HPRC
HEALTHCARE PLASTICS RECYCLING COUNCIL

Unlocking Recycling Potential: A Healthcare Plastic Packaging Sorting Pilot

Phase 2: Automated Sorting Trials of Medical Plastic Waste

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1. INTRODUCTION

Healthcare plastic packaging waste, generated in vast quantities by hospitals, clinics, and other healthcare facilities, represents a unique recycling challenge due to its specific material properties, contamination risks, and stringent regulatory requirements. However, effective collection and sorting of this waste stream has the potential to divert a significant fraction of these high-value resources from landfill and incineration, helping to reduce environmental impacts, conserve virgin resources, and support healthcare systems in meeting sustainability and circular economy commitments.

Building upon the insights gained from the initial study conducted in the Netherlands, HPRC Europe has completed a second-phase study based in Germany to investigate the feasibility and effectiveness of collecting and sorting healthcare plastic packaging waste at a more industrial-scale utilizing automated sorting technologies.

The original pilot demonstrated that with appropriate sorting technology and waste stream management, healthcare plastic packaging can be efficiently segregated as a relatively pure fraction suitable for recycling. This foundational work highlighted both the technical possibilities and emerging challenges associated with scaling such solutions to commercial levels.

The current study seeks to further investigate and enhance these findings by utilizing real-world, non-contaminated healthcare plastic packaging waste collected under controlled conditions to ensure sample integrity. The primary objective is to assess whether automated sorting systems can reliably process these materials at an industrial scale with sufficient accuracy and throughput to support sustainable recycling operations. The study will provide evidence-based findings for the collection, logistics, and handling of healthcare plastic packaging waste and look at ways to optimize the interface between waste generation points and recycling facilities.

By focusing on real-world waste streams and testing within the parameters of existing industrial infrastructure, this research endeavors to bridge the gap between theoretical feasibility and practical implementation.

2. BACKGROUND

2.1. First Pilot: Manual Sorting in the Netherlands

The first pilot, conducted in 2024 in partnership with UMC Utrecht (UMCU) and the National Test Centre Circular Plastics (NTCP), focused on a small batch of healthcare plastic packaging waste which was manually sorted. It demonstrated that sorting was technically possible and laid the groundwork for broader testing. Using existing hospital workflows without additional steps, the pilot confirmed that clean, well-segregated packaging waste can be efficiently sorted into distinct material streams suitable for recycling.

The pilot included both rigid and flexible packaging, excluding items such as sterilization wraps and shrink films because these already follow separate recycling streams at UMCU. This highlighted the need for tailored approaches by material type. The results confirmed strong technical feasibility and suggested that recycling healthcare plastics has strong potential for commercial scale-up, provided sorting rates remain high. However, the pilot also revealed key challenges: sorting at the point of use is complex, staff engagement and education are critical to minimizing contamination, and collection infrastructure must align with recycling standards to ensure economic viability. In addition, building sufficient volumes is essential to achieve economies of scale and make recycling programs sustainable.

Using these insights, the next phase expanded the scope and introduced advanced sorting technologies to test scalability and efficiency.

2.2. Second Pilot: Automated Sorting in Germany

For the second phase of the study, HPRC collaborated with Universitätsklinikum Bonn (UKB) in Germany to collect healthcare plastic waste from hospital operations. The materials were then processed at the TOMRA Test Center in Mülheim-Kärlich, Germany, using advanced sorting technologies.

This phase scaled up the process by testing automated sorting of all material types, focusing on rigid and flexible plastics, while assessing material purity under real-world conditions.

The trial provided insights into technical performance, contamination risks, and opportunities for improving pre-treatment steps, helping to define best practices for scalable recycling of healthcare plastics.

Figure 1. Ballistic separation unit to segregate flat, flexible from rigid materials

PARTICIPANTS
The project brought together partners with complementary expertise across the healthcare plastics value chain. HPRC coordinated the initiative, while CIRCULARMED played a crucial role in connecting the team with UKB and TOMRA, securing access to hospital waste streams and advanced sorting facilities. UKB provided real-world materials for testing, and TOMRA hosted the trials. HPRC members DuPont, LyondellBasell, Baxter, and Nelipak were on-site during the pilot day to support the process while Amcor and Eastman provided critical project support.

3. HOW WAS THE PILOT SET UP?

3.1. Step 1: Collecting Plastic Waste

At Universitätsklinikum Bonn, plastic packaging is routinely collected from 14 locations across the hospital campus three times per week. UKB's plastic packaging waste stream includes all non-hazardous plastic packaging from wards, pre-operating areas, canteens, and other hospital locations. After collection, these waste streams are sent to industrial-scale sorting and recycling facilities as an ongoing practice.

For this study, specific waste collection locations were selected to capture mainly flexible and rigid healthcare plastic packaging. The batch collected represents an unaltered sample of the waste flow from these locations during the collection period. In total, 8 cubic meters – or approximately 76 kg – of non-hazardous plastic packaging waste was gathered for the sorting assessment. The batch was collected in big bags, loosely placed without compaction. To ensure the sample reflected real-world conditions, no other manual pre-sorting or pre-selection was performed during collection. The waste batch was collected in August 2025.

3.2. Step 2: Sorting with Advanced Technology

The TOMRA Test Center in Mülheim-Kärlich, Germany, offers a comprehensive evaluation of sorting and recycling technologies for plastic packaging. A ballistic separator was first used to divide the waste batch into flexible and rigid material fractions, followed by optical sorting into PE, HDPE, PP, and PET streams.

Ballistic separation uses oscillating, angled decks with paddles to separate flat, flexible materials from rigid ones. Ballistic separation is typically performed on an industrial scale prior to optical sorting to improve accuracy, yield, and material purity, which is critical for achieving high-quality recycling.

While additional pre-processing steps such as non-ferrous metal removal via eddy current or light material removal via wind sifting are common in industrial settings, these were not applied in this trial.

After ballistic separation into flexible and rigid fractions, TOMRA's advanced optical sorting system (AUTOSORT™) was used to process both fractions separately, following standard industry practice. Both flexible and rigid fractions were sorted based on their prevalence in the batch following the guidance of Annex II of the Regulation (EU) 2025/040 (PPWR) and the RecyClass guidelines.

Table 1. Table 1 in Annex II of Regulation EU 2025/040 (PPWR)

Flexibles	Rigids
PE (polyethylene)	PP
PP (polypropylene)	PET bottles
PET (polyester)	PET trays
Other	PE (PE, HDPE)
	PS (PS, XPS, EPS)
	Other

Waste fractions were fed onto a moving conveyor belt to accelerate the material before passing under near-infrared (NIR) and visible light (VIS) sensors for detection. These sensors not only detect polymers but also other materials such as paper. When a target material was detected, the control unit activated compressed-air jets at the end of the conveyor, changing the trajectory of selected items for separation. The sorting line re-circulated non-targeted waste material back to the start via a conveyor system. The line speed was set at 3.0 m/s, resulting in throughput between 300 and 1,700 kg/h depending on the fraction. Both flexible and rigid material batches were processed in multiple passes to decrease the waste volume processed at a time and maximize sorting accuracy.

Figure 2. Conveyor belt (left) feeding flexible materials to near-infrared sensor (right)

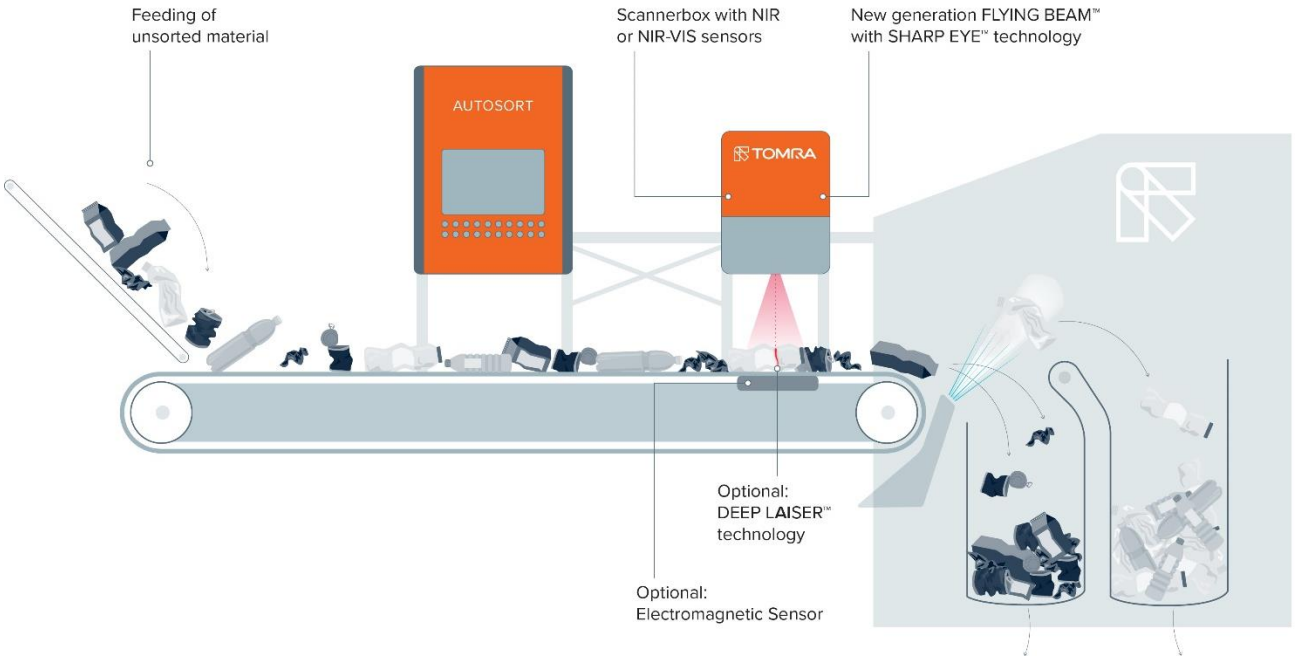


Figure 3. TOMRA's AUTOSORT™ equipment sorts objects by identifying their main polymer using near-infrared spectroscopy

4. SORTING RESULTS AND INSIGHTS

4.1. Preparing Waste for Sorting

Before any sorting took place, contaminants were manually removed from the batch based on visual inspection and safety considerations. Conventional automated sorting systems cannot identify packaging containing pharmaceutical residues, blood stains, or other potential contaminants, making safe processing more difficult. To enable viable and safe recycling, such contaminants, which can unintentionally enter the waste stream, must be prevented or removed at the source.

Potential Contaminants to Avoid

- Medicines
- Syringes
- Contaminated items with blood
- Bottles and IV bags with pharmaceutical residues
- Textiles
- Gloves
- Cleaning equipment
- Food waste

Ballistic separation sorted the waste into two fractions: 52 kg of flexible materials, such as films and porous webs, and 24 kg of rigid materials, such as rigid objects and thick-walled plastics.

Optical sorting further separated PE within the flexible fraction and PP, HDPE, and PET within the rigid material fraction, guided by estimated quantities in the stream. These estimates were derived from AUTOSORT™ point statistics, which calculate material shares based on the surface area of detected items on the conveyor belt. Sorting flexible fractions economically at scale requires dedicated equipment to increase the volume throughput as they are lighter and typically have a much larger surface area than rigid formats.

Due to safety concerns with manual handling of the material, the optically sorted fractions were not further processed for more detailed characterization, such as material properties and color distribution. Additional washing steps or decontamination (e.g. autoclaving) were not within the scope of the trial.

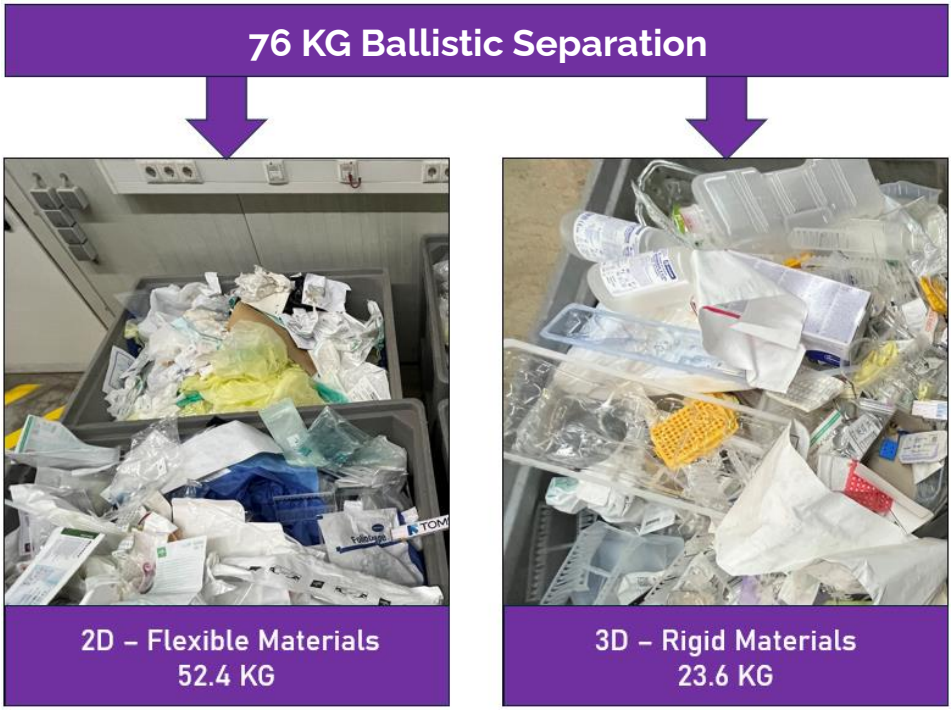


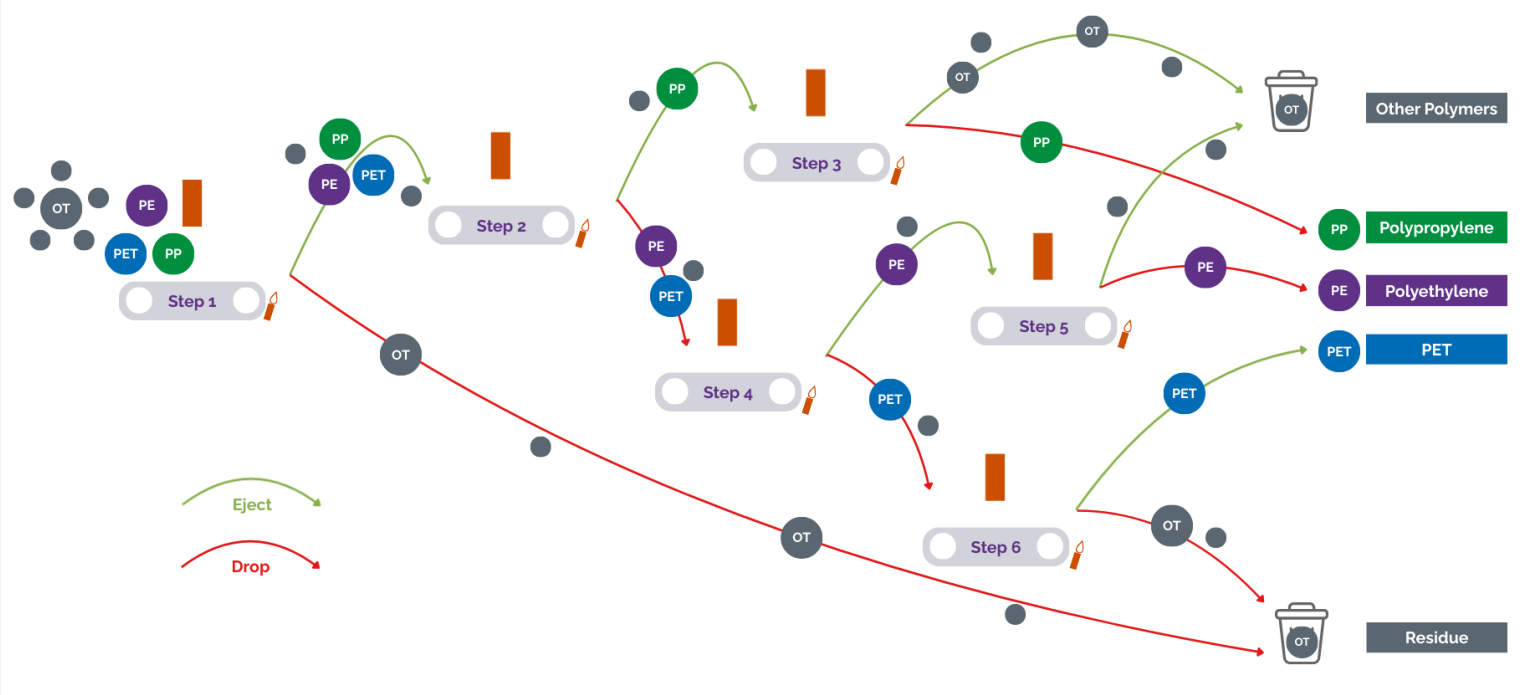
Figure 4. Results of ballistic separation

4.2. Rigid Plastics: Approach and Outcomes

A six-step optical sorting process was used to separate rigid fractions of PP, PE, and PET. This approach ensured that each target polymer, PP, PE, and PET, was sorted at least once positively (eject) and once negatively (drop), maximizing purity with the minimum number of sorting steps. The table presents the quantities of targeted polymers obtained from the rigid fraction.

Table 2. Quantities of targeted polymers obtained from rigid fraction

Rigid Materials		**Quantity**	**%**
Polypropylene		5.5 kg	24%
Polyethylene		4.3 kg	18%
PET		0.7 kg	3%
Other + Residues		*13.0 kg*	*55%*
	Total	**23.6 kg**	**100%**



Step 1: All three target polymers (PP, HDPE, PET) are ejected together, separating them from paper, other plastics, and unwanted materials.
Step 2: The PP fraction is ejected and separated from PE and PET.
Step 3: The PP fraction is further cleaned by ejecting any remaining non-PP polymers.
Step 4: The material dropped in Step 2 is processed to eject PE, creating a PE-rich fraction for Step 5.
Step 5: The PE fraction from Step 4 is cleaned by ejecting all remaining non-PE polymers.
Step 6: The PET fraction from Step 4 is cleaned by ejecting any remaining non-PET polymers.

Figure 5. Rigid fraction process

The large differences in sizes across both flexible and rigid material fractions created challenges for the sorting equipment, with objects ranging from large liquid containers (such as bottles and jerry cans) and unshredded plastic wraps to small pipette tips. The round shape of uncompacted bottles and containers often caused them to roll on the conveyor belt, preventing accurate detection and ejection. In industrial practice, this type of waste is typically compressed into bales for transportation, which flattens round items and mitigates this issue. To address size variability, initial screening is usually applied to remove both undersized and oversized materials.

Figure 6. Rigid PP items still containing undersized items like pipets and small test tubes

Figure 7. Small items such as pipette tips and medical device components

Figure 8. Optically sorted rigid materials output from Step 1 targeting and ejecting PE, PP, and PET

4.3. Flexible Plastics: Approach and Outcomes

Sorting was carried out using high-speed optical equipment with optimized airflow control (TOMRA's AUTOSORT™ SPEEDAIR) for sorting lightweight films and flexible packaging. Due to time constraints during the trials, only PE flexibles were targeted for sorting. As in the rigid material sorting sequence, purification was achieved through two consecutive steps: ejecting followed by dropping. This process resulted in 10.5 kg of PE flexibles, representing approximately 20% of the flexible fraction.

Table 3. Quantities of targeted polyethylene flexibles obtained from the flexible fraction

Flexible Materials		Quantity	%
Polyethylene		10.5 kg	20%
Other + Residues		41.9 kg	80%
	Total	52.4 kg	100%

The flexible fraction contained a significant amount of multi-layer films and multi-material structures, which is a common challenge in sorting flexible materials. For example, when plastic films are combined with paper in packaging, sorting accuracy decreases because the packaging may be identified as either paper or plastic, depending on which side faces the NIR sensor or if a paper label is attached to the plastic. In addition to paper, the flexible fraction contained structures incorporating aluminum foils. Items with a thick aluminum layer may be separated using eddy current sorting.

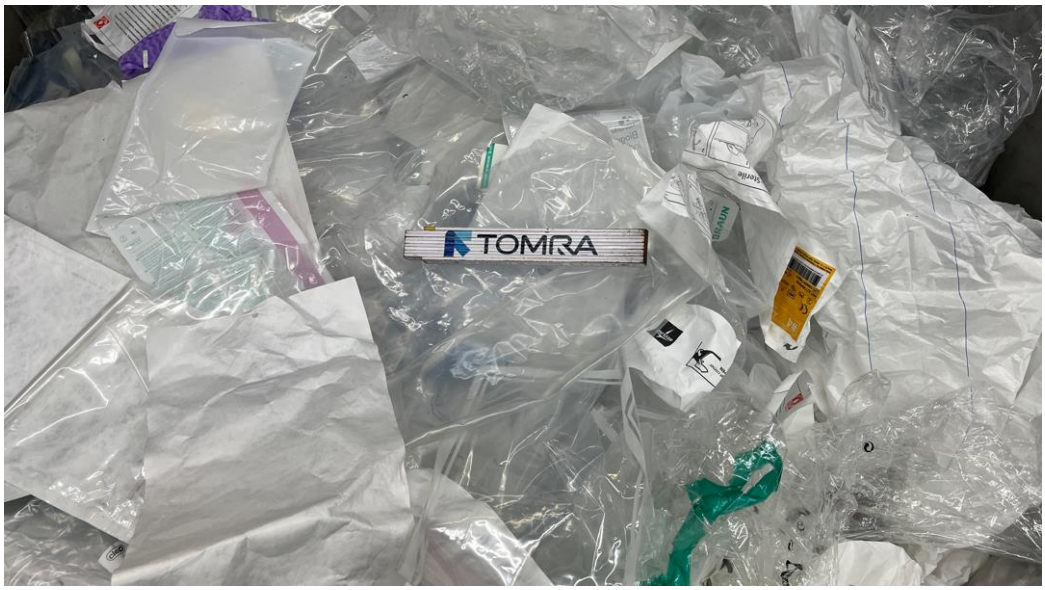


Figure 9. Optical sorting output of PE flexibles

Another challenge arose from the large surface area of some flexible packaging materials, which increased the risk of overlapping on the conveyor belt and led to incorrect sensor readings and expulsions. To reduce this risk, a lower throughput was applied to allow better spreading of items on the conveyor belt. In industrial practice, this fraction would typically have been wind sifted and shredded first to achieve a more uniform size distribution.

In the flexible waste stream, healthcare packaging formats such as pouches and bags are common. Pouches typically combine a film with a gas-permeable material to enable sterilization. One of the most widely used

materials for this purpose is Tyvek®, a flashspun HDPE material. Although it resembles paper at first glance, Tyvek® is entirely made of HDPE, making it tear-resistant and durable. In hospital settings, it is often mistakenly sorted into the paper waste stream, which should be avoided.

There is a visible structural difference between Tyvek® (left), and medical-grade paper (right) which can be seen by holding the material up to the light. Tyvek® should be sorted into the plastic waste stream.

Figure 10. Tyvek® (left) and medical grade paper (right)

5. WHAT DID WE LEARN?

5.1. Importance of Waste Stream Quality

Waste collected in the study was successfully sorted into flexible and rigid formats and then further sorted into specific material waste streams. This sorting process occurred on sorting equipment similar to that used in commercial consumer waste management facilities.

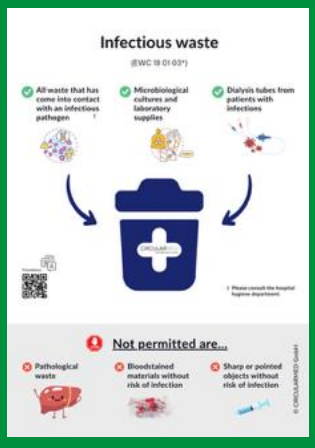
This study used a targeted healthcare packaging waste stream that was collected and fed directly into the sorting process. Under typical commercial conditions, the waste would be compacted and possibly screened by size before sorting. This may increase the sorting effectiveness and efficiency, for example, enabling more effective sorting of rigid compacted items.

In a hospital waste stream, the risk of contamination from blood, needles, or drug residues remains a critical concern. Methods for reprocessing contaminated hospital waste from existing waste streams are being developed; however, this is an expensive alternative and requires specific waste processing facilities. Accordingly, hospitals have a responsibility to ensure that packaging waste streams remain non-hazardous through appropriate segregation, staff training, and adherence to established waste-sorting protocols.

Ongoing Efforts to Standardize Hospital Waste Management

For hospital waste to be accepted by existing sorting and recycling centers, the risk of contamination must be further controlled. To address this challenge, efforts are underway to standardize hospital waste management practices. One such initiative, led by the regional German hospital association Krankenhausgesellschaft Nordrhein-Westfalen e.V. (KGNW) in collaboration with UKB, CIRCULARMED, and three other pilot hospitals, aims to establish an intuitive waste management system that reduces incorrect disposal, enhances recyclability, and ensures both healthcare worker safety and environmental protection throughout the process.

The draft waste management standard is currently being tested in these pilot hospitals. In parallel, digital solutions are being implemented to enable process tracking and transparency. Early in the project, education was identified as a critical success factor. To effectively reach all hospital staff regardless of language, posters featuring images and color coding have been developed. The standard for sorting and container management will be further refined based on pilot feedback and is scheduled for publication in 2027.



5.2. Automated Sorting Process Efficiency

For the rigid stream, this study effectively separated 45% of the rigid materials into the PP, PE, and PET recycling streams. The remaining 55% of other rigid materials were rejected and would be destined for incineration. With proper industrial pretreatment, the recovery rate is expected to be significantly higher.

In the flexibles stream, the process sorted a wide range of medical device packaging into the PE stream. Closer inspection showed this PE fraction contained multi-material films that may lead to compromises in the quality of the recycling stream.

Packaging and medical devices composed of multiple materials significantly complicate sorting and segregation. Ideally, these mixed-material components should be rejected during sorting; however, there is a substantial risk that they enter recycling streams, leading to contamination. Such contamination reduces the commercial value of the recovered material, making it less attractive to waste management companies—particularly when the waste is intended for mechanical recycling.

An alternative approach for recovering the value of waste is advanced chemical recycling. In this process, plastic materials like PE and PP are broken down into their basic chemical building blocks using heat, catalysts, or solvents. These building blocks can then be reused as feedstock, alongside fossil fuel-based feedstock to make new plastics of equivalent quality and specifications to virgin plastics. This process creates a circular system using the concept of mass balance to track the recycled component of the new material. Although more costly and energy-intensive compared to mechanical recycling, a significant advantage of chemical recycling is that it can produce virgin-quality recycled material from packaging waste, while it generally tolerates a higher degree of contamination from non-polyolefin materials.

5.3. Practical Tips for Waste Separation

Although sorting at the point of use is complex and challenging due to space, resources, and other critical priorities, it would help yield better results. Tailored approaches to healthcare plastic waste based on material type and form can lead to easier sorting and reprocessing.

Where clinical workflows allow, some multi-material packages could be sorted at the point of use by separating the lidding material from the rigid tray which are typically of different polymers and forms (e.g. PET rigid and PE flexible). However, handling packaging waste within a high-pressure hospital environment is a challenge. It requires the commitment of well-trained and motivated staff along with the proper procedures and facilities to make the process as easy as possible. Many hospitals are developing such systems including the Universitätsklinikum Bonn.

In the future, Artificial Intelligence (AI)-based object recognition could be effectively applied to further sort such waste streams and help remove unwanted contaminated items.

5.4. Smarter Design for Better Recycling

A more robust approach to support effective sorting and recycling would be to design packaging and medical devices to be recyclable, following the Design Guidance promoted by HPRC (as shown in the table below). Designing for recycling will not only make the process more effective and efficient but will also improve the value of the waste stream, encouraging take-up by waste management companies and providing a revenue stream for hospitals.

Desirable Design Practices for Healthcare Plastics

- Design with mono-material whenever possible.
- Use polyolefin seals or gaskets on polypropylene bottles.
- Combine chemically compatible or jointly processable plastics, if multiple materials are required.
- Use materials that are easily separated during automated recycling processes, if multiple materials are required.
- Use breathable plastics as an alternative to paper.
- Minimize paper labels and components.
- Use water-based adhesives.
- Allow for bottles and bags to be fully drained with ease before disposal.
- Provide information on contents that allows for easy identification of residual liquids.
- Minimize pigments.

Key Lessons

- This study has demonstrated proof of principle that healthcare packaging materials, collected within a hospital environment, can be sorted using commercial waste handling processes.
- Challenges remain in terms of the contamination risk and multi-component and multi-material packaging and devices.
- Medical devices and packaging should follow guidance to design for recycling to increase recycling efficiency.
- Sorting at the source can also increase recycling efficiency. This requires effective training, well-defined procedures, and enthusiastic coworkers.

ABOUT HPRC

HPRC is a private technical coalition of industry peers across healthcare, recycling, and waste management industries seeking to improve the recyclability of plastic products within healthcare. Made up of brand-leading and globally recognized members, HPRC explores ways to enhance the economics, efficiency, and ultimately the quality and quantity of healthcare plastics collected for recycling. HPRC is active across the United States and Europe working with key stakeholders, identifying opportunities for collaboration, and participating in industry events and forums.

For more information, visit www.hprc.org and follow HPRC on LinkedIn.