability objectives. Department managers, classified as high-power but lower-interest actors, were approached for formal approval and to provide strategic input relevant to their wards. The contracted laundry service and the linen coordinator, both holding high operational influence, were consulted to assess the technical and logistical feasibility of integrating reusable alternatives into existing linen flows. Peripheral but operationally relevant stakeholders, such as medical specialists and employees in transport and logistics, were kept informed to maintain awareness and facilitate any necessary adjustments in material handling processes. This targeted approach ensured that engagement efforts were proportionate to stakeholders' capacity to influence outcomes and their vested interest in the intervention.

The roles, interests, and influence of stakeholders were closely linked to the organisational and procedural realities of the departments in which these materials were used. To understand the practical context for both current and future practices, the next section describes the structure and workflows of the pilot departments, highlighting factors that directly affected pad usage and the feasibility of introducing reusable alternatives.

4.5 Departments structure and workflow

To assess the feasibility of introducing reusable alternatives and/or to reduce the use of disposable absorbent pads, it was essential to understand the clinical workflows and logistical infrastructure of the selected pilot departments. The organisational structure, type of care provided, and existing practices related to hygiene and material handling vary significantly between departments and directly influence the potential for successful implementation. The following subsections describe the structural and operational characteristics of the Obstetrics and Endoscopy departments at RDGG, providing the contextual basis for the case study design and tailored intervention strategies.

4.5.1 Obstetrics department

The Obstetrics Department at RDGG consists of a combined maternity and delivery ward, providing continuous care from patient admission through childbirth and postpartum recovery. The unit includes twelve delivery rooms, six obstetric rooms, fourteen maternity rooms, two isolation rooms, one four-bed day-care room where pregnant patients are seen for initial assessments and two induction rooms. A central nursing station coordinates activities across these areas. It operates 24/7 and is staffed by a multidisciplinary team of obstetricians, midwives, nurses, and support personnel. Obstetrics and maternity care share the same pool of healthcare staff, who are assigned across wards as needed to balance patient care demands. Although individual staff members may have a preference for one area, they can be deployed interchangeably.

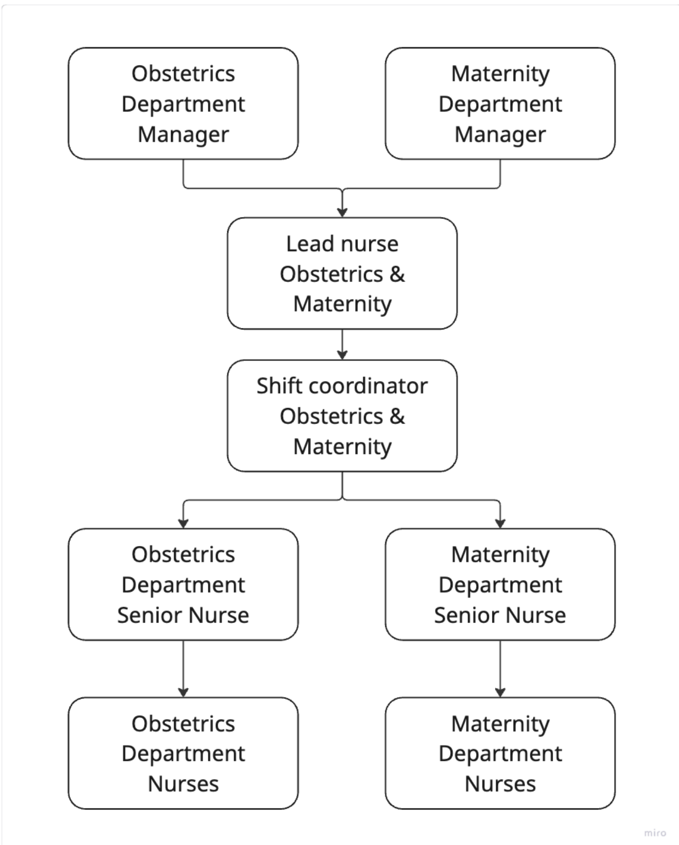


Figure 20: Organisational structure of daily nursing roles in the Obstetrics and Maternity departments at Reinier de Graaf Hospital.

Daily nursing operations follow a structured hierarchy, as shown in Figure 20. Each shift, a designated shift-responsible staff member monitors procedure schedules, patient flow, and available resources, acting as the main contact point for both clinical and support staff. The department operates in three shifts (morning, evening, and night), with structured handovers to ensure continuity of care and exchange of patient information. These moments also provide opportunities to share project updates and reinforce correct use of new materials. In addition, lead nurses play a coordinating role, receiving dedicated “regie-days” several times per month to focus on department-wide improvement projects. They are instrumental in identifying bottlenecks, supporting implementation activities, and acting as a bridge between project teams and day-to-day clinical operations.

Disposable absorbent pads are routinely placed under patients during delivery to collect amniotic fluid, blood, and other bodily fluids. They are also used to protect surfaces during obstetric procedures, postpartum wound care, personal hygiene, and bed changes. Depending on labour duration, volume of fluid loss, and type of procedures performed, multiple pads may be used per patient. Hygiene protocols require frequent replacement between patients to maintain a clean environment and reduce infection risk, even when soiling is minimal. Pads are also used for non-essential purposes, such as protecting medical equipment surfaces, lining trolleys, or pre-emptively covering areas, which can lead to avoidable consumption [6][45].

The department already operates a well-structured linen flow for reusable textiles such as bed sheets, hospital clothing, and towels, which are collected, laundered, and redistributed via the contracted laundry provider. This existing infrastructure provides a strong logistical foundation for introducing reusable alternatives with minimal additional complexity.

4.5.2 Endoscopy department

The Endoscopy Department is a specialised outpatient unit that performs both diagnostic and therapeutic procedures, primarily targeting the gastrointestinal tract and, to a lesser extent, the respiratory system. The range of interventions includes gastroscopies, colonoscopies (including national screening colonoscopies), enteroscopies, and endoscopic ultrasound. The unit operates during weekday daytime hours and handles a high throughput of patients, often scheduled back-to-back. Of the 20 employees, approximately 14 are on duty daily, including medical specialists, endoscopy nurses and support staff.

The department contains four procedure rooms, each staffed by one medical specialist and two nurses. Department-wide roles include one quality advisor, four planners and a shift coordinator. The shift coordinator role is rotated daily among six qualified nurses and monitors procedure schedules, patient flow and available resources, acting as the main contact point for both clinical and support staff. This role is essential for resolving workflow disruptions and ensuring adherence to procedural schedules.

Given the invasive nature of the procedures and the risk of exposure to bodily fluids, absorbent disposable pads are used extensively. Pads are placed under patients during preparation and examination, and replaced after each procedure and/or patient to maintain hygiene and reduce cross-contamination risk. The rapid turnover between cases drives high disposable absorbent pad consumption. Unlike Obstetrics, the Endoscopy Department does not have a linen infrastructure. Patients are admitted through the Day Care Department and return there after their procedure, which means that beds, linens, and related laundering flows are not part of the unit’s operations. Consequently, all contaminated materials, including absorbent pads, are classified as medical waste and sent for incineration. The absence of a reusable linen stream implies that the introduction of sustainable alternatives would require entirely new logistical arrangements for collection, storage, and laundering.

5 Interviews

In the transition toward more sustainable healthcare practices, reducing the use of disposable absorbent pads or implementing more sustainable alternatives represents a tangible opportunity for both environmental and economic improvement. Nurses, as the primary users of these pads in clinical settings such as Endoscopy and Obstetrics, occupy a central role in determining the feasibility of such changes. Because they are responsible for the placement, replacement, and disposal of pads on a daily basis, any modification to current practices directly affects their workflows, routines, and perceptions of patient hygiene.

To capture these perspectives, qualitative interviews were conducted with stakeholders identified in the stakeholder analysis as key actors in the reduction of disposable absorbent pad use and/or the adoption of reusable alternatives, with a particular focus on nurses and members of the Green Team. The discussions explored current usage patterns, opportunities for reduction or replacement, and the practical requirements for introducing new materials. They also examined perceived barriers, facilitators, and attitudes toward both disposable and reusable options.

The results presented in this chapter highlight the practical, behavioural, and systemic factors that shape the feasibility of reducing disposable absorbent pad use and/or implementing sustainable alternatives in the hospital setting.

5.1 Methods

5.1.1 Human research ethics committee

This research was conducted in accordance with the ethical standards for human research set by TU Delft's Human Research Ethics Committee (HREC) [46]. A signed HREC checklist was approved by the responsible researcher and submitted to the committee prior to data collection. Informed consent was obtained from all participants using a structured consent procedure, which included a detailed information sheet outlining the study purpose, participation conditions, data usage, and withdrawal rights.

Participants were informed that their involvement was entirely voluntary and that they could withdraw at any time without providing a reason. All interviews were recorded only with explicit consent, and recordings were deleted after transcription. Transcripts were anonymised, with names and personally identifiable information removed. Consent forms were stored securely and were destroyed after the project concluded. The study was carried out in collaboration with RDGG, and all data remained within the hospital's secured internal environment.

5.1.2 Data collection

This study employed a qualitative descriptive (QD) design to examine current practices and attitudes related to the use of disposable absorbent pads in the Endoscopy and Obstetrics departments. QD is particularly suited for research that seeks to capture realistic, first-hand experiences and perspectives of individuals [47], presenting them in a structured and accessible manner without relying on excessive theorisation [48]. This approach provides first-hand insights from healthcare professionals [49], enabling an in-depth understanding of the practical barriers and opportunities that healthcare professionals encounter when transitioning toward more sustainable practices, thereby supporting the design of feasible implementation strategies.

Sixteen semi-structured interviews were conducted in person at RDGG in March 2025. Participants included clinical and support staff from the endoscopy and obstetrics departments (see Table 7). Participants were selected based on their availability and their active roles in the workflow of disposable absorbent pad usage. Interviews were audio-recorded using Fireflies.AI, with informed consent. Each interview lasted approximately 30 minutes.

Table 7: Overview of departments represented in the semi-structured interviews (n = 16).

Department	**Number of Participants**
Endoscopy	6
Obstetrics	4
Maternity Care	3
Operating Room (OR)	1
Outpatient Treatment	1
Outpatient Operating Room	1
Total	**16**

Prior to the interviews, a set of open-ended guiding questions was prepared to ensure consistency across participants while allowing flexibility to pursue emerging themes (see Appendix Figure A4). The interviews followed a semi-structured format, a widely applied approach in qualitative research that balances structure with adaptability [50]. In contrast to structured interviews that rely on predetermined, closed-ended questions, semi-structured interviews promote open-ended dialogue and enable the interviewer to probe deeper into issues raised by participants. This approach harnesses the knowledge-producing potential of dialogue [51], while providing sufficient structure to ensure alignment with the study objectives. Within this format, participants acted not only as respondents but as active contributors, shaping both the depth and direction of the conversation.

The primary objectives of the interviews were to:

1. Document current usage practices and motivations behind the use of disposable absorbent pads
2. Explore perceived opportunities for reduction, reuse, or implementation of alternative materials
3. Identify logistical, behavioural, and organisational requirements for implementing change

5.1.3 Data analysis

Audio recordings were transcribed using Fireflies.AI and subsequently reviewed alongside the recordings by the researcher to correct any transcription errors and ensure alignment with participants' actual responses. The data were analysed using thematic analysis as described by Braun and Clarke (2006), which allows for the identification of recurrent patterns ('themes') across qualitative datasets [52]. This method was chosen for its flexibility and suitability for applied research contexts, particularly when the aim is to derive both descriptive and explanatory insights.

The coding process followed an iterative structure. Initial codes were developed deductively, informed by the primary research objectives of the interviews. At the same time, the analysis remained open to inductively emerging themes that arose directly from the interview data [53]. This dual approach helped ensure that the findings were both practically grounded and conceptually informed.

Coded segments were then grouped into overarching themes based on internal coherence and relevance to the research questions. Atlas.ti software was used to support coding, comparison, and refinement. Throughout the process, the central research objective of understanding barriers and opportunities for the reduction of disposable absorbent pad use and/or the implementation of more sustainable alternatives remained the guiding framework for the analysis [53].

5.2 Results

5.2.1 Obstetrics department

Current usage practices

In the obstetrics department, disposable absorbent pads are used extensively to protect against fluid loss during delivery and postpartum care. Their primary application is under patients during childbirth, but they are also used on shower chairs, under intravenous lines, for newborn care, and to monitor postpartum blood loss. Usage frequency varies considerably, from a few pads in uncomplicated cases to more than ten in situations involving heavy bleeding, prolonged labour, or significant amniotic fluid leakage. In some cases, larger pads are placed beneath smaller ones to prevent seepage onto the underlying mattress or bed. Pad sizes range from 60×40 cm on the maternity ward to 60×60 cm and 90×60 cm on the delivery ward, with larger pads preferred in cases such as caesarean section aftercare or heavier postpartum bleeding.

> "On the delivery bed, there is always a pad, because when the membranes are ruptured, amniotic fluid keeps leaking. On the maternity ward, there is almost always a pad in the bed, because postpartum women experience blood loss."

> "During a delivery... I could easily reach ten in that case."

> "If there is significant bleeding after birth, we sometimes remove the pad quickly, weigh it to monitor blood loss, and then place a clean one underneath."

Pads are also placed on shower chairs for hygiene purposes and on birthing balls to protect against leakage from ruptured membranes. Staff sometimes use pads for warmth and insulation for newborns.

> "We always place an absorbent pad on the shower chair... And on the maternity ward, I sometimes use them for babies if they are cold."

The decision to replace a pad is often hygiene-driven. During labour, pads may be replaced because they have absorbed large volumes of fluid, but in other cases they are changed simply because they are visually soiled, rather than having reached their full absorbent capacity. Pad replacement can also be patient-driven, as patients in this department are typically healthy, alert, and vocal about their comfort needs. When familiar with the ward layout, some patients replace pads themselves.

> "Sometimes they are saturated, then you have to change them. But often, when they look dirty after a vaginal check or catheterisation, we replace them as well."

Disposal practices differ according to contamination: pads contaminated with bodily fluids are discarded as hazardous waste, whereas clean but used pads may be placed in non-hazardous waste.

> "If it [the disposable absorbent pad] is drip-free, then it can just go with the regular waste."

Practices also vary between staff, with differences in pad size selection and replacement routines.

> "Not everyone pays attention to which size pad they grab. Some just take whatever is in the drawer."

Reduction opportunities and alternatives

Staff identified several contexts where pads could be omitted without compromising care. Examples include using a bedsheet on a skippy ball or towel on a shower chair. Staff also noted that, for some tasks, a simple gauze could replace a pad, such as during intravenous line insertion, where the pad mainly serves to catch small amounts of fluids.

> "If I am placing an IV, I just put a gauze underneath rather than a pad."

Some staff questioned the need for the largest pads (90×60 cm) and/or the smallest pads (40×60 cm), suggesting a possible department-wide shift to only using 60×60 cm pads. Others, however, expressed a preference for the smallest pads, indicating that opinions on optimal pad size vary within the department.

> "Those small white pads [40x60 cm], we'd rather be rid of them."

Several alternative warming solutions for newborn care are already in place, such as heated mattresses and molton or hydrophilic warm blankets from the warming cabinet. These make the use of a pad for insulation unnecessary in most cases. In some cases, staff combine a disposable pad with a towel for added comfort, as towels are perceived as more comfortable against the skin and less prone to trapping heat.

Requirements for adoption

When shown the reusable, washable absorbent pad, staff reactions varied. Some respondents could easily imagine the pad working well in the maternity ward, but were more hesitant about its suitability in the delivery room, where high fluid volumes and frequent pad changes are common. In the pushing phase of child-birth alone, six to seven pads may be required, even without excessive blood loss, and postpartum care can involve an additional eight pads. Concerns were raised that reusable pads might require even more frequent replacement if they feel damp to the touch, as patients are unwilling to remain in a wet bed. Disposable pads were described as feeling dry once fluids are absorbed, similar to a diaper.

> "I can imagine this working well on the maternity ward, but in delivery... I don't think so. We'd have to change it too often."

Size was another point of discussion. The 90×90 cm reusable sample was generally seen as too large for practical use. Most staff preferred the 60×60 cm or 60×90 cm format, with the latter often used underneath smaller pads as a backup layer. Some staff indicated that the 60x60 cm pads are often positioned diagonally, as this orientation provides extended coverage in the direction where protection is most needed.

> "Ninety-by-ninety is too big. We mostly use 60×60 or 60×90."

Operational factors were also important for adoption. Staff wanted assurance that pads would be reliably laundered and returned in a clean state, even when heavily soiled. Ease of use was considered essential: pads should be easy to grab, position, and replace without adding extra workload. Durability, absorption capacity, and turnaround time from laundry to reuse were seen as critical points to evaluate.

> "It just has to be easy to use. If it's easy to grab and put down, it will work here."

Behavioural and organisational aspects were also discussed. Many agreed that successful adoption would require awareness-raising, consistent communication, and reinforcement through departmental routines. Examples included posters, quizzes, thematic weeks, and repeated messaging at shift handovers. Several emphasised the need to "start small" and monitor results before scaling up. Some preferred piloting the product in specific scenarios (for example, a certain number of deliveries per day), rather than restricting it to one room, as room occupancy is unpredictable. Barriers to change included the large team size, varied individual preferences, and resistance to altering long-standing practices. Nonetheless, interviewees indicated that if the product met functional needs without adding complexity, adoption could be feasible. Cost was seen as less relevant from a frontline perspective, as purchasing decisions are made elsewhere.

> "The key is making it simple and reinforcing it. Repetition is powerful in a big team."

5.2.2 Endoscopy department

Current usage practices

Disposable absorbent pads are widely used across almost all endoscopic procedures, including gastroscopies, colonoscopies (including national screening colonoscopies), enteroscopies, and endoscopic ultrasound. Their primary purpose is to protect surfaces and manage fluid leakage. Common placements include under the head during gastroscopies, under the buttocks during colonoscopies, over pillows or patient shoulders to protect clothing. Pads are also used on carts and on the floor to absorb spills from patients or equipment.

> "We use them for almost everything. If something might leak, there's a pad under it."

Usage frequency is high. Most patients receive one pad per procedure, but additional pads are used if the initial one becomes wet or soiled, or in cases with heavy leakage. In colonoscopies, for example, patients may require a second pad in the recovery area. In some cases, pads are also used for general protection where the risk of spillage is low, reflecting a habitual pattern of use. Post-procedure handling varies. Some staff replace pads immediately, while others leave a patient on a lightly soiled pad if the moisture level is minimal. Most used pads are discarded in non-hazardous waste.

> "Usually one per patient, yes. Two or three times a day we need multiple pads."

Reduction opportunities and alternatives

Opportunities for reducing pad use within endoscopy are limited, as typically only one pad is used per procedure. However, there is potential to replace disposables with more sustainable alternatives in certain contexts. Towels were frequently mentioned as a viable option for procedures with minimal fluid loss, particularly gastroscopies. Staff noted that some other hospitals already use towels instead of disposable pads for endoscopic procedures.

> "A towel is absorbent too, I think it would work fine for a gastroscopy."

Opinions varied regarding the necessity of pads in all cases. For high-fluid procedures such as colonoscopies or cases involving older or less continent patients, staff considered disposable pads essential. In rare cases with very minimal leakage, no absorbent material was deemed necessary. Some participants suggested that small hand towels or washcloths could be sufficient for specific tasks, or that a combination of disposable and linen materials might be a workable alternative.

Pads are also frequently used outside direct patient care, for example to clean spills on the floor or to protect equipment. Staff indicated that a readily available stack of towels could replace disposables for these purposes, as their use is often driven by convenience and immediate availability. Practical barriers included the absence of a linen supply system in the department and limited storage space.

> "If you had a big stack of towels and a good laundry bin, you could mop up the floor with those instead of a pad."

Requirements for adoption

From a product perspective, participants emphasised that any alternative must match the absorbency, strength, and usability of the current disposable pads, while also providing adequate comfort for the patient. Size was generally considered less important, as long as the product prevented moisture from spreading to the patient's clothing or bedding. However, larger pads were seen as potentially increasing the area of dampness if not fully absorbent. Strength was also highlighted, with concerns that weak materials might tear during use or require multiple items to achieve the same effect as a single disposable pad.

> "As long as it absorbs moisture. That's the most important thing."
> "It needs to be workable for us, but also comfortable for the patient."

From a logistical standpoint, availability of alternatives in the procedure or delivery rooms was considered crucial for uptake. Without ready access to the product, staff anticipated that disposables would continue to be used by default. Supporting infrastructure, such as laundry bins and sufficient storage space for clean linen, would be necessary to integrate reusables into routine workflows.

> "But we don't have those [towels] available in the room."
> "The next step would be laundry bins in the room, and space to store them."

Adoption was also seen as dependent on cultural and behavioural change. Many participants noted that healthcare staff are accustomed to disposable products, particularly for infection prevention reasons, and may initially resist reusables. Clear communication of the environmental rationale, supported by data on waste reduction and potential recyclability, was viewed as essential to generate engagement. Involving staff early in the decision-making process and ensuring that key decision-makers are supportive were also identified as critical factors.

> "We are so used to everything being disposable in healthcare because of infection prevention, changing that will take time and explanation."
> "If you tell people the reason for change and for example, that it reduces CO_2 emissions and waste, I think they are more likely to get on board."

Ultimately, alternatives must balance practicality, hygiene, patient comfort, and sustainability, while being integrated into existing workflows in a way that minimises disruption.

Table 8: Thematic coding framework for interviews in Obstetrics and Endoscopy: current handling, sustainable practices, and pathways to change.

Theme group	Sub-category	Examples from interviews
Current handling of absorbent pads	Where are pads currently used?	*Obstetrics:* delivery bed, child-birth, maternity ward, shower chair, birthing balls, inserting IV. *Endoscopy:* under patient during procedures, spills, protection of equipment.
	How are pads currently used?	Size and replacement routines vary across staff, multiple pads in high-fluid cases.
	Why are pads currently used?	Protect surfaces, contain fluids, hygiene perception, routine behaviours.
Possible sustainable practices	Types of practices	Towels for low-fluid procedures, reusable pads for high-fluid procedures, omit pad for minor tasks like inserting an IV, and apply smaller pad sizes where feasible.
	Where can practices be implemented?	*Obstetrics:* maternity ward, selected deliveries. *Endoscopy:* gastroscopy, recovery room, spills management.
How to achieve change	Barriers to change	Limited linen logistics and storage, routine behaviours, infection prevention norms, damp feel of reusables, lack of leadership/time.
	Facilitators of change	Clear rationale (waste and CO_2), visible access to reusables (nudging), reliable laundry turnaround, leadership and repetition at shift changes.

5.3 Conclusion

The interviews revealed frequent and often unconscious use of disposable absorbent pads in both Endoscopy and Obstetrics, driven more by routine, availability, and perceived hygiene than strict necessity. Pads were seen as indispensable in high-fluid situations, but several opportunities for reduction and substitution emerged. In Obstetrics, staff suggested omitting pads for low-fluid tasks, using towels or linen for surface protection, and exploring washable pads for high-fluid scenarios. In Endoscopy, use per patient was already low, yet substitution with reusable towels appeared feasible for selected low-fluid procedures and non-clinical spill management.

Implementation of alternatives would require ease of use, seamless integration into workflows, infection prevention compliance, and reliable storage, laundering, and restocking systems. Cultural and behavioural barriers, including resistance to change and ingrained preferences for disposables, would need to be addressed through clear communication, evidence of environmental benefits, and early staff engagement.

These insights shaped the pilot study: washable pads in Obstetrics, integrated into existing linen flows, and towels in Endoscopy, requiring a new laundry workflow. The pilots assessed technical performance, user acceptance, and logistical feasibility under real-world conditions.

6 Pilot study

To assess the feasibility of introducing reusable absorbent materials into clinical workflows, a pilot study was conducted in the Obstetrics and Endoscopy departments at RDGG. The aim was to evaluate practical use, staff acceptance, and logistical implications of replacing disposable absorbent pads with reusable alternatives in real-world conditions. Staff were informed through departmental presentations and informational materials. Feedback was collected via forms, informal conversations, and on-site engagement throughout the pilot. Observations, usage data, and reported experiences were used to identify department-specific enablers and barriers for long-term implementation.

This chapter begins with the methods used in the pilot study, including departmental set-ups, the evaluation survey, data analysis procedures, and validation through member checking. This is followed by the results, with separate subsections for the Obstetrics and Endoscopy departments, and an overall comparison of findings. The chapter concludes with a summary of key outcomes and implications of the pilot for future implementation.

6.1 Methods

6.1.1 Pilot study design

Obstetrics department

The pilot study design for the Obstetrics department was based on interview results. The most feasible option was to test washable absorbent pads that were already available through the hospital's external laundry provider. In consultation with the departmental manager and a lead nurse from the Obstetrics Green Team, the details of the pilot were determined. A workflow analysis was performed to identify required changes and the stakeholders to be informed. A visualisation of the product flow of absorbent pads within the Obstetrics department is provided in the Appendix (see Figure A5).

Disposable workflow

The Obstetrics department has twelve delivery rooms where disposable absorbent pads are standard practice. Pads are stored in cabinets in the sterile supply room and in baskets placed in drawers near the bed for quick access, containing all items required for labour and obstetric care. Refilling of the sterile supply room is handled by logistics staff, while departmental assistants restock baskets and drawers. Clean bedding is prepared by the clean-up crew. After use, disposable pads are discarded in either general waste bags (non-hazardous waste) or SZA containers (hazardous waste), which are emptied by logistics staff according to a daily schedule.

Disposable products in the sterile supply room are managed through a scan card system. Each product has a card placed in its cabinet compartment. When one of the two compartments for a product is empty, the card is placed on its side. This signals logistics staff to scan the card, automatically generating an purchase order. Disposable absorbent pads are ordered only on demand, so the reduced use during the pilot did not require changes to the ordering process.

Linen workflow

The external laundry provider confirmed that the washable pads could be delivered together with the department's regular daily linen supply. Linen arrives on carts and is refilled in the linen supply room; items needed in delivery rooms are stored in drawers close to the bed. Used linen is placed in linen bags located next to the waste bins. Once full, these bags are transferred to a larger cart and collected daily by logistics staff. The washable pads were incorporated into this existing linen outflow without requiring additional handling steps.

Linen replenishment follows a set daily norm for each product in each department. During their rounds, logistics personnel count the remaining stock of each linen item and enter this into the ordering system. The difference between the counted amount and the daily norm is ordered from the laundry service and delivered the next day. For the pilot, a new daily norm was created for the washable absorbent pad in consultation with the linen coordinator and the lead nurse. Logistics personnel were informed about the new product and instructed to include it in their daily counts and ordering process.

Communication and coordination

The pilot was implemented during a six week period in two delivery rooms, where all disposable absorbent pads were removed and replaced with washable, reusable pads. Clear communication materials and presentations were shared with all relevant staff members, including information on the rationale, handling procedures, and hygiene protocols. Coordination was required with the linen coordinator, laundry services, logistics staff, departmental assistants, and the entire clinical team (nurses, midwives, and medical specialists) to ensure everyone was informed about the changes and the designated pilot rooms. Forms for quick and minor feedback were placed in common areas to enable rapid resolution of issues during the pilot. The researcher maintained a regular presence in the department to monitor usage, respond to questions, and collect informal feedback.

Cost analysis

To compare the economic impact of disposable and reusable absorbent pads in the Obstetrics department, a cost analysis was performed. The analysis was based on cost per kilogram of material as well as cost per use (see Table 9). The following assumptions were applied:

- The most frequently used disposable pad in Obstetrics is the 60×60 cm format, weighing 42 g per piece. The purchase price is €0.14 per pad.
- Waste disposal costs were included in the calculation. It was assumed that 50% of used absorbent pads are disposed of as hazardous hospital waste (SZA) at €0.79/kg, and 50% as regular waste at €0.177/kg.
- The reusable absorbent pad has a weight of 525 g and costs €0.893 per use, including rental, washing, and transport. No disposal costs were added, since the pad is used multiple times.

Table 9: Cost comparison between disposable and reusable absorbent pads in Obstetrics.

Category	**Disposable pad (60×60 cm)**	**Reusable pad**
Weight per pad	42 g (0.042 kg)	525 g (0.525 kg)
Purchase / rental cost	€0.14 per pad	€0.893 per use
Waste cost	€0.02 per pad (0.042 kg × €0.4835/kg)	Not applicable
Total cost per use	**€0.16 per pad**	**€0.893 per use**
Cost per kg (including purchase and waste)	€3.81/kg	€1.70/kg

The results show that disposables are considerably cheaper on a per-unit basis (€0.16 vs. €0.893), which is the most relevant perspective for day-to-day departmental costs. However, when costs are normalized to weight, reusable pads are financially more efficient (€1.70/kg vs. €3.81/kg). This difference highlights the trade-off between the higher per-use costs of reusables and the lower waste burden they generate.

Endoscopy department

The pilot study design for the Endoscopy department was based on interview results, which indicated that introducing towels would be a practical first step towards more sustainable practices. Approval for the pilot was obtained from the departmental manager, and a lead nurse from the Green Team was consulted for further planning. A workflow analysis was conducted to identify necessary changes and the stakeholders who needed to be informed.

Disposable workflow

Disposable absorbent pads are supplied to the sterile supply room by logistics staff. Nurses in the Endoscopy department restock the cabinets within the procedure rooms as needed. After use, pads are disposed of in either hazardous or non-hazardous waste, depending on the procedure and contamination level. Ordering of disposable absorbent pads follows the same scan card process as in other departments, and no changes to this process were required during the pilot.

Linen workflow

The Endoscopy department had no existing linen workflow prior to the pilot, so arrangements were made to enable towel use. A designated storage space for towels was created in the cabinets within the procedure rooms, and linen bags were added to each room for collecting used towels. A cart for full linen bags was already present in the department, and logistics staff were reminded to collect these according to the daily schedule.

The Endoscopy department did not have a linen supply room, and establishing one was not feasible in the short term. Moreover, infection prevention staff advised against storing linen in the sterile supply room due to hygiene protocols. Consequently, a temporary arrangement was adopted whereby the daily towel norm in the linen supply room of the adjacent department was doubled. This enabled Endoscopy staff to collect towels there and restock procedure room cabinets as needed.

Communication and coordination

The pilot was implemented during a six week period for three specific procedures identified as suitable for towel use in place of disposable absorbent pads: gastroscopy, endo-echography, and ERCP. Disposable absorbent pads remained available in the department for other procedures where they were still required. Towels were made available in all procedure rooms for the designated pilot procedures. Dedicated bins for used towels were installed, and coordination with transport and laundry services was established to ensure timely collection and cleaning.

Staff were informed about the pilot through departmental presentations, which included the rationale, handling procedures and hygiene requirements (see Appendix Figure A6 for example slides). Coordination was required with the departmental manager, Green Team lead nurse, infection prevention, logistics staff, laundry services, and the clinical team to ensure all stakeholders were aware of the changes. Feedback forms were placed in the staff break room and procedure rooms to allow staff to report issues or suggestions quickly. The researcher maintained a visible presence in the department throughout the pilot to answer questions, resolve problems, and make adjustments as needed.

Cost analysis

A cost analysis was performed for the Endoscopy department, comparing disposable absorbent pads and reusable towels. The following assumptions were applied:

- Endoscopy primarily uses 40×60 cm disposable pads, with a purchase price of €0.11 per pad and a weight of 32 g (0.032 kg).
- All disposable pads used in Endoscopy are assumed to be disposed of as regular waste, at €0.177/kg.
- The reusable towel has an average weight of 218 g (0.218 kg) and a cost of €0.178 per use, including rental, washing, and transport. No disposal costs were added, since the pad is used multiple times.

The calculations were again performed both per kilogram and per individual use.

Table 10: Cost comparison between disposable absorbent pads and reusable towels in Endoscopy.

Category	**Disposable pad (40×60 cm)**	**Reusable towel**
Weight per item	32 g (0.032 kg)	218 g (0.218 kg)
Purchase / rental cost	€0.11 per pad	€0.178 per use
Waste cost	€0.006 per pad (0.032 kg × €0.177/kg)	Not applicable
Total cost per use	**€0.116 per pad**	**€0.178 per use**
Cost per kg (including purchase and waste)	€3.62/kg	€0.82/kg

This analysis shows that disposables are cheaper on a per-unit basis (€0.116 vs. €0.178). However, when normalized to weight, reusable towels are substantially more cost-efficient (€0.82/kg vs. €3.63/kg). As in the Obstetrics department, this highlights the trade-off between higher per-use costs of reusable products and the lower waste burden they create.

6.1.2 Data collection

To evaluate the use, acceptance, and practical feasibility of reusable absorbent materials, two structured online questionnaires were developed and distributed among healthcare staff on the Obstetrics and Endoscopy departments. The purpose of the surveys was to collect both quantitative and qualitative insights after pilot implementation of the reusable alternatives.

Each survey was tailored to the context of the respective department but followed a similar structure and logic. The questionnaires were developed in Dutch and consisted of a combination of multiple-choice, Likert-scale, and open-ended questions. Participants were only eligible to complete the survey if they had experience with both the conventional disposable absorbent pads and the newly introduced reusable alternatives.

The surveys addressed several key topics, including demographic characteristics such as professional role and years of experience, as well as specific clinical use cases and frequency of use. Participants were asked about their motivations for replacing a product during use and their perceptions of differences in absorbency, weight, usability, hygiene, and logistics. In addition, the surveys explored observed or self-reported changes in routines or behaviour resulting from the introduction of reusable materials, and invited respondents to share suggestions for improvement alongside any general remarks or concerns.

All responses were collected anonymously and voluntarily via a digital platform that was licensed through the hospital (Exploratio). Responses were reviewed and interpreted descriptively, focusing on recurring patterns, dominant concerns, and suggestions for improvement.

6.1.3 Data analysis

Evaluation questionnaire

Descriptive and comparative analyses were performed to evaluate the results of the pilot questionnaires. Nominal categorical variables, such as yes/no responses to use indications and practical experiences, were presented as frequencies and percentages visualized using stacked bar charts. Ordinal data obtained via Likert-scale questions were depicted in percentages and supported by visual figures to provide insight into general tendencies and satisfaction levels. Additionally, numeric responses were summarized using the mean, standard deviation (SD), and range.

To enhance the validity of the analysis, key findings from the questionnaire were discussed with a lead nurse involved in the pilot, who also served as a member of the departmental Green Team. This member-checking step helped to verify that no major themes were overlooked or exaggerated and that the interpretations aligned with actual clinical experiences.

Usage analysis of absorbent materials

Obstetrics

To assess the impact of the pilot intervention on disposable absorbent pad consumption, monthly usage data for the Obstetrics department were retrieved from the hospital's procurement and supply records. These records specified the total number of disposable absorbent pads supplied and used per month, as well as the number of admitted patients during the same period. For each month, the mean number of pads used per patient was calculated by dividing the total number of pads by the total number of patients. This correction allowed for direct comparison across months with different patient volumes, thereby isolating the effect of the intervention from natural fluctuations in admissions. Data on the use of reusable absorbent pads were collected separately through internal records maintained by the linen coordinator.

Endoscopy

For the Endoscopy department, disposable absorbent pad use was analysed in relation to the total number of procedures performed. In addition, towel consumption was compared using supply records from the adjacent day-care unit, contrasting three time periods: before the pilot, during the pilot, and after the pilot. This enabled evaluation of changes in towel use patterns attributable to the intervention.

6.2 Results

6.2.1 Obstetrics department

A total of 29 staff members from the Obstetrics and Maternity departments completed the questionnaire. All respondents were female, with a mean age of 40.5 years (SD = 13.0) and an average of 15.3 years of work experience (SD = 12.0). Most participants were obstetrics nurses (86%) and all had prior experience working with both disposable and reusable absorbent pads (see Appendix Tables A2 and A3).

Reported use of disposable absorbent pads

Disposable absorbent pads were reported to be most frequently used to absorb moisture, blood, and/or feces (100%). They were also commonly placed under patients sitting on a birthing ball (66%) or on a shower chair (62%). Other reported uses included absorbing leakage during catheter or IV placement (59%) and wrapping a neonate (55%). Only 10% of respondents reported using the pads to clean the floor (see Appendix Figure A7).

The main reasons for replacing disposable pads were that they appeared unhygienic according to the respondent (62%), were torn (59%), or looked unhygienic according to the patient (48%). Less common reasons included the pad falling on the floor (34%) or the patient lying on it for a long time (31%) (see Appendix Figure A8).

Reported use of reusable absorbent pads

Reusable pads were reported to be most frequently used to absorb moisture, blood, and/or feces (100%). Other reported uses were infrequent, including placing under a patient on a birthing ball (28%), absorbing leakage during catheter or IV placement (17%), and placing under a patient on a shower chair (3%). No respondents indicated use of reusable pads for wrapping a neonate or cleaning the floor (see Appendix Figure A9).

The most frequently reported reason for replacing the reusable absorbent pad was that it had become too wet, as indicated by the respondent (90%), followed by perceptions of excessive wetness reported by patients (66%). Concerns about hygiene were also common, with 59% of respondents and 45% of patients indicating that the pad appeared unhygienic. Physical damage (21% torn) and accidental floor contact (17%) were less frequently reported, while prolonged patient use was rarely mentioned (14%) (see Appendix Figure A10).

Comparative evaluation

When directly comparing products, 44% agreed or strongly agreed that the reusable pad felt more pleasant than the disposable pad, although 31% were neutral. Most participants agreed (69%) that the reusable pad absorbed fluids effectively. However, convenience scored lower, with only 31% agreeing or strongly agreeing that it was more convenient to use than the disposable version, and 14% expressing strong disagreement. Opinions on logistics were positive, with 55% agreement and 17% neutrality. Assessing fluid color on the reusable pad was considered easy by 59% of respondents and 31% of respondents remaining neutral. 55% of respondents indicated a preference for using the reusable pad over the disposable one (see Appendix Figure A11).

Of the 29 respondents, 63% reported changes in their use of pads since the introduction of reusables. Staff described being more conscious about replacement, generally changing mats less frequently due to their larger size and higher absorbency. Strategies included folding or repositioning mats to extend use. However, some found the mats impractical for smaller tasks and a few replaced them quickly to avoid patient discomfort with visibly soiled mats. Overall, use became more deliberate but challenged by size and perceptions of hygiene.

Suggestions for improvement

Qualitative feedback indicated that size and weight were the most prominent concerns. 24 out of 29 respondents mentioned the pad being too large, too heavy, or cumbersome to handle, with repeated suggestions for a smaller version (60x60 cm). Several respondents highlighted that the heavy pads contributed to full and heavy laundry loads and complicated blood loss estimation during procedures. While most agreed that reusable pads were a positive sustainability initiative, they stressed the need to balance environmental benefits with practical usability, handling, and workflow efficiency.

Disposable absorbent pad usage analysis

Disposable pad usage decreased during the pilot period, from a pre-pilot mean of 3.42 pads per patient (January–April) to 2.96 pads per patient (May–June). This represents a relative reduction of approximately 13,5% (see Appendix Figure A4).

Washable absorbent pad usage analysis

Procurement data indicated that 580 reusable pads were used during the six-week pilot period. Hospital records showed that 81 deliveries took place in the two rooms equipped with reusable pads, corresponding to an average of approximately seven pads per delivery.

6.2.2 Endoscopy department

A total of 10 staff members from the Endoscopy department completed the questionnaire. The mean age of respondents was 46.9 years (SD = 10.1), ranging from 35 to 64 years. The average duration of employment in their current position was 12.4 years (SD = 7.5), with a range of 1 to 24 years. The sample consisted of 90% female and 10% male respondents, all employed as nurses. All participants had prior experience working with both disposable absorbent pads and the reusable towel introduced in the pilot (see Appendix Tables A5 and A6).

Reported use of disposable absorbent pads

Disposable pads were most frequently reported to be used to absorb moisture, blood, and/or feces (100%), to place under a patient sitting in a chair (60%), and for cleaning the floor (50%). Less common uses included absorbing leakage during catheter and/or IV placement (30%) (see Appendix Figure A12).

The main reasons for replacing disposable pads were that they were too wet according to the respondent (90%), the procedure had finished (80%), or the pad was torn (70%). Other reasons included the pad falling on the floor (60%), looking unhygienic according to the respondent (60%), being too wet according to the patient (50%), or looking unhygienic according to the patient (20%). No respondents reported replacing the pad because the patient had been lying on it for a long time (0%) (see Appendix Figure A13).

Reported use of reusable towels

Reusable towels were most frequently reported to be used during gastroscopy (100%) and endo-echography (70%), as well as to place under a patient sitting in a chair (60%). Less common uses included absorbing moisture, blood, and/or feces (20%), cleaning the floor (0%), and absorbing leakage during catheter and/or IV placement (0%) (see Appendix Figure A14).

Comparative evaluation

When directly comparing products, 80% agreed or strongly agreed that the reusable towel was more convenient to use than the disposable absorbent pad. Only 10% reported the towel as absorbing fluids effectively, with 70% remaining neutral. The towel was perceived as more pleasant than the disposable pad by 20% of respondents. Opinions on logistics were positive, with 60% agreeing or strongly agreeing that towel logistics worked well. Preferences showed that 10% indicated they preferred using the reusable towel over the disposable pad, with 70% remaining neutral (see Appendix Figure A15).

In Endoscopy (n = 10), 64% reported changes in their use of pads since the introduction of reusables. Towels were increasingly used in gastroscopies and endo-echographies, often replacing disposables. They were considered sufficient when folded and sometimes used for practical purposes, such as on chairs for patient dressing. Still, not all staff adopted towels, citing habit or doubts about absorbency. Adoption was therefore selective and procedure-dependent.

Suggestions for improvement

Qualitative feedback indicated a need for better absorbency, particularly for high-fluid procedures such as gastroscopy. Several respondents also highlighted the need for improved logistics, ensuring towels are readily available near procedure rooms. Some comments suggested that disposable pads might still be preferable in specific high-fluid contexts, while acknowledging the environmental benefit of using reusable towels.

Disposable absorbent pad usage analysis

To correct for variability in clinical workload, pad usage was calculated per endoscopic procedure performed. In the pre-pilot period (January–April), usage ranged from 1.38 to 1.61 pads per procedure. During the pilot period (May–June), this decreased to 1.34 and 1.21 pads per procedure respectively, indicating a downward trend (see Appendix Table A7).

Estimated towel usage

Towel usage in the Endoscopy department was estimated based on procurement data, as direct measurement was not feasible due to shared storage with the adjacent department. Prior to the pilot (weeks 1–16), average weekly usage was 46 towels. During the pilot (weeks 17–24), usage increased to 98 towels per week (total 780). This increase of 52 towels per week can be attributed to adoption of towels by the Endoscopy department. After the pilot (weeks 25–28), usage decreased slightly to 80 towels per week (total 320), but remained above pre-pilot levels (see Appendix Table A8).

6.2.3 Overall comparison

To evaluate the perceived overall quality of absorbent materials used in clinical practice, participants were asked to rate both the conventional disposable absorbent product and the newly introduced reusable alternative. This was assessed separately within the Obstetrics and Endoscopy departments (see Appendix Table A9.

In the Obstetrics department ($n = 29$), the disposable pad (M = 7.76, SD = 1.24) received significantly higher ratings than the reusable pad (M = 6.21, SD = 1.66), $t(28) = 3.67$, $p = .001$.

In the Endoscopy department ($n = 10$), the disposable pad (M = 8.60, SD = 0.84) was also rated significantly higher than the reusable towel (M = 7.10, SD = 0.99), $t(9) = 5.58$, $p < .001$.

6.3 Conclusion

Member checking with lead nurses from both departments, each of whom was also a member of their respective Green Team, confirmed that the thematic analysis accurately reflected clinical practice and that no critical observations were overlooked or overstated.

Reusable absorbent materials were perceived as a promising and functionally sufficient alternative to disposables in both departments. Behavioral changes were observed, including more conscious replacement and reduced use of materials. However, ratings consistently favored disposable pads in both departments, with a moderate preference in Obstetrics and a strong preference in Endoscopy. Identified limitations included concerns about absorbency and insufficient logistical accessibility.

Despite these barriers, the pilot confirmed that reusable materials could be introduced without compromising infection prevention or core clinical procedures, provided that contextual requirements are met. However, questions remain about the objective functional performance of reusable versus disposable products, particularly regarding absorption speed, total volume retention, and surface dryness, all cited as critical factors influencing perceived satisfaction.

To address these questions and guide future implementation strategies, standardized absorption tests were conducted. These laboratory-based evaluations quantitatively assessed the functional properties of each product type under controlled conditions. By systematically comparing absorption characteristics, the tests aimed to bridge the gap between subjective experience and technical performance, supporting evidence-based decisions for sustainable procurement and clinical integration.

7 Absorption tests

In clinical scenarios such as gastroscopies and childbirth, disposable absorbent pads play a critical role in fluid management. Their performance in absorbing and retaining bodily fluids directly impacts patient comfort and infection prevention standards. Standardized absorption tests, such as ISO 11948-1 and ISO 11948-2, have been developed to evaluate the performance of absorbent products. As described in Section 3.2, these methods typically use submersion-based techniques, in which the product is fully immersed in liquid for a fixed period and then weighed to determine fluid uptake. While this provides a reproducible laboratory measure, it does not adequately reflect clinical conditions, where fluid deposition is gradual and variable in volume.

In this study, a clinically realistic protocol was used to evaluate the real-world absorption performance of different materials, including absorption time, rewetting, and leakage thresholds. Absorption tests were conducted under simulated clinical conditions to generate evidence for decision-making on the replacement of disposable absorbent pads with more sustainable alternatives. This chapter describes the methodology and presents the results, comparing the performance of disposable and reusable products. The aim is to assess whether reusable options can provide equivalent or superior fluid management, thereby informing product selection and supporting hospital implementation strategies.

7.1 Methods

This section outlines the experimental procedures used to assess the absorption performance of disposable and reusable absorbent materials under simulated clinical conditions. A unified testing protocol was applied to enable a controlled yet realistic comparison between products. The methods detail the selection of test materials, the experimental setup, and the measurement procedures for key performance parameters: absorption time, total absorbed volume, surface rewetting and leakage thresholds.

7.1.1 Materials and products

Test materials

All test materials (see Figure 21) were selected based on feasibility and, with the exception of the reusable absorbent pad, because they were already in use within the hospital setting, facilitating potential implementation. Each material type was obtained in five units to enable repeated testing under consistent conditions.

List of materials:

- Washable absorbent pad 85x90 cm
- Disposable pad 40x60 cm
- Disposable pad 60x60 cm
- Disposable pad 60x90 cm
- Towel (flat)
- Towel (folded once)
- Towel (folded twice)
- Tea towel (flat)
- Tea towel (folded once)
- Tea towel (folded twice)
- Kleenex hygiene pad (Kimcare green, 37.5x50 cm)

Equipment and supplies

A minimum 100 mL measuring cylinder was used to standardise fluid application volumes. Water was heated to approximately 34°C using a submersible Smart Heater (55 W), which maintained a constant fluid temperature throughout testing to replicate typical clinical conditions (see Figure 22). Absorption time was recorded using a stopwatch.

Two digital scales were employed: a precision scale for blotting paper measurements and a laboratory scale for weighing both dry and wet test materials (see Figure 22). A tray was positioned directly on the laboratory scale to collect and measure volumes, ensuring that all leaked fluid was accurately captured and included in the weight measurements.

Additional supplies included ∅11 cm blotting paper for surface rewetting assessments (see Figure 22) and colored water to improve visual tracking during testing. All experiments were conducted on a non-absorbent, flat testing surface to eliminate background

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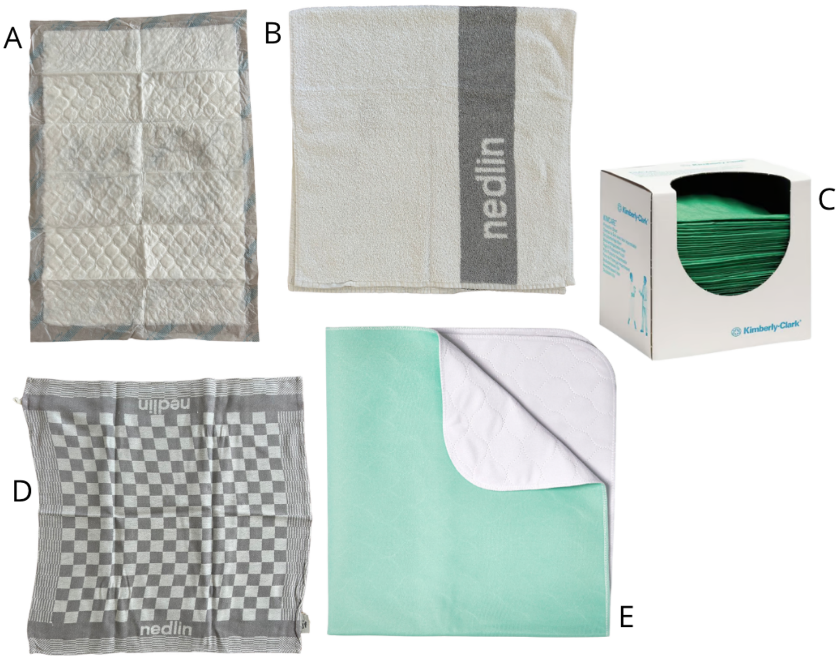

Figure 21: Materials tested for fluid absorption and rewetting properties. A: Disposable absorbent pad (40x60 cm), B: Towel (Nedlin), C: Kimberly-Clark Kleenex 7093 hygiene wipe, D: Tea towel (Nedlin), E: Washable absorbent underpad (85x90 cm, Nedlin).

absorption.

List of equipment:

- Measuring cylinder (min. 100 mL)
- Water bath to warm water to approximately 34°C
- Stopwatch
- Digital precision scale (0.1 g accuracy, 200 g capacity)
- Digital lab scale (1 g accuracy, 2.2 kg capacity)
- Tray or bin to catch leakage placed directly on the lab scale
- Blotting paper
- Colored water
- Non-absorbent flat testing surface

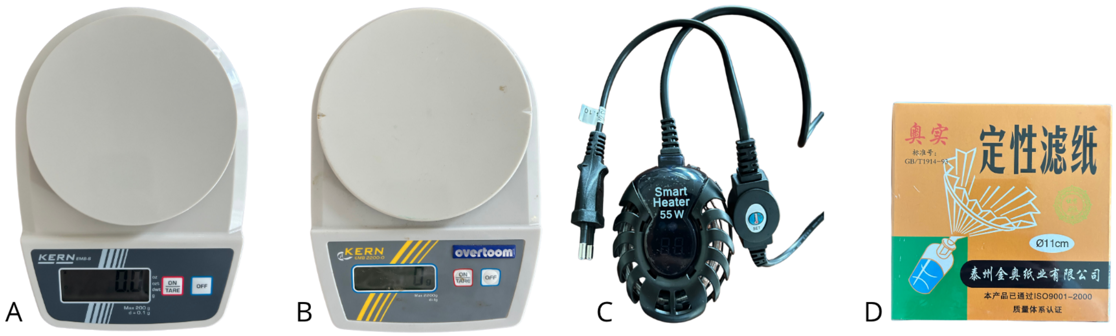

Figure 22: Overview of the equipment used for the absorption and rewet testing protocol. A: Digital precision scale (KERN EMB-S, ±0.1 g) used for blotting paper measurements, B: Digital scale (KERN EMB 2200-0, ±1 g) used for weighing dry and wet materials, C: Submersible Smart Heater (55 W) used to maintain a constant fluid temperature during testing, D: Ø11 cm qualitative filter paper (medium retention) used for assessing surface rewetting after fluid absorption.

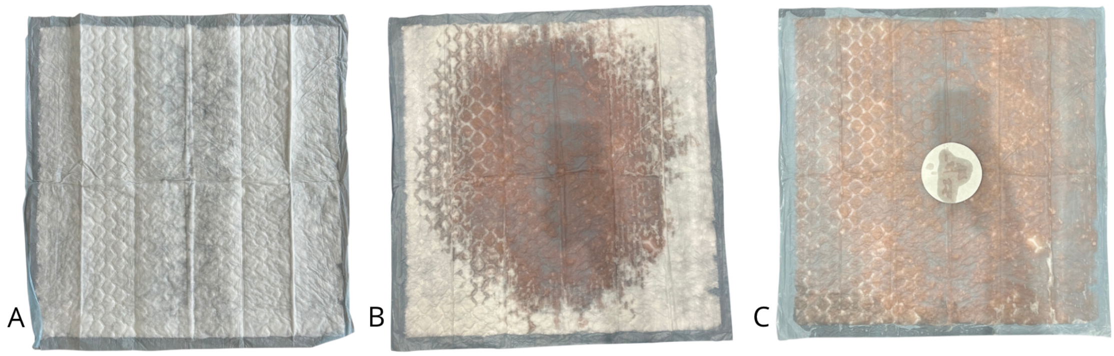

Figure 23: Visual progression of a disposable absorbent pad (60×60 cm) during testing. A: Dry pad before fluid application. B: Pad after multiple 100 mL doses, showing lateral spread of absorbed fluid. C: Final state after maximum absorption, with rewet assessment using filter paper indicating transferred moisture.

7.1.2 Test protocol

Each product was tested on a flat, non-absorbent surface. Colored water was used to simulate clinical fluids and qualitatively assess lateral spread across the surface. Liquid was applied to the center of the material in 100 mL increments, with pouring initiated simultaneously with the stopwatch and performed steadily over 30 seconds to mimic clinical application. A maximum of 1000 mL was applied unless testing was discontinued earlier due to:

1. Visible leakage beneath or around the edges of the material.
2. Incomplete absorption with visible pooling after 5 minutes.
3. Reaching the 1000 mL cumulative limit.

Five minutes after the start of each pouring step, a rewet test was performed by placing a pre-weighed blotting paper sheet onto the wetted area for exactly 30 seconds, then reweighing it. The increase in weight (1 g = 1 mL) was recorded as the rewet value.

All materials were weighed before and after testing to determine the total absorbed volume. A plastic tray was placed on the laboratory scale to collect and measure any leaked fluid during final weighing. Absorption time, rewet values, leakage occurrence, and qualitative observations of fluid spread were recorded for each trial.

Step-by-step protocol:

1. Weigh dry material (g).
2. Pour 100 mL of water over the material during 30 seconds.
3. Record the time until visible pooling stops (absorption time).
4. At exactly 5 minutes after start of pouring, place a pre-weighed blotting paper sheet onto the wetted area for 30 seconds.
5. Weigh the blotting paper immediately after removal to determine the rewet value.
6. Check for leakage:
   - If no leakage is observed, proceed to the next 100 mL dose.
   - If leakage occurs, weigh the wet material and end the test.

7.1.3 Data collection

All measurements were recorded in a structured Excel template to ensure consistent data entry. For each test, the following parameters were documented:

- Weight of dry material prior to testing (g)
- Weight of dry blotting paper prior to testing (g)
- Absorption time per 100 mL dose (s)
- Weight of wet blotting paper after each dose (g)
- Total weight of the material after absorption (g = mL)
- Leakage occurrence (yes/no and after which dose)

7.1.4 Data analysis

For each material type (n = 5 replicates), the following parameters were calculated or assessed:

- **Total absorbed volume (mL)**, calculated as:

  $$\text{Total absorbed volume (mL)} = \text{Weight wet (g)} - \text{Weight dry (g)}$$

  assuming 1 g = 1 mL based on the density of water.

- **Total absorption time (s)**, calculated as the sum of absorption times per dose:

  $$\text{Total absorption time (s)} = \sum_{i=1}^{n} \text{Absorption time}_{\text{dose } i}$$

- **Absorption speed (mL/s)**, calculated as:

  $$\text{Absorption speed (mL/s)} = \frac{\text{Total absorbed volume (mL)}}{\text{Total absorption time (s)}}$$

- **Absorption speed corrected for surface area (mL/s/cm^2)**, calculated as:

$$\text{Absorption speed (mL/s/cm}^2\text{)} = \frac{\text{Absorption speed (mL/s)}}{\text{Surface area of material (cm}^2\text{)}}$$

- **Absorbed volume corrected for surface area (mL/cm^2)**, calculated as:

$$\text{Absorped volume (mL/cm}^2\text{)} = \frac{\text{Absorped volume (mL)}}{\text{Surface area of material (cm}^2\text{)}}$$

- Mean and standard deviation of absorption time across replicates (s)
- Mean and standard deviation of rewet value after the final dose (g = mL)

Statistical analysis

Data normality for each material type and outcome variable was assessed using the Shapiro–Wilk test. As most datasets were not normally distributed, non-parametric tests were applied. Overall differences between materials were analysed using the Kruskal–Wallis test across all eleven materials.

Two outcome variables were tested:

1. Total absorbed volume (ml)
2. Absorption speed (ml/s)

When the Kruskal–Wallis test indicated a statistically significant difference, pairwise comparisons were conducted using the Mann–Whitney U test, with exact significance values reported. The following pairwise comparisons were tested:

- Disposable absorbent pad 40×60 cm vs Disposable absorbent pad 60×60 cm
- Disposable absorbent pad 40×60 cm vs Disposable absorbent pad 60×90 cm
- Disposable absorbent pad 60×60 cm vs Disposable absorbent pad 60×90 cm
- Tea towel (flat) vs Tea towel (folded once)
- Tea towel (flat) vs Tea towel (folded twice)
- Tea towel (folded once) vs Tea towel (folded twice)
- Towel (flat) vs Towel (folded once)
- Towel (flat) vs Towel (folded twice)
- Towel (folded once) vs Towel (folded twice)
- Disposable absorbent pad 60×90 cm vs Washable absorbent pad

All statistical analyses were performed in IBM SPSS Statistics (version 29.0.2.0). A significance threshold of $p < 0.05$ was applied.

Table 11: Average absorption performance of eleven disposable and reusable absorbent materials, based on five replicates per material. All values are reported as means and rounded to an appropriate number of decimal places to avoid false precision, reflecting the accuracy limits of the measurement instruments and experimental procedure.

Material	**Dry weight (g)**	**Total absorption time (s)**	**Total weight wet (ml)**	**Total absorbed volume (ml)**	**Rewet (ml)**	**Absorption speed (ml/s)**
Disposable pad (40×60 cm)	31	172	310	279	0.17	1.7
Disposable pad (60×60 cm)	42	187	501	459	0.26	1.6
Disposable pad (60×90 cm)	61	354	849	651	0.45	1.8
Kleenex	7	0	63	56	0.90	0.0
Tea towel (flat)	104	73	229	125	0.18	1.7
Tea towel (folded once)	104	106	425	234	0.16	3.0
Tea towel (folded twice)	104	37	516	112	0.10	3.1
Towel (flat)	217	38	346	129	0.16	3.4
Towel (folded once)	218	33	354	137	0.16	4.1
Towel (folded twice)	220	32	348	128	0.10	3.9
Washable absorbent pad	520	602	1736	1216	0.00	2.0

7.2 Results

Table 11 summarises the mean absolute absorption performance of eleven disposable and reusable absorbent materials, each tested in five replicates. Parameters include dry weight, total absorption time, wet weight, total absorbed volume, rewet, and absorption speed. Values are reported as means, rounded to an appropriate number of decimal places to prevent false precision and to reflect the measurement accuracy and procedural variability inherent to the experimental setup.

Disposable pads

Within the disposable category, the 60×90 cm pad demonstrated the highest absolute absorption capacity (651 mL). Its mean absorption speed (1.8 mL/s) was comparable to the smaller formats, while rewetting was highest among all pads in this category (0.45 mL), potentially influencing perceived dryness during clinical application. The 60×60 cm pad absorbed 459 mL in 187 s, corresponding to the lowest absorption speed among the disposable formats (1.6 mL/s) and a rewet value of 0.26 mL. The 40×60 cm pad exhibited the lowest total absorbed volume (279 mL) and an intermediate absorption speed (1.7 mL/s), combined with a relatively low rewetting value (0.17 mL).

Washable pad

The washable absorbent pad (85×90 cm) displayed the highest absolute absorbed volume across all tested materials (1216 mL) and a prolonged absorption time (602 s). The corresponding mean absorption speed (2.0 mL/s) exceeded that of all disposable pads but remained below that of the towel configurations. No rewetting was recorded for this material.

Towels

Towel configurations were characterised by relatively low absorbed volumes (128–137 mL) yet achieved the highest absolute absorption speeds observed in the study. The once-folded towel attained the highest value (4.1 mL/s), followed by the twice-folded (3.9 mL/s) and flat towel (3.4 mL/s). Rewet values for all towel configurations were consistently low (0.10–0.16 mL).

Tea towels

Tea towel performance varied notably with folding configuration. The once-folded tea towel absorbed the largest volume within this category (234 mL) but required the longest time (106 s), resulting in a moderate absorption speed (3.0 mL/s). The flat tea towel absorbed 125 mL with the lowest absorption speed in this group (1.7 mL/s), whereas the twice-folded tea towel demonstrated the fastest absorption speed (3.1 mL/s) despite a lower absorbed volume (112 mL). Rewetting values were low across all folding configurations (0.10–0.18 mL).

Kleenex hygiene pad

The Kleenex hygiene pad exhibited the lowest absolute absorption capacity of all tested materials (56 mL), with visible pooling on the surface persisting after extended waiting periods. No reliable absorption speed could be calculated, and the rewetting value was the highest recorded (0.90 mL), indicating limited suitability for clinical fluid management.

Overall comparison

Figure 24 compares total absorbed volume with absorption speed for all materials. The results show a clear trade-off between absorption capacity and speed.

Disposable pads occupied the mid-range in both parameters, with the 60x90 cm variant absorbing the most fluid but requiring more time. Towels achieved the highest absorption speeds, particularly when folded, but managed only modest volumes. Tea towels performed intermediately, with folding increasing speed but reducing volume. The washable pad outperformed disposables in absorbed volume while maintaining a comparable absorption speed. The Kleenex hygiene pad is not included, as it failed to absorb 100 mL.

These results indicate that material choice depends on the balance between rapid absorption and total capacity: disposables represent a middle ground, towels excel in speed, and the washable pad provides superior volume.

Normalized results

Figures 25 and 26 present absorption speed and absorbed volume per unit surface area (cm^2) for the four largest pad formats (three disposable, one washable).

In terms of *normalized absorption speed*, the disposable 40×60 cm pad exhibited the highest median value, followed by the 60×60 cm and 60×90 cm pads. The washable pad displayed a similar median absorption speed to the 60x90cm disposable absorbent pad. Regarding *normalized absorbed volume*, the washable pad demonstrated the highest median value, whereas the disposable 60×60 cm and 60×90 cm pads exhibited similar median capacities, both exceeding that of the 40×60 cm pad, which had the lowest capacity per unit area.

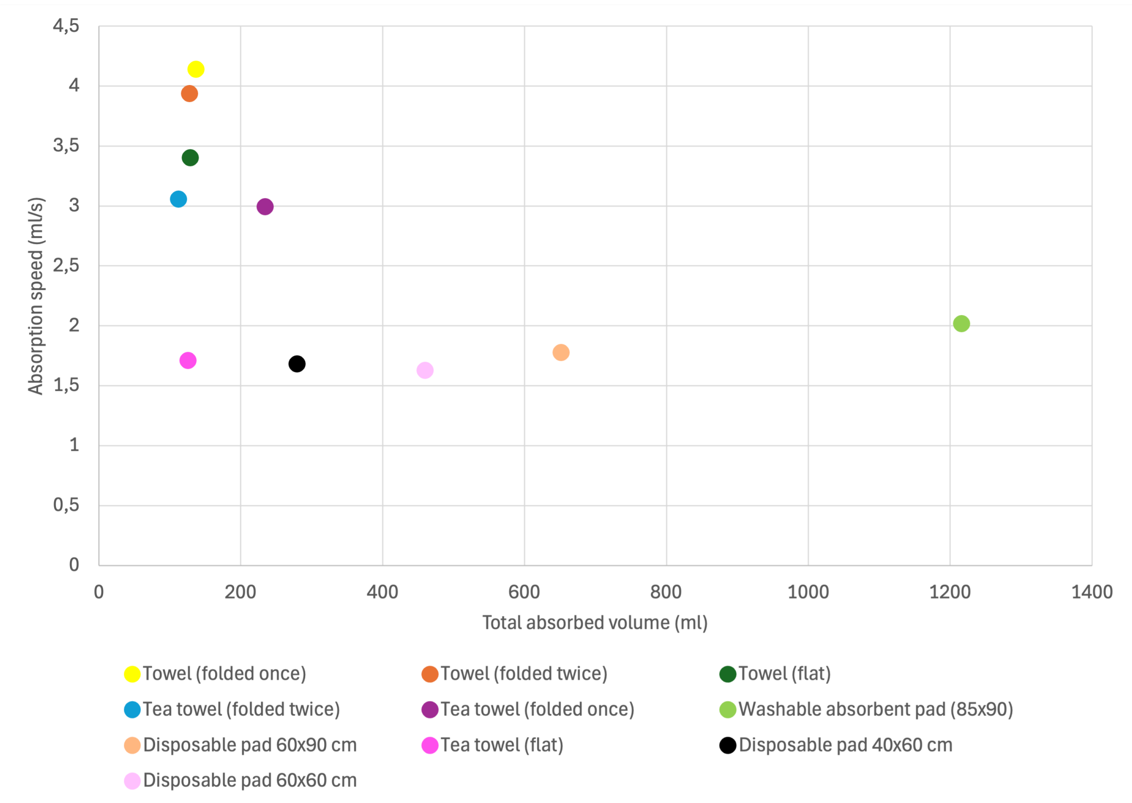

Figure 24: Relationship between total absorbed volume (mL) and absorption speed (mL/s) of tested absorbent materials. Each point represents the mean of five replicates per material. The graph illustrates the trade-off between absorption capacity and speed across disposables, towels, tea towels, and the washable absorbent pad. The Kleenex hygiene pad is excluded, as it did not reach 100 mL absorption.

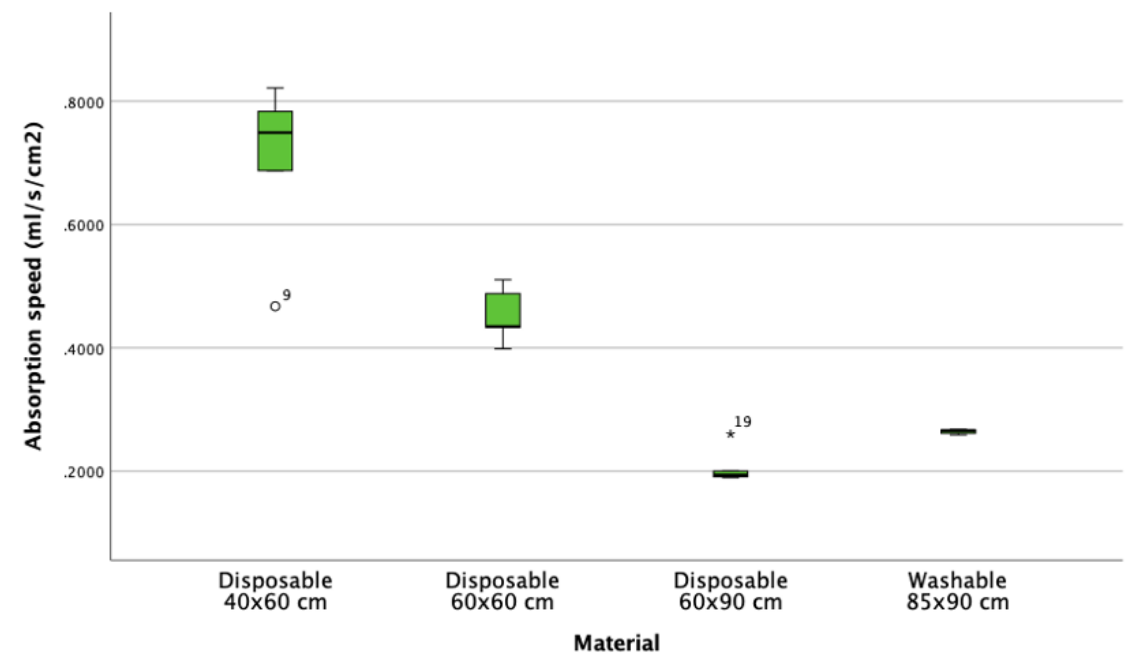

Figure 25: Absorption speed, corrected for surface area, (mL/s/cm^2) of four absorbent materials (three disposable and one washable) based on five replicates per material. Boxplots display the interquartile range (IQR), median, and potential outliers (°) or extremes (*).

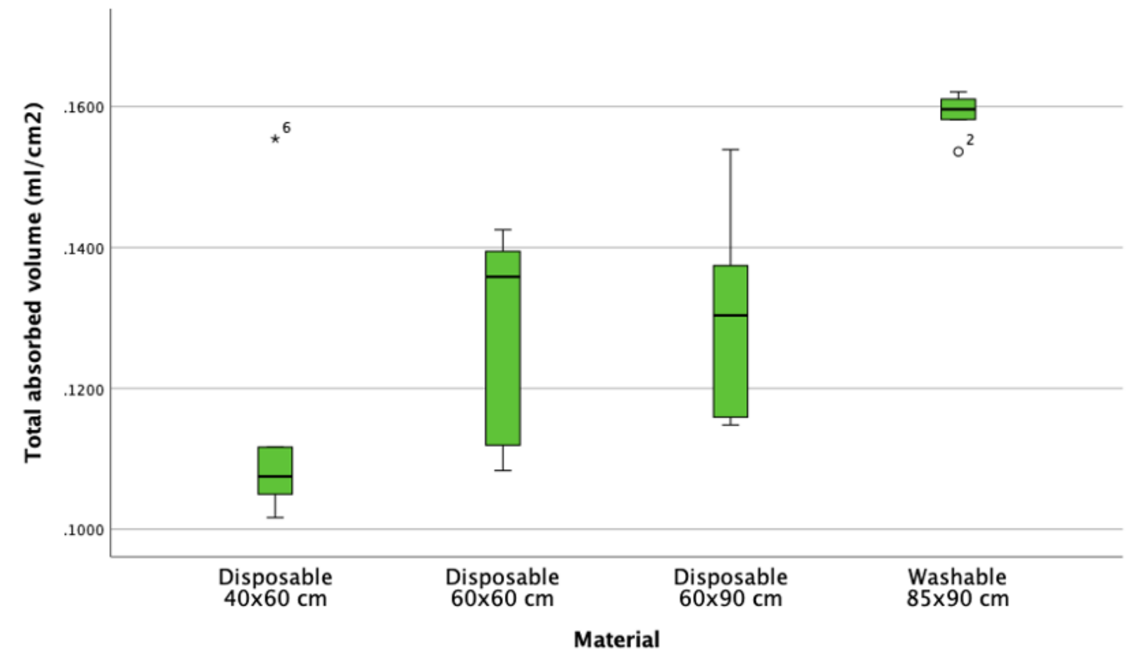

Figure 26: Total absorbed volume, corrected for surface area, (mL/cm^2) of four absorbent materials (three disposable and one washable) based on five replicates per material. Boxplots indicate interquartile range (IQR), median, and potential outliers (°) or extremes (*).

Pairwise comparisons

Post-hoc pairwise comparisons using the Mann–Whitney U-test were performed to identify significant differences between individual materials.

Among disposable absorbent pads, both the 60×60 cm and 60×90 cm variants absorbed significantly greater volumes than the 40×60 cm pad ($p = 0.008$ for both). In addition, the 60×90 cm pad absorbed significantly more than the 60×60 cm pad ($p = 0.008$). In terms of absorption speed, the 60×90 cm pad absorbed faster than the 40×60 cm pad ($p = 0.016$) and the 60×60 cm pad ($p = 0.008$), while no significant speed difference was observed between the 40×60 cm and 60×60 cm pads ($p = 0.347$).

For tea towels, the flat variant absorbed more liquid than the twice-folded variant ($p = 0.008$), and the once-folded variant absorbed more than the twice-folded variant ($p = 0.032$). Regarding absorption speed, the twice-folded tea towel absorbed significantly faster than the flat variant ($p = 0.008$), but differences between the flat and once-folded ($p = 0.095$) and between the once- and twice-folded variants ($p = 0.151$) were not statistically significant.

No significant differences in either total absorbed volume or absorption speed were found between the three towel configurations (flat, once-folded, twice-folded).

When comparing the washable pad to the 60×90 cm disposable pad, the washable pad absorbed a significantly greater volume ($p = 0.008$) and did so at a significantly higher speed ($p = 0.008$). No other pairwise differences reached statistical significance.

7.3 Conclusion

The absorption tests enabled a comprehensive comparison of disposable and reusable absorbent materials under standardized conditions, evaluating total absorbed volume, absorption speed, and rewetting behavior. Clear trade-offs were observed between material types and configurations. Folded towel configurations achieved the fastest fluid uptake, making them suitable for low-fluid settings where rapid absorption is critical. In contrast, the washable absorbent pad demonstrated the highest fluid retention capacity and no rewetting, indicating strong suitability for longer procedures where fluid management and sustained dryness are essential.

These findings allow the hospital to match material properties to specific clinical requirements, supporting a selective transition from single-use disposable pads to appropriate reusable options without compromising functionality. Such targeted implementation directly contributes to hospital-wide sustainability objectives while maintaining safe and effective fluid management across diverse care settings.

8 Discussion

8.1 Summary of key findings

Main research question

How can a hospital-wide implementation strategy for reducing the use of single-use products be designed, while ensuring cost-effectiveness, infection prevention, logistical feasibility, and usability, based on a case study of disposable absorbent pads in the Obstetrics and Endoscopy departments?

Absorption tests and pilot studies showed that reusable pads and towels can provide comparable fluid uptake to disposables, but their performance depends on task-specific use. Successful implementation requires integration into linen logistics, consistent availability at the point of care, and clear communication with staff. Adoption was primarily influenced by hygiene concerns, routine use, and limited sustainability knowledge. A hospital-wide strategy should therefore pair technically adequate products with logistical integration, visible leadership, and targeted staff training, tailored to departmental workflows.

Sub-research questions

1. What are the current usage patterns and drivers of disposable absorbent pad use in the Obstetrics and Endoscopy departments?

Disposable absorbent pads are firmly embedded in clinical routines. In Obstetrics, they were used extensively during deliveries and postpartum care, with replacement primarily based on visual appearance or patient request. In Endoscopy, use was typically restricted to one pad per procedure, except in cases of heavy leakage. Non-essential use was frequent, particularly in Obstetrics, driven by perceptions of hygiene, convenience, and habit. These patterns highlight both the embedded reliance on disposables and the potential for reduction through behavioural change.

2. Which behavioural, procedural, and organisational factors influence the reduction or substitution of single-use products in clinical settings?

Behavioural factors included strong perceptions of hygiene, embedded habits, and limited knowledge of sustainability, which often reinforced reliance on disposables. Time pressure and high workload further reduced willingness to change routines. Procedural factors were mainly linked to logistics: consistent availability and integration into linen flows enabled adoption, while lack of standardisation and accessibility hindered it. At the organisational level, insufficient managerial support and resources posed barriers, whereas visible leadership, clear communication, and the involvement of implementation facilitators strengthened uptake.

3. What sustainable alternatives exist for disposable absorbent pads, and how do they perform in terms of functionality, environmental impact, and staff acceptance?

Absorption tests and pilot study findings indicated that reusable pads and towels can provide fluid uptake comparable to disposable pads. However, their leakage prevention was more variable and strongly influenced by folding practices and handling. Washable pads proved most suitable for high-fluid procedures, though their large size and weight limited use in smaller interventions. Towels offered a practical substitute in low-fluid procedures. Environmentally, reusable products reduced both waste generation and associated CO_2 emissions. Staff evaluations showed that while reusables were functionally sufficient in most cases, their successful adoption depended on behavioural adaptation and context-specific use. No single alternative was universally applicable, underscoring the need for procedure-specific selection and clear implementation guidance.

4. How can sustainable alternatives be integrated into existing workflows and hospital logistics without compromising cost-effectiveness or infection prevention?

Sustainable alternatives can be integrated effectively when embedded in existing linen flows and made consistently available at the point of care. Successful logistical integration requires clear storage protocols, standardisation across departments, and coordination with laundry services to ensure a reliable supply. Cost-effectiveness is difficult to determine, since comparisons between disposables and reusables are often limited to procurement data. A more accurate assessment should also include upstream and downstream costs of disposables, such as transport and waste processing. Infection prevention can be maintained when reusable products are reprocessed under validated cleaning protocols and staff are trained in correct handling. Finally, alignment with hospital procurement systems and visible leadership support are essential to balance economic, hygienic, and operational demands, ensuring that the transition does not compromise care quality.

8.2 Interpretation of results

This study examined the feasibility of integrating reusable absorbent alternatives into hospital workflows as substitutes for disposable absorbent pads. To understand the mechanisms shaping this transition, findings from interviews, pilot studies, and absorption tests were interpreted through the COM-B model, the Behaviour Change Wheel (BCW), and the Consolidated Framework for Implementation Research (CFIR). This combined perspective enables a comprehensive analysis of behavioral, contextual, and organizational factors that influence the adoption of sustainable alternatives in clinical practice.

COM-B Model

The COM-B model provided a useful lens to interpret the behavioural mechanisms underlying the use of disposable absorbent pads and the potential adoption of reusable alternatives. The model highlights that behavior (B) is a function of capability (C), opportunity (O), and motivation (M), each of which played a distinct role in shaping staff practices in the Obstetrics and Endoscopy departments.

Capability

Psychological capability emerged as a major barrier. Interviews and observations revealed that staff had limited knowledge of sustainability in general, with little awareness of the environmental impact of disposables or the contribution of alternatives to waste reduction. Most staff reported operating on "autopilot," lacking insight into the actual volume of disposables consumed. These findings highlight the need for targeted education and visual reminders to build awareness and improve competence in using reusable products.

By contrast, *physical capability* did not emerge as a barrier. Staff did not report challenges related to dexterity, strength, or physical ability when handling reusable products, suggesting that individual capacity was sufficient to support behavior change.

Opportunity

Physical opportunity proved to be highly influential. Staff across both departments emphasized high workload and limited time for additional tasks, underlining the importance of an environment in which alternatives are as easy, or even easier, to access than disposables. In the Obstetrics department, the presence of an existing laundry system facilitated the integration of reusable pads with minimal disruption. In contrast, endoscopy lacked such infrastructure, creating logistical challenges around collection, storage, and return flows. Additionally, the automatic use of disposables highlighted the potential value of environmental cues, such as reminders of environmental impact or visual prompts directing staff toward available alternatives.

Social opportunity also shaped behavior. Staff consistently noted that change is more likely to occur when colleagues actively discuss sustainability and hold each other accountable. At the same time, interviews highlighted that constant peer correction can be socially uncomfortable, reducing motivation for engagement. Members of departmental Green Teams reported declining enthusiasm when sustainability advocacy created tension in workplace relationships. Hierarchical structures were also important, as local leaders and senior staff were seen as key drivers, both by setting the example and by embedding new expectations in daily routines.

Motivation

Reflective motivation played a mixed role. While some staff expressed concern for the environment or framed sustainability as part of their professional responsibility, many others were sceptical. Common perceptions included the belief that sustainable practices are more costly, more time-consuming, and offer limited benefits. Misconceptions about the actual environmental performance of alternatives (negative assumptions about the impact of laundering) circulated informally, further undermining acceptance. Personal convictions varied strongly, with older staff members in particular expressing reluctance to "switch back" to reusables, as many of them had themselves experienced the transition from reusable to disposable products decades ago.

Automatic motivation, in the form of habits and routines, was a dominant driver of behaviour. Disposables were often used without conscious reflection, and embedded reliance reinforced their continued use. Hygiene-related emotions further influenced staff perceptions, and concerns about the cleanliness of reusables persisted, even in light of neutral or positive pilot experiences. At the same time, the pilot suggested a potential leverage point as staff tended to replace reusable materials more consciously than disposables, indicating that once alternatives are introduced, habitual patterns can be disrupted and adjusted over time.

Table 12: Summary of COM-B components as applied to the adoption of reusable absorbent pads

COM-B component	Definition	Findings in this study
Psychological capability	Knowledge, cognitive skills, awareness	Major barrier: limited knowledge of sustainability and environmental impact of disposables; staff often operated on "autopilot" without insight into actual volumes consumed. Need for education and reminders.
Physical capability	Physical skills, strength, dexterity	Not a barrier: staff did not report challenges in handling reusable products; individual physical ability was sufficient.
Physical opportunity	Environmental context, time, infrastructure, resources	Highly influential: heavy workload and lack of time limited adoption. In Obstetrics, existing linen infrastructure enabled integration; in Endoscopy, absence of logistics posed barriers. Disposables remained easier to access.
Social opportunity	Cultural and social influences, peer norms, leadership	Peer influence shaped behaviour: change was more likely with active discussion and accountability. However, constant peer correction reduced motivation. Leadership by local champions was a strong facilitator.
Reflective motivation	Conscious beliefs, evaluations, intentions, values	Mixed role: some staff motivated by environmental concern or professional responsibility, others sceptical. Misconceptions (laundering impact) undermined acceptance. Older staff often reluctant to "switch back" to reusables.
Automatic motivation	Habits, routines, emotions	Strong driver: disposables used without reflection, hygiene-related emotions reinforced reliance. Habits dominated but pilots suggested that routines can shift when alternatives are introduced.

Behaviour Change Wheel

Building on the COM-B model, the Behaviour Change Wheel (BCW) offers a systematic framework for linking determinants of behaviour to concrete intervention functions and policy categories [16]. Within this study, the BCW provided a useful lens to identify how hospital staff could be supported in transitioning from disposable absorbent pads to sustainable alternatives.

Intervention functions

- **Education** targets knowledge and awareness gaps that constrain psychological capability. Interviews revealed limited understanding among staff of the environmental impact of disposables, while habits of use were often described as "automatic." Training modules, illustrated protocols, and short workshops could therefore increase awareness of the environmental footprint and provide clear instructions on correct handling of and choosing the correct sustainable alternatives.

- **Enablement** reduces barriers and increases the means to act. High workload and hygiene concerns were repeatedly cited as barriers in both departments. Enablement interventions include ensuring reliable stock availability, providing dedicated storage space, and clarifying hygiene guidelines through collaboration with infection prevention teams. These measures would directly reduce perceived and practical obstacles that currently reinforce reliance on disposables.

- **Environmental restructuring** changes the physical or social context to facilitate alternative behaviours. In Obstetrics, existing linen logistics enabled straightforward integration of washable pads, demonstrating how infrastructure can support adoption. In contrast, Endoscopy lacked a linen system, requiring new workflows for transport, storage, and laundering. More broadly, increasing the visibility and accessibility of reusable products, while making disposables less accessible, could nudge staff toward sustainable choices.

- **Modelling** provides behavioural examples for others to imitate. Interviews identified that lead nurses play a pivotal role in influencing departmental practices. Visible adoption of reusables by local leaders and sustainability champions may normalise their use. In Obstetrics, patients occasionally requested replacement of pads themselves, suggesting that patient engagement could also indirectly shape staff practices.

Although not strongly supported by the findings, two additional intervention functions may hold potential. **Persuasion**, through communication strategies that emphasise professional responsibility and environmental benefits, could help strengthen reflective motivation and stimulate action. Similarly, **incentivisation**, for instance through recognition programs or hospital-wide competitions, may provide an additional stimulus for engagement.

Policy categories

In addition to intervention functions, the BCW highlights seven policy categories that can support and sustain behavioural change [16]. Within this study, three categories emerged as particularly relevant to embedding reusable absorbent products into hospital practice:

- **Guidelines:** The absence of institutional or departemental guidelines on disposable absorbent pad use leaves a gap in current practice. Integration of reusable absorbent products into departmental and hospital-wide protocols would provide clarity and reassurance to staff. Such guidelines should cover handling, storage, and laundry flows to prevent inconsistencies, as highlighted during the pilot evaluation.

- **Communication and marketing:** Hospital-wide campaigns can raise awareness of the environmental burden of disposables and normalise the use of reusables. This is particularly important given the interviews showed that "sustainability" is often perceived negatively, being associated with extra workload or costs. Positive communication may counter these views and increase acceptance.
- **Environmental and social planning:** Storage space and workflow organisation strongly influence staff opportunity to adopt reusables. The pilot studies demonstrated that placement of materials near procedure rooms increased uptake, whereas lack of storage posed barriers. Scaling up to hospital-wide implementation will require structural planning of storage capacity, as demand for reusable products grows.

Other policy categories, such as **regulation** and **service provision** were not directly observed in this study, but remain relevant at higher policy or institutional levels. For example, the *Green Deal Duurzame Zorg* provides external regulatory pressure and reliable hospital-wide laundry services will be essential for sustainable adoption.

Table 13: Behaviour Change Wheel: intervention functions and policy categories relevant for reusable absorbent pads

Intervention function / Policy category	Description and relevance in this study
Education	Addressed knowledge and awareness gaps about environmental impact. Training modules, illustrated protocols, and workshops could increase awareness and competence in handling reusables.
Enablement	Reduced barriers by ensuring reliable stock, storage space, and clear hygiene guidelines. Directly addressed workload and hygiene concerns.
Environmental restructuring	Changed the physical/social context. Existing linen flows in Obstetrics enabled integration, while Endoscopy lacked such systems. Increasing accessibility of reusables and reducing visibility of disposables could nudge adoption.
Modelling	Role models (lead nurses, Green Teams) influenced behaviour.
Persuasion (potential)	Communication strategies emphasising professional responsibility and environmental benefits could strengthen reflective motivation.
Incentivisation (potential)	Recognition programmes or hospital-wide competitions could stimulate engagement, though not central in this study.
Guidelines	Lack of institutional protocols was a barrier. Departmental and hospital-wide guidelines on handling, storage, and laundry flows would provide clarity and reassurance.
Communication and marketing	Hospital-wide campaigns could normalise reusables and counter negative perceptions of sustainability as "extra work".
Environmental and social planning	Placement of materials near procedure rooms increased uptake; lack of storage was a barrier. Scaling up requires structural planning of storage capacity.

Consolidated Framework for Implementation Research

The Consolidated Framework for Implementation Research (CFIR), developed by Damschroder et al. (2009), offers a structured taxonomy of constructs that shape the success of implementation efforts in healthcare [17]. CFIR comprises five domains: *Innovation Characteristics*, *Outer Setting*, *Inner Setting*, *Characteristics of Individuals*, and *Process*. Applied to this study, CFIR highlights how systemic, organisational, and individual factors influenced the adoption of reusable absorbent products, complementing the behavioural insights derived from COM-B and BCW.

Intervention characteristics

Staff perceptions of reusable towels and absorbent pads were shaped primarily by *relative advantage*, *adaptability*, and *complexity*. Relative advantage was acknowledged not only in terms of environmental and long-term cost benefits, but also in clinical practice. For example, in the Endoscopy department, towels were perceived as more comfortable for patients and allowed staff to wipe the patient's mouth post-procedure, a function not feasible with disposable absorbent pads. Such positive experiences are important focal points for future implementation.

Adaptability was constrained in departments without laundry infrastructure or where product size reduced practicality. Perceived complexity was a recurring barrier, as staff emphasised their limited time; innovations that seamlessly fit existing workflows are therefore more likely to be adopted. Cost did not emerge as a facilitator, since frontline staff are not directly responsible for departmental budgets. Furthermore, savings from reduced material use are not reinvested within departments, eliminating a potential incentive. Finally, for some professionals, *evidence base* was crucial, with scepticism expressed about the actual environmental benefits of reusable textiles when laundry processes are considered.

Outer setting

External drivers exerted limited influence. National programmes such as the *Green Deal Duurzame Zorg* provided a supportive policy backdrop but were poorly known among staff and did not translate directly into departmental-level requirements. Overall, external pressure was not a major driver of behavioural change in this context.

Inner setting

The organisational context strongly shaped outcomes. *Compatibility* with existing routines was essential, with infrastructure and storage capacity determining departmental readiness for change. Early adoption is therefore more feasible in departments with established linen systems, such as Obstetrics, than in settings without logistical support, such as Endoscopy. *Relative priority* was another barrier: sustainability was rarely a central concern for staff, emphasising the importance of making interventions as seamless as possible and using nudging strategies to reduce disruption to workflows. *Communication* and *access to knowledge and information* emerged as critical facilitators of change. Clear communication regarding the purpose of the intervention enhanced adoption, whereas the generally limited level of sustainability knowledge among staff represented an important barrier. These findings suggest a need for hospital-wide awareness campaigns, which have been reported as successful in other institutions.

Characteristics of individuals

Variation among staff was evident in their knowledge, beliefs, and motivation. Some expressed strong environmental commitment and confidence in reusables, whereas others remained sceptical, particularly regarding hygiene. Lead nurses often acted as informal role models, shaping group behaviour. Demographic characteristics, professional background, and personal sustainability attitudes further influenced adoption. Importantly, CFIR highlights the role of *opinion leaders* and *implementation facilitators*.

In this study, Green Team members reported barriers such as lack of time, insufficient information, and limited organisational authority, which reduced their ability to coordinate sustainability initiatives effectively. These findings underscore the need to involve stakeholders across all organisational layers, from senior leadership to frontline staff, in order to build legitimacy and ensure a smooth implementation process. Implementation facilitators appear to play a crucial role in bridging the gap between Green Team members and the sustainability coordinator, thereby supporting the translation of bottom-up initiatives into organisational change.

Process

The pilot studies served as both *execution* and *evaluation* mechanisms, enabling iterative learning. Engagement varied in healthcare personnel, as some actively adapted workflows and provided constructive feedback, while others experienced unclear instructions or limited ownership. These differences highlight the importance of early and structured stakeholder engagement, where expectations and rationales are clearly communicated across all organisational levels. For large-scale implementation, structured *planning*, formalised roles for implementation leads, and continuous feedback loops should be required. Interventions initiated and introduced by healthcare professionals themselves were perceived as more credible and necessary. This underscores the importance of local champions in driving adoption and highlights the need to *engage* healthcare personnel, as end-users, in the design and implementation of sustainability initiatives.

Table 14: CFIR domains and key findings in the implementation of reusable absorbent products

CFIR domain	Key constructs	Findings in this study
Intervention characteristics	Relative advantage, adaptability, complexity, cost, evidence strength	Reusables perceived as environmentally advantageous and in some cases more comfortable (towels in Endoscopy). Adaptability constrained by lack of infrastructure or impractical product size. Complexity increased perceived workload. Cost not relevant at staff level. Some professionals sceptical due to uncertain evidence base.
Outer setting	External policy, patient needs, peer pressure	National programmes (Green Deal Duurzame Zorg) provided supportive backdrop but were poorly known at department level. Limited external pressure for adoption.
Inner setting	Compatibility, implementation climate, communication, resources	Organisational context shaped adoption strongly. Obstetrics benefited from existing linen infrastructure (compatibility), while Endoscopy lacked logistics (barrier). Limited knowledge reduced readiness for change. Need for clear communication and awareness campaigns. Storage capacity and infrastructure were decisive.
Characteristics of individuals	Knowledge and beliefs, self-efficacy, opinion leaders, implementation facilitators	Strong variation: some staff confident and supportive, others sceptical (especially regarding hygiene). Lead nurses acted as informal role models. Green Team members motivated but limited in authority and time. Implementation facilitators played key role in bridging bottom-up initiatives to management.
Process	Planning, engaging, executing, reflecting & evaluating	Pilots acted as execution and evaluation. Engagement varied among staff: some adapted workflows actively, others resisted or needed clearer instructions. Findings highlighted importance of early planning, structured engagement, and continuous feedback loops for hospital-wide scaling.

Synthesis of frameworks

While COM-B, BCW, and CFIR were analysed separately, applying them side by side in this study revealed both overlap and complementarity. Across all three frameworks, knowledge gaps and routine reliance on disposables emerged as central barriers, demonstrating convergence in the domains of capability (COM-B), education/enablement (BCW), and access to knowledge and information (CFIR). Similarly, logistical constraints and the absence of infrastructure were captured simultaneously as physical opportunity (COM-B), environmental restructuring (BCW), and inner setting compatibility (CFIR). Social influences, such as peer correction and leadership roles, also cut across models, appearing as social opportunity (COM-B), modelling and persuasion (BCW), and characteristics of individuals (CFIR).

These overlaps underline that the frameworks do not provide entirely distinct perspectives. Instead, their combined use offered a layered understanding: COM-B identified the core behavioural mechanisms, BCW translated these into actionable intervention functions and policy levers, while CFIR contextualised them within systemic, organisational, and process-level factors. Together, the frameworks thus provided conceptual clarity and practical guidance for implementation, even though some repetition was unavoidable.

8.3 Comparison with existing literature

Sustainability and behavioural change in healthcare

The findings of this study align with previous research highlighting both opportunities and challenges in implementing sustainable practices in healthcare. Similar to the present study, Nieuwenhuizen et al. (2023) revealed barriers such as insufficient leadership, lack of dedicated time, and unclear institutional commitment, despite initiatives such as the Dutch Green Deal 3.0. Respondents emphasized that sustainability efforts are often driven by passionate individuals but remain unsupported structurally. Recommendations included embedding sustainability into hospital strategy, appointing dedicated leaders, and ensuring transparent communication platforms [54]. Comparable trends are reported internationally: Harris et al. (2021) showed that most UK and Irish surgeons expressed willingness to adopt sustainable practices, yet highlighted the absence of leadership and national guidance as key obstacles [55]. Together, these studies underscore that professional awareness alone is insufficient; organizational alignment and leadership are crucial to move from intention to practice.

Nursing research further reinforces the crucial role of frontline healthcare workers as change agents for sustainability. Zoromba and El-Gazar (2022) demonstrated that nurses' sustainability behaviours are shaped by attitudes, practices, and barriers, with engagement often hindered by insufficient training and limited institutional support [56]. Similarly, a systematic review [57] identified recurring barriers such as inadequate education, competing clinical priorities, and weak organizational frameworks. Research has also identified effective interventions, demonstrating that targeted workshops can enhance nurses' knowledge and confidence, while visible managerial commitment plays a key role in motivating staff [58]. Facilitators such as leadership, teamwork, and education are therefore repeatedly cited as essential drivers for embedding sustainability into clinical practice.

These findings also resonate with research on healthcare professionals as change agents. Krijgsheld (2022) demonstrated that bottom-up initiatives often depend on individual motivation and peer enthusiasm (micro-level), but are frequently hindered by limited managerial support (meso-level) and restrictive regulations (macro-level). This multi-level perspective provides a useful framework to interpret the present findings, where staff-driven initiatives (using towels or reusable pads) emerged, yet faced institutional barriers similar to those reported in previous studies [59].

Absorption testing and Rothwell comparison

The absorption tests performed in this study demonstrated substantially lower absorption capacities for disposable pads compared to the Rothwell values reported by the manufacturer (Table 15). For example, the 40×60 cm disposable pad absorbed an average of 279 ml in our test protocol, whereas the manufacturer indicates a Rothwell capacity of 700 ml. Similarly, the 60×60 cm and 60×90 cm pads absorbed 459 ml and 651 ml, respectively, compared to Rothwell values of 900 ml and 1200 ml.

Table 15: Comparison between absorption test results and manufacturer-reported Rothwell values.

Material	Measured absorption (ml)	Rothwell value (ml)	Difference (%)
Disposable pad 40×60 cm	279	700	–60%
Disposable pad 60×60 cm	459	900	–49%
Disposable pad 60×90 cm	651	1200	–46%

These differences can be attributed to the distinct methodologies employed. The Rothwell method (ISO 11948-1) was originally developed for large body-worn incontinence pads [30]. It involves complete saturation of the pad, strict timing of liquid application, and measurement using filter paper. However, as highlighted in previous evaluations, small variations in timing and interpretation can substantially influence the outcomes [31]. In this study, non-body-worn pads were evaluated using a protocol tailored to clinical practice, focusing on absorption capacity and the point at which the material could no longer retain fluid without leakage.

From a clinical perspective, the results of this study provide a more realistic estimate of pad performance under conditions relevant to obstetrics and endoscopy. Whereas Rothwell values reflect maximum theoretical capacity, our findings demonstrate that effective capacity in real-world use is considerably lower. This discrepancy underscores the need for clinically relevant performance testing when assessing alternatives to disposable absorbent products.

Material composition of washable absorbent pads

The reusable absorbent pads studied in the reference literature differ in material composition from the pads implemented at Reinier de Graaf Hospital. Table 16 provides an overview of these differences. The reference pad consists of a multilayer structure with woven polyester, a nonwoven polyester–rayon mixture, and a woven polyester backing with an additional TPU coating [28]. In contrast, the RDGG reusable absorbent pad is composed predominantly of polyester, with a small proportion of rayon in the absorbent core, and a PU barrier combined with a knitted polyester backing. These distinctions are relevant for subsequent Life Cycle Assessment (LCA), since material type and weight directly influence upstream production impacts and end-of-life scenarios.

Table 16: Comparison of material composition between washable absorbent pads used in reference research and in Reinier de Graaf Hospital

Layer	**Reference research pad (85 × 75 cm)**	**Reinier de Graaf pad (85 × 90 cm)**
Upper layer	Woven polyester	100% polyester
Absorbent core (soaker)	Nonwoven polyester mixed with rayon	95% polyester, 5% rayon (nonwoven, 340 g/m^2)
Bottom layer	Woven polyester	Knitted polyester (110 g/m^2)
Barrier layer	Thin TPU (thermoplastic polyurethane) coating	PU (polyurethane) barrier, 70 g/m^2
Stitching / assembly	Polyester yarn	Stitched connection of soaker to upper layer

Another important factor is the variability in washing processes. The comparative research explicitly noted that the consumption of electricity, gas, water, detergents, and packaging varies not only between industrial laundries but also between locations of the same provider. As the data was considered confidential, only ranges and averaged values were reported [28]. In contrast, RDGG collaborates with Nedlin, a laundry service that has achieved BREEAM Outstanding certification, representing the highest level of environmental performance in building and operational sustainability [44]. This certification implies optimized resource efficiency, renewable energy use, and stringent environmental management, which is assumed to surpass the “average” assumptions applied in the reference LCA study [28]. Consequently, the environmental impact of laundering in the Reinier de Graaf case is likely lower than that of the generic average reported in the literature.

8.4 Implications for clinical practice

The findings of this study provide evidence-based guidance for RDGG in reducing disposable absorbent pad use while maintaining patient safety, hygiene protocols, and workflow efficiency. Based on interviews, pilot studies, and absorption tests, several practical recommendations can be made for clinical practice in the Obstetrics and Endoscopy departments.

Obstetrics department

In Obstetrics, the integration of reusable underpads into the existing linen infrastructure proved feasible, with relatively little disruption to workflows. Staff reported that the washable pad was functionally sufficient during procedures. Absorption testing confirmed that the reusable underpad provided the highest fluid capacity (approximately 1200 ml), making it particularly suitable for high-fluid procedures. The 60 × 60 cm version is preferable for hospital-wide use, as the larger 60 × 90 cm variant was considered too bulky for routine handling.

For disposable absorbent pads, both interviews and absorption testing indicated that the 60 × 90 cm version does not provide additional practical value. It is typically replaced as frequently as the 60 × 60 cm version and therefore not used to its full capacity. Excluding the 60 × 90 cm pad from procurement would reduce unnecessary material use while maintaining clinical functionality.

Behavioural factors were critical in adoption. Interviewees highlighted that habits, perceptions of hygiene, and automatic reliance on disposables drove overuse. Behavioural interventions such as nudging, awareness campaigns, and visible leadership support are therefore needed. For example, making reusables the default option, combined with clear guidance on when disposables are still required, can support sustained behavioural change.

Endoscopy department

In Endoscopy, implementation challenges were mainly logistical, as no linen stream was present. Pilot results showed that staff were willing to use reusable towels when they were readily available in procedure rooms, but additional steps were required to organize collection and return. Absorption tests confirmed that towels absorbed liquid rapidly (3–4 ml/s) but had limited overall capacity (150–250 ml), restricting their suitability to procedures. For higher-fluid cases, a combination of towels with a disposable pad may be appropriate, though this requires confirmation from the Infection Prevention department regarding reuse of non-soiled pads between patients.

The Endoscopy pilot highlighted that the absence of a linen stream poses a major barrier to wider adoption of reusable products. Clean linen storage and return systems were identified as critical issues, and these challenges are expected to become a hospital-wide concern as the transition toward more reusables expands. To enable sustainable implementation, it is recommended that RDGG develops a long-term strategy for linen logistics, including solutions for point-of-care availability, standardized collection, and efficient transport of used materials.

Hospital-wide recommendations

At the organizational level, several measures are recommended to enable sustainable and long-term adoption of reusable absorbent products:

- Embed reusable products into procurement guidelines and departmental budgets;
- Appoint implementation facilitators to act as a bridge between hospital policy and clinical practice;
- Develop a clear decision tree or best-practice visuals to guide staff in selecting the appropriate sustainable products;
- Standardize linen logistics and plan for future hospital-wide storage and return flows to accommodate the increasing use of reusables;
- Provide targeted staff training on sustainability initiatives;
- Reinforce adoption through nudging strategies, awareness campaigns, and feedback on environmental impact;
- Support motivation and legitimacy through visible leadership engagement, sustainability champions, and alignment with hospital-wide sustainability goals;

RDGG is well-positioned to reduce disposable absorbent pad use through a combination of behavioural interventions, logistical adaptations, and organisational support. For successful hospital-wide adoption, implementation should be guided by behavioural nudges, strong leadership engagement, and integration into existing logistical and procurement systems.

8.5 Strengths and limitations of this study

Interviews
A key strength of the interviews was the focus on nurses, providing detailed insights from the group most responsible for the daily use of disposable absorbent pads. The interviews not only documented usage practices, explored options for reduction, and identified requirements for adoption, but also actively engaged staff in the project. This participatory element is a strength, as it involved end-users early and fostered a sense of ownership, which may increase the likelihood of successful adoption of sustainable alternatives.

A limitation is that most interviewees were members of departmental green teams, which likely introduced a pro-sustainability bias. Furthermore, the interview format was vulnerable to recall and self-reflection bias, while the strong social norm to support sustainability goals may have influenced responses.

Pilot studies
A key strength of the pilot studies was their ability to provide real-world insights into the feasibility of integrating reusable alternatives into clinical workflows. In the Endoscopy department, the researcher's presentation ensured direct communication and engagement, which facilitated understanding and acceptance among staff. In the Obstetrics department, staff themselves had already identified disposable absorbent pads as problematic, which strengthened the legitimacy of the intervention and created a natural entry point for introducing alternatives.

Limitations of the pilots include uneven communication across departments, as the large number of staff in Obstetrics made it challenging to provide consistent information and presentations could not be organised for all employees. Furthermore, patient perspectives were not included, even though healthcare professionals frequently emphasised that patient acceptance and comfort are critical to the adoption of sustainable products.

Absorption tests

A key strength of the absorption tests was that their design combined elements of recognised standards (ISO norms and NWSP 70.9) with adaptations to reflect clinical practice. This ensured that the results are directly relevant for hospital decision-making, as they provide realistic estimates of product performance under conditions closer to actual use.

Limitations include the use of water instead of biological fluids, which reduced realism, and the absence of pressure-based rewet testing, even though absorbent pads are typically used under patients who exert pressure on the material. In addition, the timing of when pooling was considered to have ended was subjective, introducing variability between tests. Finally, the lack of benchmarking against Rothwell or ISO protocols restricts external validity and limits comparability with other studies.

Cost analysis

A strength of the cost analysis is that it accounted for downstream costs of washing, transport, and waste processing, rather than relying solely on purchase prices. This provided a more realistic and fair comparison between disposable and reusable products.

Limitations include the exclusion of several cost components. The weight of disposable absorbent pads was not considered, even though waste disposal and transport are calculated per kilogram and pads become significantly heavier after absorbing fluids. In addition, hazardous waste is disposed of in specific SZA containers, and both the frequency of use and the associated container costs may influence overall expenditures. Excluding these factors limits the completeness of the analysis and may underestimate the true economic burden of disposable pad use.

Methodological considerations

The COM-B model, although widely applied, has been criticised for its broad and sometimes overlapping constructs, which can complicate the categorisation of specific behavioural influences. Certain behaviours do not align neatly with a single COM-B component [60][61]. Similarly, while the Behaviour Change Wheel (BCW) offers a systematic structure for designing interventions, the selection of appropriate intervention functions still requires careful contextual interpretation [16].

The Consolidated Framework for Implementation Research (CFIR) is comprehensive, but its wide scope necessitates prioritisation of domains to avoid overly complex or resource-intensive assessments [62]. Furthermore, CFIR provides a largely static overview of implementation determinants, which may limit its ability to capture the dynamic changes typical of hospital environments [63].

These limitations were also visible in the present study. When applying COM-B, BCW, and CFIR side by side, there was some degree of overlap and repetition, and not all findings aligned neatly across the models. Nevertheless, their combined use provided a clearer overall picture of the behavioural, organisational, and systemic factors shaping implementation. In particular, COM-B and BCW offered a structured lens for understanding individual and team-level behaviour, while CFIR complemented this by situating those behaviours within the institutional and logistical context.

8.6 Recommendations for future research and practice

Based on the findings of this study, several priority actions are recommended for the Reinier de Graaf Hospital and future research.

1. Appoint implementation facilitators. The most urgent recommendation is to establish dedicated implementation facilitators who actively bridge the gap between hospital management and healthcare personnel. These individuals should coordinate logistics, monitor progress, and translate policy ambitions into workable practices for clinical staff. Without this role, adoption risks remaining fragmented and dependent on informal champions.

2. Integrate reusable products into existing workflows. Reusable underpads (60 × 60 cm) should be standardised and embedded into routine care across departments. Integration requires alignment with linen logistics, clear storage protocols, and visible accessibility at the point of care. The larger 60 × 90 cm version should be excluded from procurement, as evidence indicates it is impractical and does not provide added value.

3. Strengthen staff engagement through communication and role models. Targeted campaigns, visual reminders, and peer role models should reinforce awareness and normalise sustainable practices. Communication should not only highlight environmental benefits, but also emphasise usability and infection safety to address staff concerns directly.

4. Address high-consumption hotspots. The endoscopy reprocessing unit represents a major source of disposable pad use. Alternatives such as reusable transport solutions or drying cabinets (as used in urology) should be prioritised for evaluation and investment.

5. Provide structural support to Green Teams. Green Teams and sustainability committees must be equipped with resources, authority, and managerial backing. Their current reliance on voluntary engagement limits impact; formalising their role can ensure continuity and effectiveness.

6. Advance the evidence base. Future research should conduct large-scale, multicentre studies to generate generalisable evidence on clinical performance, workflow integration, environmental outcomes, and costs of reusable products. Infection prevention requires particular attention, including microbial contamination under routine use and the effectiveness of disinfection protocols.

7. Move from pilots to institutional strategy. Pilots are useful for testing, but hospital-wide adoption requires integration into institutional policies, procurement strategies, and sustainability goals. Embedding reusable absorbent products in procurement guidelines and hospital sustainability planning will secure long-term impact.

9 Conclusion

This thesis investigated the implementation of sustainable alternatives to disposable absorbent pads in a hospital setting, using the obstetrics and endoscopy departments of Reinier de Graaf Hospital as pilot cases. A combination of literature review, qualitative interviews, pilot implementation, and absorption testing, interpreted through the R-ladder, COM-B and BCW model, and CFIR framework, provided a comprehensive understanding of the opportunities and challenges in reducing single-use products.

The findings show that reusable products, such as towels and washable absorbent pads, can meet clinical requirements for absorption and usability when applied in a task-specific manner. Pilot results highlighted that successful implementation depends not only on product performance but also on integration into existing linen flows, reliable availability at the point of care, and clear communication with staff. Nurses, as primary end-users, played a pivotal role in adoption, while barriers included routine use of disposables, perceived hygiene risks, and limited awareness of sustainability.

Applying theoretical frameworks provided further insight into the mechanisms of change. The COM-B model underscored that capability, opportunity, and motivation must all be addressed to achieve behavioural change. The Behaviour Change Wheel (BCW) translated these determinants into concrete intervention strategies, such as education and training to build capability, environmental restructuring and enablement to address logistical barriers, and persuasion and modelling to shift social and motivational norms. The CFIR framework highlighted the organisational context by emphasising the importance of leadership, resources, and implementation climate, while also pointing to the need for structured processes of planning, engagement, and evaluation. Finally, the R-ladder demonstrated that the most impactful strategies extend beyond product substitution, requiring the refusal of unnecessary pad use and the rethinking of workflows to structurally reduce single-use consumption.

This thesis concludes that reducing disposable absorbent pad use in hospitals is both feasible and desirable, provided that behavioural, logistical, and organisational factors are addressed in an integrated manner. Sustainable change requires not only technically adequate alternatives but also bottom-up staff involvement, visible leadership, and alignment with hospital-wide sustainability goals.

Reinier de Graaf Hospital has set a target of reducing disposable absorbent pad use by 20% in 2025 compared to 2024. While this has not yet been achieved, the findings of this thesis demonstrate that it is attainable through hospital-wide awareness campaigns, targeted behavioural interventions, and the adoption of reusable alternatives. More broadly, this study illustrates how practical solutions, staff engagement, and organisational alignment can be combined to reduce clinical waste without compromising quality of care, offering a model that can inform sustainable practice in hospitals beyond RDGG.

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11 Appendix

Table A1: Sustainability initiatives related to disposable absorbent pad reduction in Dutch hospitals.

Hospital	Departments	Actions	Approach	Outcomes	Challenges	Date
UMCG	Surgery	Pilot with reusable, washable absorbent pad as replacement for disposable absorbent pads.	1. Removed disposable absorbent pads from department during pilot 2. Clear right and wrong use indications 3. Surveys with patients and hospital personnel 4. Technical tests	1. 40% reduction in usage disposable absorbent pad 2. Overall positive responses from staff	1. Not always sufficient absorption capacity 2. Not found equally workable by everyone, as it was too large for some purposes	Feb-24
Noordwest Ziekenhuis-groep	1. ICU 2. Obstetrics	Pilot with reusable, washable absorbent pad as replacement for disposable absorbent pads.	1. Hygiene, user experience, and CO_2 impact evaluated 2. Reduction strategy promoted alongside pilot 3. Business case and implementation plan created 4. Trainee appointed for rollout and implementation	1. Pads came back clean 2. Positive user (patient and hospital personnel) experience 3. Business case is budget neutral 4. CO_2 case is positive 5. 20% disposable absorbent pad use reduction	1. Less moisture absorption than disposable (IC context: not an issue) 2. Not suitable for childbirth due to bleeding and variability in pad weight 3. Long delivery time for reusable pads: 5 months	Aug-24
	3. Endoscopy	Use of towels as replacement for disposable absorbent pads.		1564 m^2 disposable absorbent pad reduction		
LUMC	Obstetrics	Multi-centre pilot study focused on user experience, functionality, and sustainability	1. Replaced disposable pads with reusable mats 2. Conducted surveys among patients and staff 3. Collected and weighed used mats 4. Evaluated cleaning after 1, 5, and 10 washes 5. Organized redesign session with manufacturers	1. 42% reduction in mat use per month 2. 86% reduction in CO_2 emissions 3. Higher satisfaction from patients and staff 4. Mats used longer and more efficiently	1. Surface area decreased after repeated washing 2. Some mats returned stained 3. Initial resistance to new use approach	May–Jul 2024
St. Antonius	OR	Behavioral change through awareness campaign	1. Posters and materials explaining when pads are needed 2. Team discussions 3. Focus on reducing 60x60 cm mats	43% reduction in use of 60x60 disposable pads	Long-term behavior change requires reinforcement	Nov-24

Hospital	Departments	Actions	Approach	Outcomes	Challenges	Date
Medisch Spectrum Twente	Endoscopy, OR, ENT, Orthopedics, ICU	Department-specific implementation and awareness	1. Double-folded towels for gastroscopy 2. Blue cloths from instrument sets 3. Towels from sterilization packages 4. Pads removed from orthopedic rooms 5. Washable underpads on beds (ICU)	31% reduction compared to 2022 (70,000 fewer mats/year)		Feb-25
Deventer Ziekenhuis	OR	Towels and non-absorbent mats replace disposable absorbent pads		50% reduction over 3 years		Mar-25
Erasmus MC	Cardiology	Staff behavior change through education and access to alternatives	1. Poster campaign 2. Stickers at point of use 3. Towels in linen carts and rooms 4. Newsletters 5. Stakeholder involvement	1. 42% reduction in deliveries 2. Average use dropped from 63 to 37		Oct-24
Haaglanden MC	OR	Targeted education to change behavior	Raise awareness about CO_2 impact and alternatives	3750 fewer pads used per quarter		Mar-23
Radboud UMC	OR	Challenge to reduce disposable absorbent pad use	Awareness and education on CO_2 impact	7000 fewer pads used in 2022 than 2021		
UMC Utrecht	OR	1. Challenge for reducing disposable absorbent pad use 2. Partly replaced by sustainable alternatives (towels, green cloth)	1. Take time to research 2. Involve stakeholders 3. Create awareness 4. Listen to concerns	1. 74% reduction in disposable pads 2. Strong team-building 3. Often no pad or alternative needed		Jan–Mar 2025

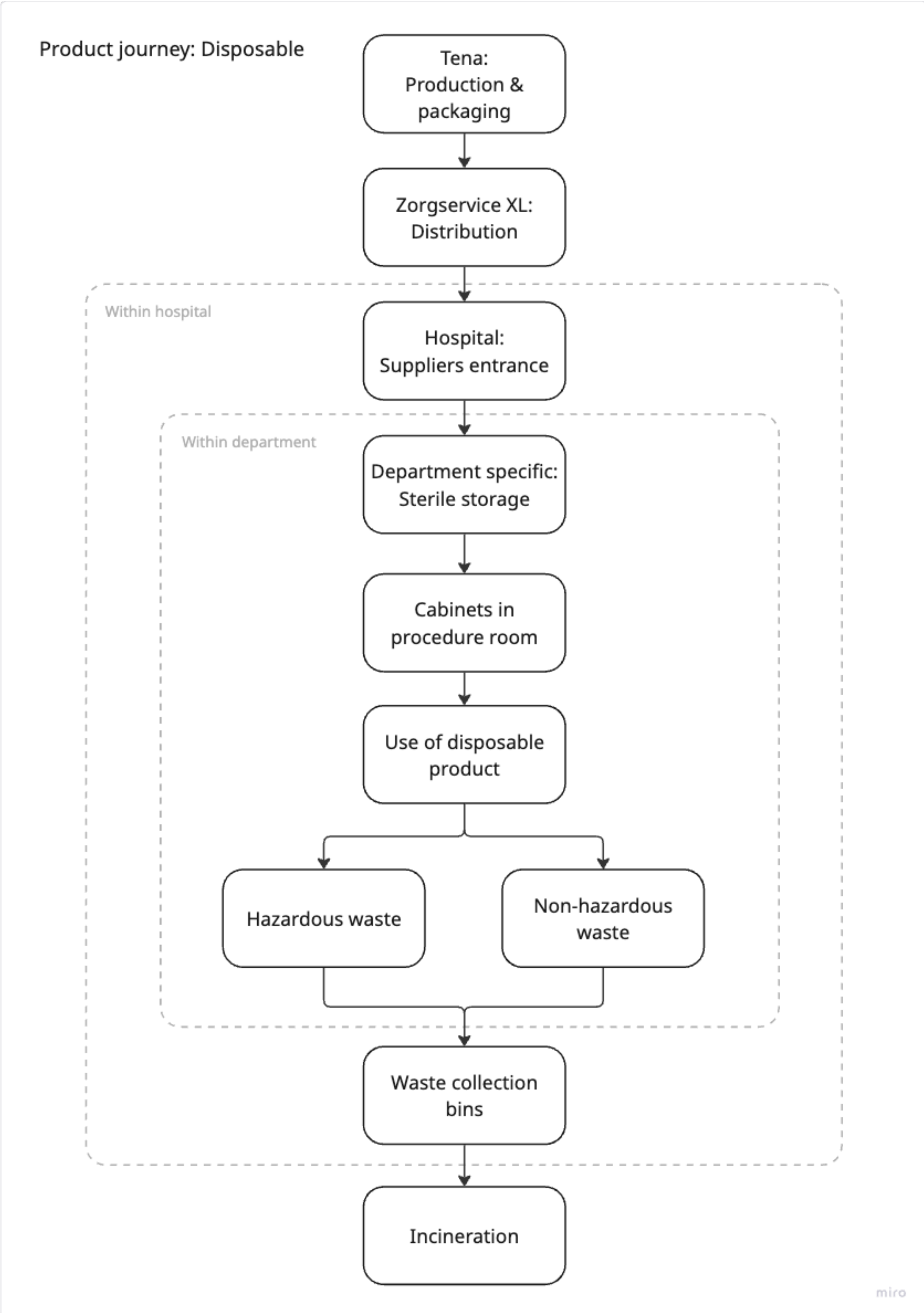

Figure A1: Product journey map for disposable products.

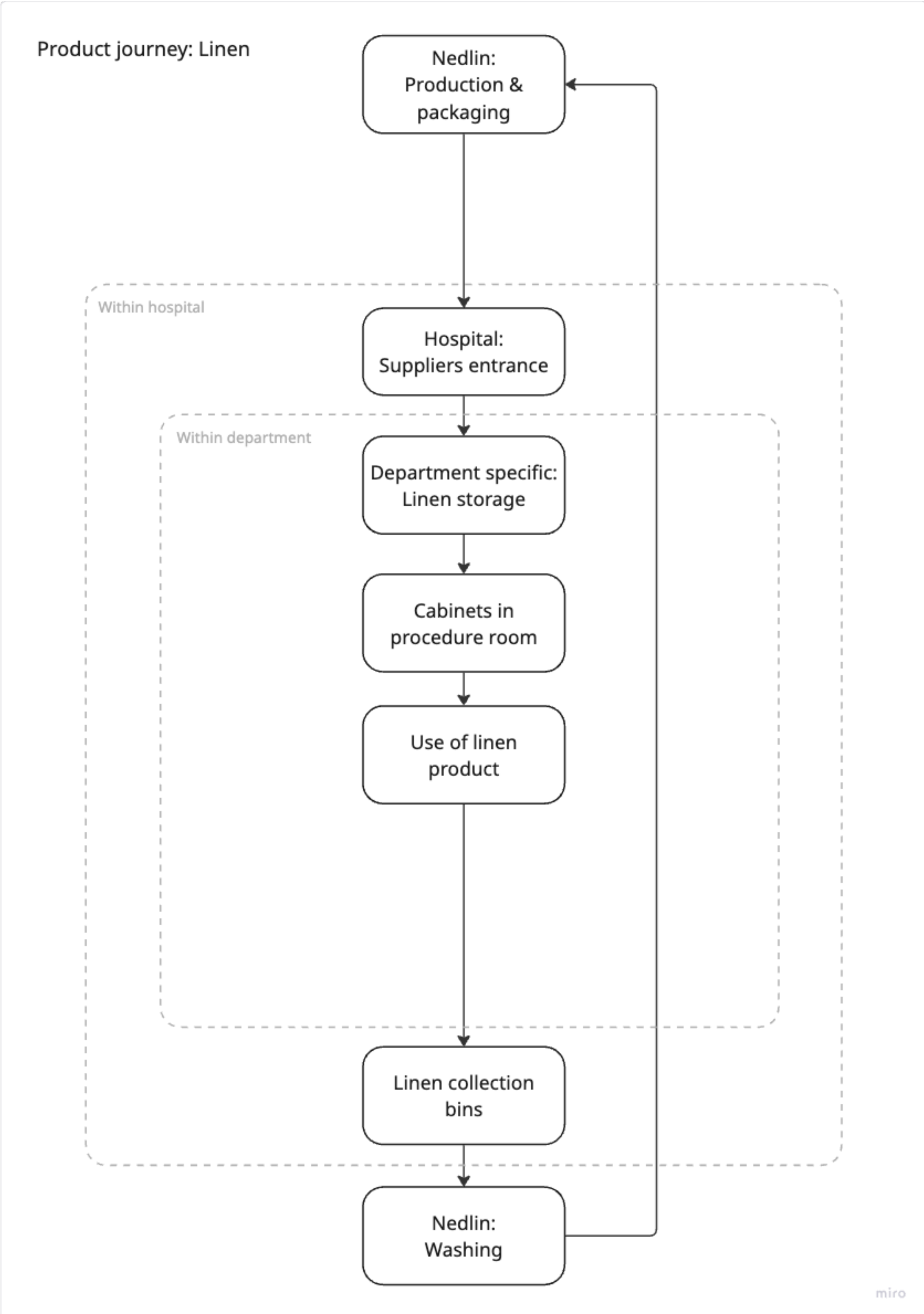

Figure A2: Product journey map for linen products.

nedlin

A new day,
new opportunities.

Onderlegger

ALGEMEEN	
Artikelnaam Nedlin:	Onderlegger
Artikelcode Nedlin:	200128
Dienstverlening:	Huur standaard
KENMERKEN/EIGENSCHAPPEN	
Samenstelling bovenzijde:	100% polyester (170 gr/m²
Afmeting (cm):	Ca. 85 x 90 cm.
Gewicht p/stuk (gram):	Ca. 525
Soaker:	95% polyester/ 5% rayon, non woven (340 gr/m²), d.m.v stiksel verbonden met de bovenzijde
Onderzijde:	PU-barriere (70 gr/m2) verbonden aan een 100% polyester breisel (110 gr/m2)
Vochtopname:	> 1, 5 liter vocht
Bijzonderheden:	Hygiënisch en efficiënt, Ruime afmeting, Dankzij de polyester bovenzijde snelle vochtopname, Gemakkelijke handling, Door de verbinding van de diverse lagen en de toepassing van breisel aan de onderkant verschuift de onderlegger niet
VISUEEL	
Kleur:	Bovenzijde groen, Onderzijde wit
PROCES EN VERPAKKING	
Afwerking:	Gemangeld, gevouwen
Verpakkingsaantal:	Per 5
Verpakkingswijze:	Gebundeld met een strap
OVERIG	
Slijtagecyclus:	Minimaal 100 wasbeurten
Afkeur:	Op basis van zichtbare slijtage (dun, gaten), vlekken en verkleuringen

Figure A3: Product specifications of the washable reusable absorbent pad (Nedlin).

1. Hoe lang werkt u al bij Reinier de Graaf?
2. Kunt u kort uw functie en werkzaamheden omschrijven?

3. Bij welke werkzaamheden gebruikt u celstofmatjes? En waarom?
4. Hoe vaak gebruikt u een celstofmat per patiënt/procedure?
5. Wat zijn redenen om een celstofmat te vervangen?
6. Gebruikt u celstofmatjes ook weleens voor toepassingen waarvoor het product eigenlijk niet bedoeld is?
7. Bij welk afval wordt een gebruikte celstofmat weggegooid?

8. Bent u zich bewust van hoeveel celstofmatjes dagelijks op uw afdeling worden gebruikt en weggegooid?
9. Heeft u een idee van de milieu-impact van wegwerp celstofmatjes?
10. Waar ziet u verbeteringsmogelijkheden om het gebruik van celstofmatjes op uw afdeling te verminderen?
11. Heeft u voor bepaalde toepassingen weleens een alternatief gebruikt in plaats van een celstofmat? Waarom wel/niet?
12. Zou u openstaan voor een duurzamer alternatief? Waarom?
13. Waar zou een goed alternatief volgens u aan moeten voldoen?

14. Wordt er op uw afdeling al nagedacht over duurzamere oplossingen of alternatieven? Hoe wordt dit aangepakt? Hoe reageren collega's hierop?
15. Hoe zouden collega's kunnen worden gestimuleerd of geïnspireerd tot milieubewuster gedrag?
16. Wat zou u helpen of nodig hebben om zelf duurzamer te werken?

Figure A4: Interview guide used as a supporting tool during the interviews.

Figure A5: Visualisation of the product flow of absorbent pads within the Obstetrics department. (A) Sterile supply room cabinet with disposable pads. (B) Scan card in cabinet compartment. (C) Basket for in-drawer storage near bed containing pads and related items. (D) Linen cart delivery from laundry services. (E) Linen supply room within department with carts stocked. (F) Bed setup with disposable pads in Obstetrics department. (G) Linen waste and non-hazardous waste bins. (H) SZA container. (I) Non-hazardous waste container.

Figure A6: Example slides from departmental presentation used to inform staff about the pilot, including rationale, handling procedures and hygiene requirements.

Table A2: Descriptive statistics for age and years of work experience among participants in the Obstetrics & Maternity Department (n = 29).

	N	Minimum	Maximum	Mean	Std. Deviation
Age (years)	29	25	64	40.52	12.99
Years in job	29	1	40	15.28	11.95

Table A3: Gender, job role, and previous product use (disposable and reusable absorbent pad) of participants in the Obstetrics & Maternity Department (n = 29).

	N	**%**
Gender		
Female	29	100%
Male	0	0%
Other	0	0%
Job		
Obstetrics nurse	25	86%
Maternity nurse	1	3%
Lead nurse	1	3%
Medical specialist	0	0%
Student	0	0%
Medical assistant	0	0%
In training	1	3%
Primary care midwife	0	0%
Secondary care midwife	0	0%
Other	1	3%
Worked with disposable absorbent pad	29	100%
Worked with reusable absorbent pad	29	100%

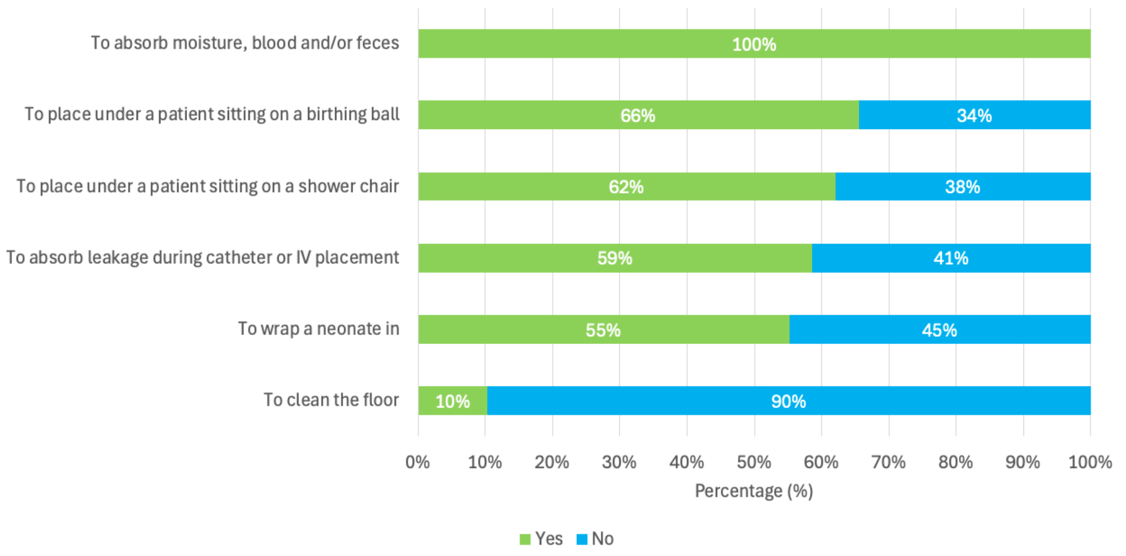

Figure A7: Reported reasons for using the disposable absorbent pad during the pilot study in the obstetrics department (n = 29). Multiple indications could be selected per respondent.

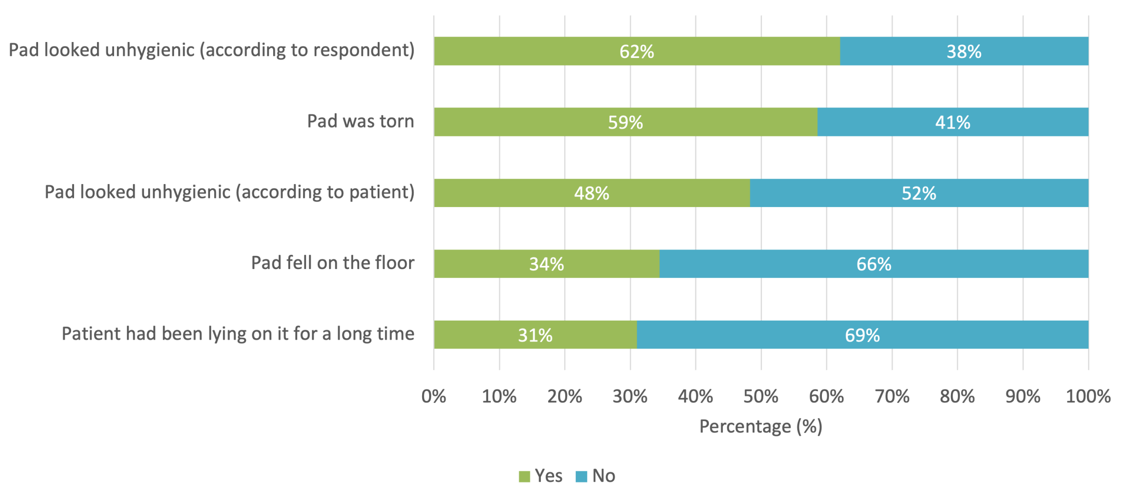

Figure A8: Reported reasons for replacing the disposable absorbent pad during the pilot study in the obstetrics department (n = 29). Respondents could select multiple reasons per case.

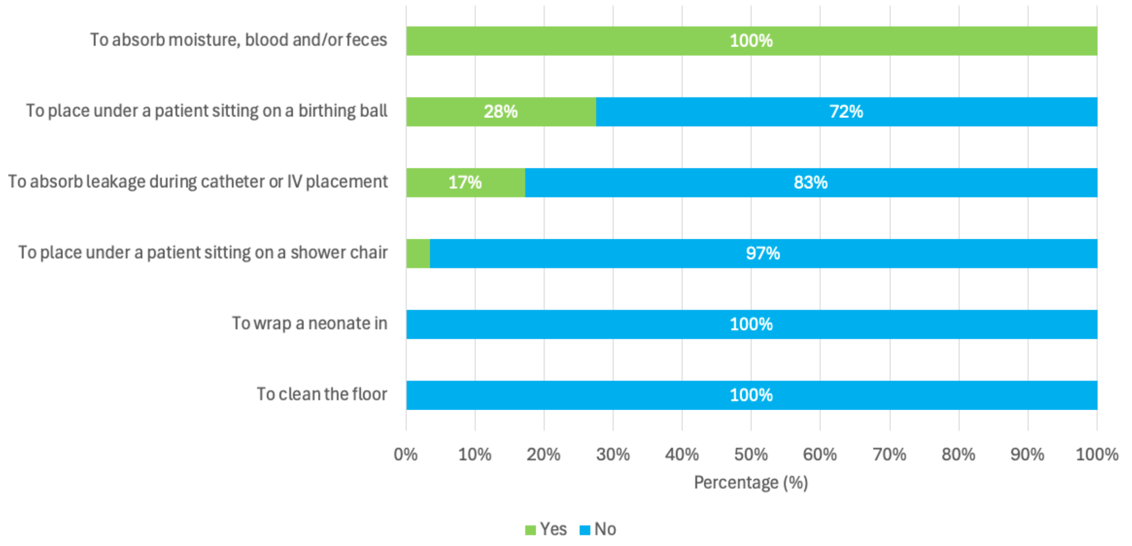

Figure A9: Reported reasons for using the reusable absorbent pad during the pilot study in the obstetrics department (n = 29). Multiple indications could be selected per respondent.

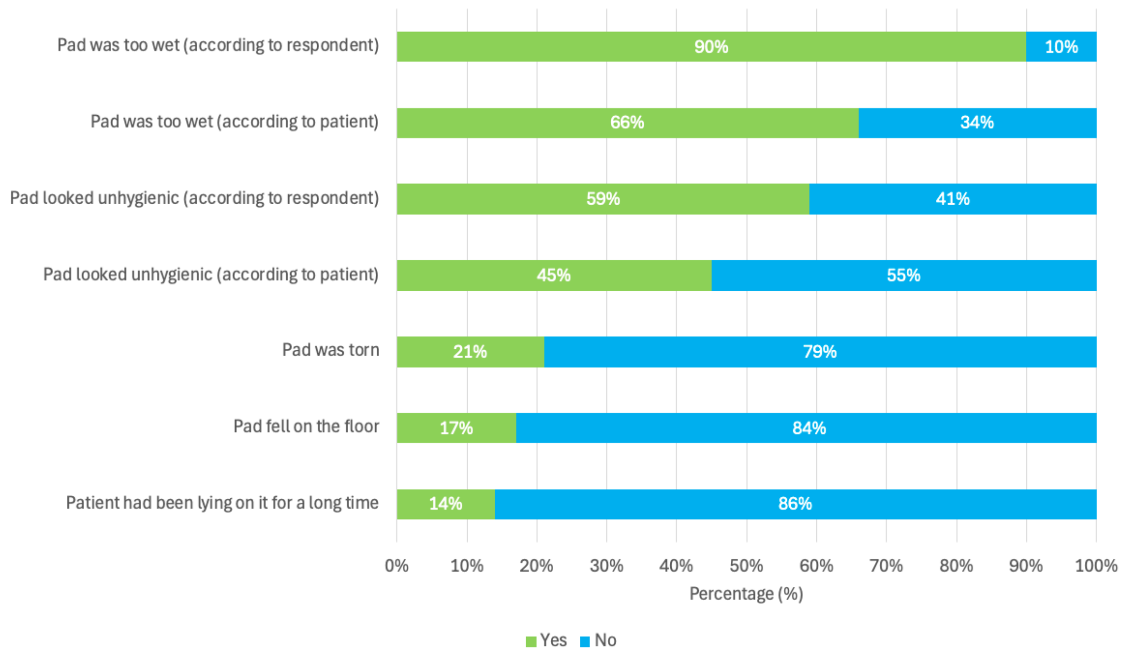

Figure A10: Reported reasons for replacing the reusable absorbent pad during the pilot study in the obstetrics department (n = 29). Respondents could select multiple reasons per case.

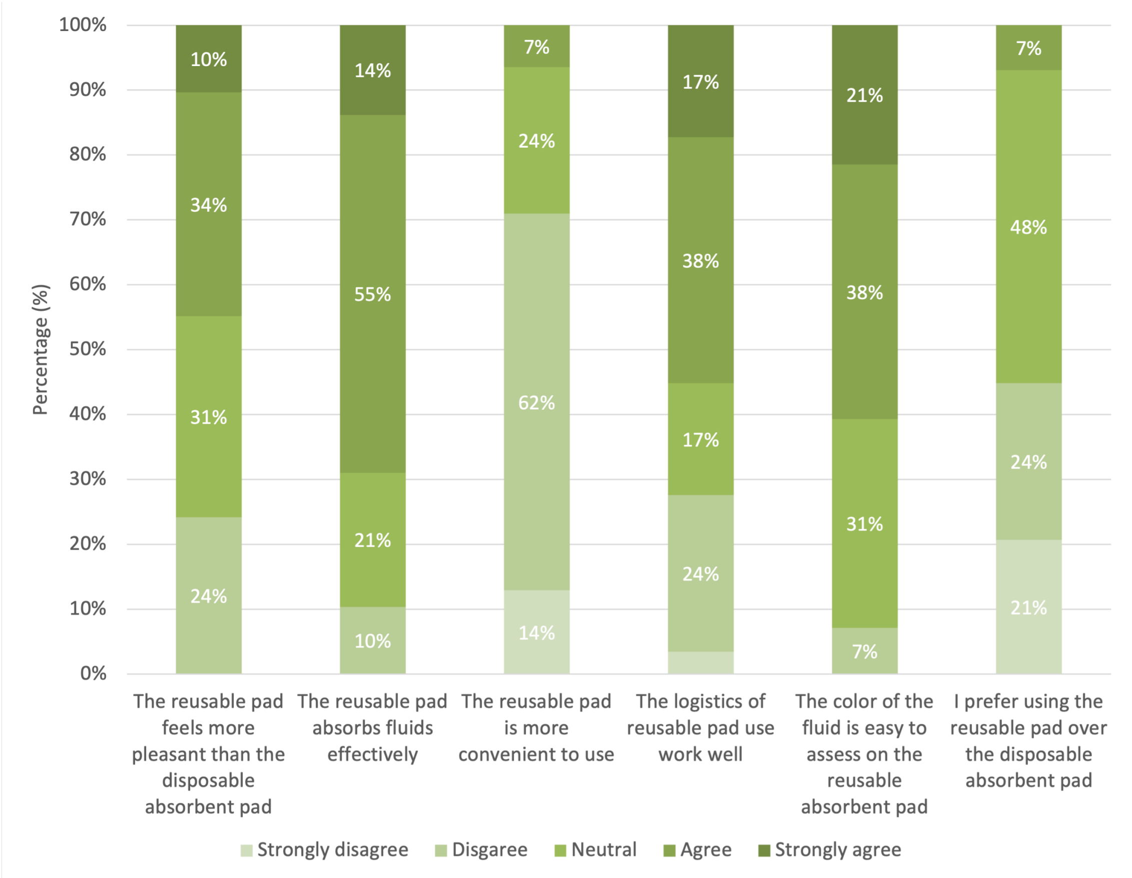

Figure A11: Responses from 29 obstetrics & maternity staff members on six statements comparing the reusable absorbent pad to the disposable absorbent pad. The chart shows the distribution across a 5-point Likert scale ranging from 'strongly disagree' to 'strongly agree'.

Table A4: Corrected Disposable Pad Usage Per Patient in Obstetrics (2025)

Month	**Total Disposable Pads**	**Patients**	**Pads/Patient**	**Pilot Period**
January	3450	1060	3.25	No
February	3530	908	3.89	No
March	2900	1040	2.79	No
April	3850	1022	3.77	No
Mean (Jan–Apr)	–	–	**3.42**	
May	2855	995	2.87	Yes
June	2810	924	3.04	Yes
Mean (May–Jun)	–	–	**2.96**	

Table A5: Descriptive statistics for age and years of work experience among participants in the Endoscopy Department (n = 10).

	N	Minimum	Maximum	Mean	Std. Deviation
Age (years)	9	35	64	46.89	10.068
Years in job	10	1	24	12.40	7.500

Table A6: Gender, job role, and previous product use (disposable mat and towel) of participants in the Endoscopy Department (n = 10).

	N	%
Gender		
Female	9	90%
Male	1	10%
Other	0	0%
Job		
Nurse	10	100%
Medical specialist	0	0%
Student	0	0%
Medical assistant	0	0%
Medical trainee	0	0%
Other	0	0%
Worked with disposable mat	10	100%
Worked with towel	10	100%

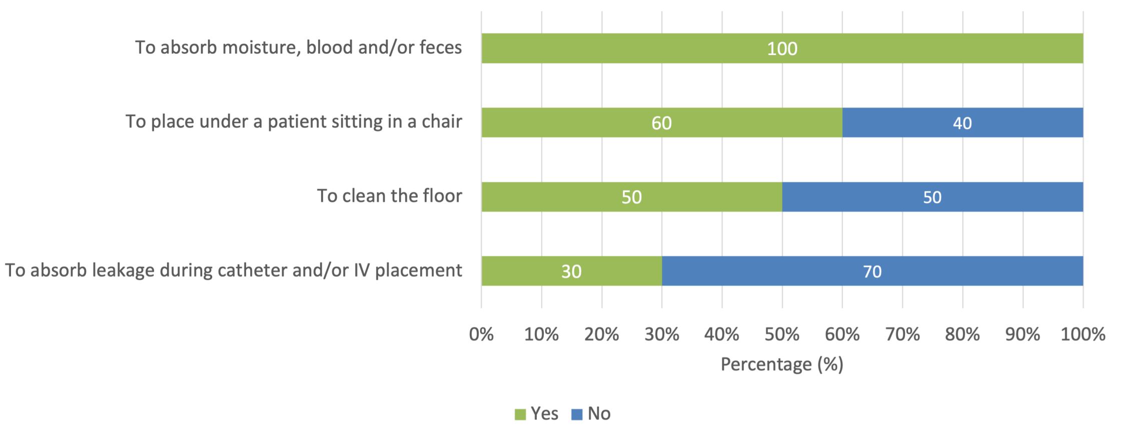

Figure A12: Reported reasons for using the disposable absorbent pad in the endoscopy department (n = 10). Multiple answers were allowed.

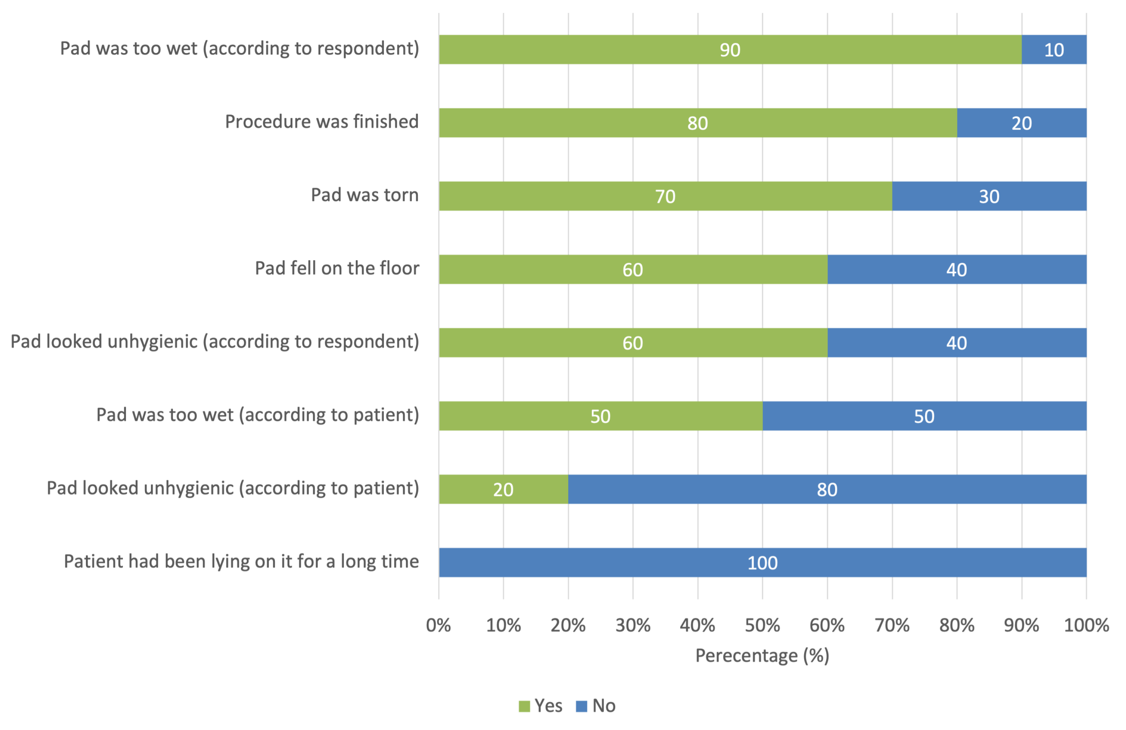

Figure A13: Reported reasons for replacing the disposable absorbent pad during procedures (n = 10). Respondents could select multiple reasons.

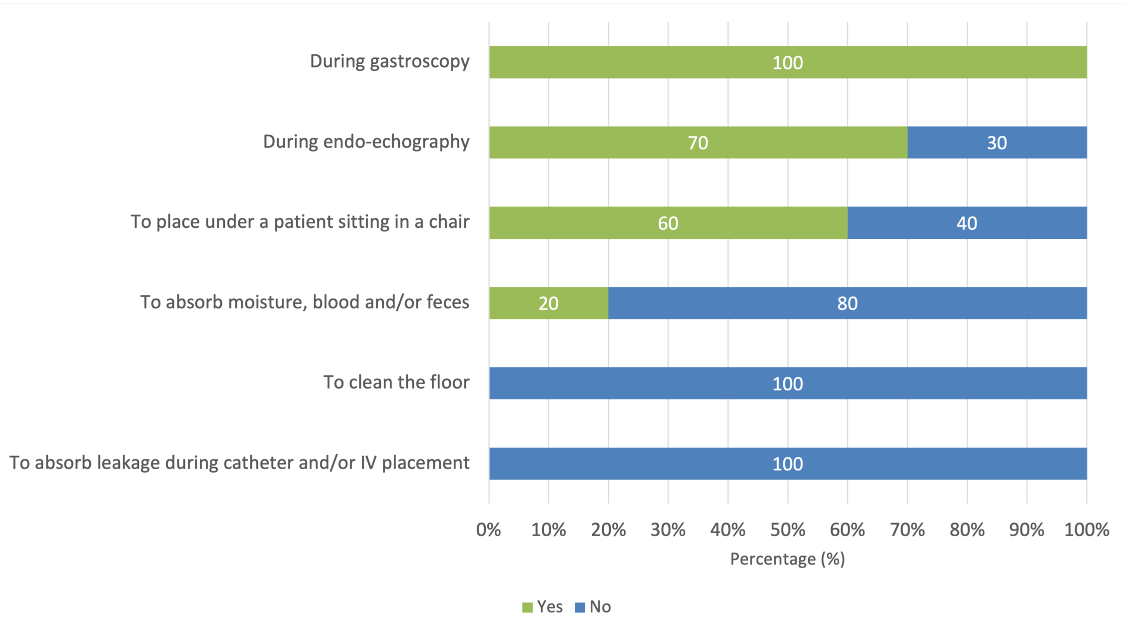

Figure A14: Reported reasons for using the reusable towel during the pilot study (n = 10). Multiple indications could be selected per respondent.

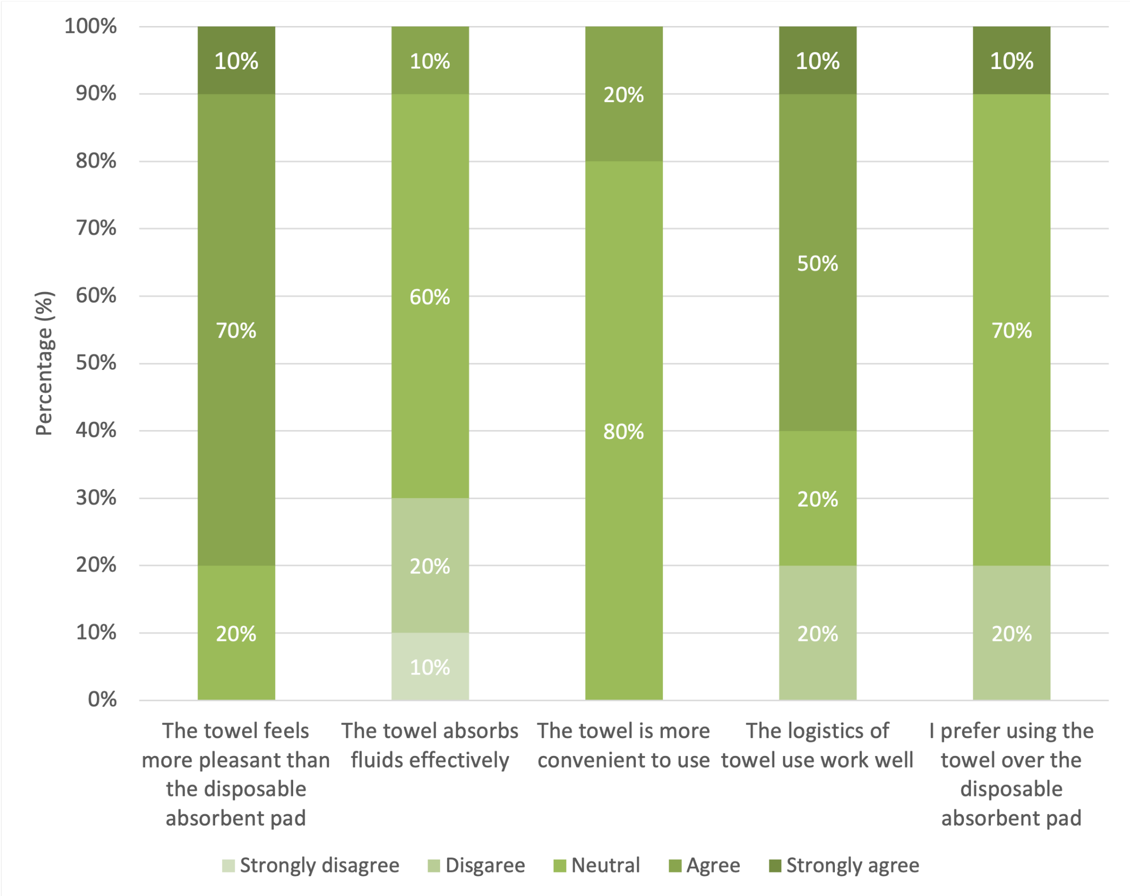

Figure A15: Responses from 10 endoscopy staff members on five statements comparing the reusable towel to the disposable absorbent pad. The chart shows the distribution across a 5-point Likert scale ranging from 'strongly disagree' to 'strongly agree'.

Table A7: Corrected disposable pad usage per endoscopic procedure (40x60 cm)

Month	Pads used (40x60)	Procedures	Pads per procedure
January	1400	900	1.56
February	1160	840	1.38
March	1400	872	1.61
April	1200	793	1.51
May	1120	835	1.34
June	1000	824	1.21

Table A8: Towel usage before, during, and after the pilot period in the Endoscopy department.

Time period	Total in period	Mean towels used per week
Pre-pilot (week 1–16)	735	46
During pilot (week 17–24)	780	98
Post-pilot (week 25–28)	320	80

Table A9: Comparison of mean ratings and effect sizes for disposable and reusable absorbent products in two hospital departments

Department	**Product**	**Mean (SD)**	**t**	**p**	**Cohen's *d* (CI)**
Obstetrics (n = 29)	Disposable pad	7.76 (1.24)	3.67	.001	0.681 [0.272, 1.082]
	Reusable pad	6.21 (1.66)			
Endoscopy (n = 10)	Disposable pad	8.60 (0.84)	5.58	< .001	1.765 [0.734, 2.761]
	Reusable towel	7.10 (0.99)			