Blue Wrap Waste Stream Analysis

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Abstract

Blue sterilization wrap, made of spunbond-meltblown-spunbond (SMS) polypropylene, is a single-use plastic commonly used in hospitals to maintain surgical instrument sterility. At UVA Hospital, approximately 12 tons of blue wrap are discarded annually, contributing to the 225 million pounds of plastic waste generated across U.S. healthcare facilities yearly. Because polypropylene resists degradation and is difficult to process using conventional recycling methods, this waste stream presents significant environmental challenges. This project aimed to quantify the environmental impact of blue wrap disposal at UVA and evaluate its potential for recovery and reuse. A Life Cycle Assessment (LCA) was conducted to estimate environmental impacts such as greenhouse gas emissions, water use, and energy consumption. Processing experiments assessed the average melting rate of .12941 lbs/min and found that blue wrap could be melted without cutting, with smaller molds improving efficiency. Mechanical testing using dog-bone tensile samples showed that recycled blue wrap retained strong mechanical properties yet was variable, with Young's modulus and tensile strength approaching those of virgin polypropylene, supporting its potential for injection molding. Overall, this study demonstrates that blue wrap can be feasibly recycled tangent to hospital settings and repurposed into new materials. By diverting blue wrap from landfills and incinerators, healthcare systems can reduce their significant environmental footprint and advance scalable, sustainable waste management practices.

Keywords: Blue wrap, sterilization wrap, hospital waste stream, medical plastic reuse, sustainable healthcare, life cycle assessment (LCA), polypropylene.

Introduction

Hospitals in the United States generate a staggering amount of waste, over 6 million tons annually, with daily estimates ranging from 6,600 to 14,000 tons, making healthcare the second largest contributor to landfill waste after the food industry.[1-3] This immense volume not only strains landfill capacity but also drives significant greenhouse gas emissions and other pollutants, contributing to public health and environmental challenges. As the healthcare sector continues to grow, the need for more sustainable waste management practices becomes urgent.

A promising solution lies in adopting circular economy principles, which focus on minimizing resource consumption, extending product life cycles, and optimizing waste recovery through reuse, recycling, and repurposing. Applying circularity in hospitals means moving away from the traditional linear "take-make-dispose" model and instead designing systems that keep materials in use for as long as possible, reducing both environmental impact and operational costs.

To make meaningful progress, it's essential to analyze and target individual waste streams within hospitals. One particularly significant stream is blue wrap – a polypropylene plastic used to maintain the sterility of surgical instruments. Blue wrap alone accounts for up to 19% of surgical services waste and about 255 million pounds of hospital plastic waste each year in the U.S.[4,5] Despite being clean and highly recyclable, much of this material ends up in landfills, where it can persist for centuries. By focusing on waste streams like blue wrap, hospitals can implement targeted interventions-such as recycling, upcycling, or switching to reusable sterilization containers – to reduce their environmental footprint and advance toward a more circular, sustainable healthcare system.

Blue sterilization wrap is used by medical professionals all over the world to maintain the sterility of surgical instruments used in the operating room. Blue wrap is made of SMS (spunbond-meltblown-spunbond) Polypropylene, or #5 plastic, and it makes up about 19% of all waste in the surgical department according to the US Environmental Protection Agency.[5] The material works by allowing the sterilizing agent, typically steam, to pass through the pores and seal the pores to create a sterile environment. This creates a pouch for the instruments so that no contaminants can enter during the handling and storage of the instruments. However, since SMS polypropylene fabric is single-use, it is a significant source of environmental pollution. In the United States alone, 115 million kilograms on average is estimated to be thrown away yearly, contributing to pollution.[6] This has produced a significant amount of greenhouse gas of about 800,000 kg of CO2 over the last 10 years.[7] The University of Virginia (UVA) Hospital contributes 12 tons annually, which equates to roughly 11,000 kg, with a significant portion coming from operating rooms. Currently, UVA has no formal material recovery setup for this ample waste stream.

When blue wrap is discarded, it is typically landfilled or incinerated. As a non-biodegradable plastic, polypropylene can degrade in landfills for 20 to 30 years, contributing an estimated 1.95 to 3.5 kilograms of CO2 emissions per kilogram of plastic.[8] Landfilled polypropylene also contributes to the growing microplastic pollution. While controlled incineration of polypropylene can reduce waste volume and recover energy, it poses its own environmental drawbacks. Controlled incineration of polypropylene emits toxic compounds such as dioxins and furans, in addition to CO2, which contributes to GWP. Even with waste-to-energy strategies, incineration contributes approximately 2.3 to 2.8 kg CO2 equivalent per kilogram of polypropylene burned.[9] These values depend on the life cycle assessment method: the avoided-burden approach credits energy recovery by subtracting emissions from displaced fossil fuels, while the cut-off approach assigns all incineration impacts to the original product, providing reason for its higher estimates. These findings underscore the urgency of developing recycling solutions for hospital plastic waste, especially blue wrap, to avoid long-term environmental and health impacts while advancing more sustainable material recovery practices.

One such program addressing this issue is Halyard Health's Blue Renew program. This program helps hospitals connect with their local balers and start a blue wrap recycling initiative at their hospital. As of right now, 250 hospitals across the US have been enrolled in the program, and around 4 million pounds of blue wrap have been diverted from landfills each year. Once the blue wrap has been recycled, it gets turned into products via a proprietary blend BLUECON resin, a trademarked Halyard partner.[10] However, this approach has limitations. It relies on local recycling centers accepting blue wrap, and it is currently not available at UVA Hospital. Another challenge, especially for hospitals the size of UVA, is the cost-benefit associated with the program. The value of the services added to the hospital is around $6,000 per facility, however, the program takes the profits of the products made and sold from the recycled blue wrap. This situation is not ideal for a larger hospital that generates over 1 ton of blue wrap per month, and the $6,000 added value is minimal compared to the missed profits from their recycled blue wrap.

Another program is the Iron Mountain Sterilization Wrap Recycling service. This program handles the recycling of uncontaminated blue wrap at the Iron Mountain facility.[11] This wrap then gets processed into pyrolysis oil, which can be used to make new plastic products. However, high transportation costs to Iron Mountain facilities and limited transparency in publicly available data, particularly around carbon footprint reporting, make this option impractical for UVA Hospital.

At present, UVA participates in an internal reuse initiative through UVA's Medical Equipment Recovery of Clean Items (MERCI) program, which collects clean, unused medical supplies for donation to divert from landfills. They also collect blue wrap and repurpose it into reusable bags. While this represents a creative form of reuse, creating extra step of use, it is not scalable and eventually is still thrown away. The process ultimately delays, rather than prevents, disposal of the material.

Given the significant environmental impact and current limitations, this project aims to take a comprehensive approach to blue wrap waste management at UVA Hospital. The scope includes the quantification of blue wrap waste at UVA Hospital and an assessment of its total environmental impact through a Life Cycle Assessment (LCA). In addition, this project identifies barriers to remanufacturing, such as labels and adhesives on the blue wrap, by evaluating their impacts on blue wrap processing time. Sample recycled blue wrap is manufactured to assess their mechanical performance through material testing. Overall, this study intends to generate data-driven insights and design pathways for sustainable blue wrap recovery solutions for UVA Hospital, potentially scaled to other healthcare institutions.

Results

Life Cycle Assessment

To assess the environmental impact of blue wrap used at UVA Hospital, we calculated the impact data from producing the blue wrap used by UVA in a year, outlining its global warming potential (GWP), energy consumption, and water usage per kilogram of produced polypropylene (PP). These values were obtained from the openLCA ecoInvent polypropylene production, granulate location: RER, a resource that consolidates reliable data from manufacturers and life cycle analyses. As our study lacked the tools and resources to generate these values independently, we relied on this comprehensive dataset, which provided a foundation for evaluating the environmental impact. By multiplying the impact values per kilogram by the total annual weight of blue wrap used at the hospital, we calculated its specific environmental footprint across these key metrics. From our interviews with UVA hospital staff and MERCI, we chose the amount of blue wrap used by UVA in a year, 10886.2 kg, as our functional unit. Our analysis calculates the impact of producing all of this blue wrap and assumes all blue wrap heads to landfill. The resulting environmental impact is meant to show the lost energy in landfilling this recyclable material and make a case for implementing a recycling program.

Our analysis focused specifically on the life cycle stage of production of blue wrap. The results revealed that the annual usage of blue wrap at UVA Hospital contributes to 169.375 cubic meters of water consumption, 22,901.12 kilograms of CO_2 equivalent emissions to global warming potential, and 5,248.04 megajoules of energy consumption. These findings are summarized in Table 1 below:

Table. 1. LCA Calculations

Impact Category	Impact Per Kilogram	Annual Impact	Unit
Water Usage	0.01555869166	169.3753403	m^3
Global Warming Potential	2.103679521	22901.11807	kg^2 CO_2 eq
Energy Consumption	0.4820811841	5248.041828	MJ

Contextualizing these findings provides a clearer perspective on their real-world implications. The energy consumption associated with the lifecycle of blue wrap is comparable to running a flat-screen TV continuously for over 86 years, while the water usage equals filling a bathtub roughly 639 times. The GWP represents the carbon emissions generated by driving an average gasoline-powered passenger vehicle for approximately 58,319 miles. These comparisons help visualize the substantial resource demands and emissions tied to the hospital's reliance on polypropylene blue wrap.

Despite these significant impacts, several approaches can mitigate the environmental footprint of blue wrap. Repurposing blue wrap into reusable products offers a practical and creative solution to extend the production impact across several uses. Programs such as the Blue Wrap Project at Flagstaff Medical Center demonstrate how blue wrap can be transformed into items like durable bags, sandbags, and garment covers, effectively reducing waste and supporting sustainable practices[12]. Transitioning from single-use blue wrap to reusable sterilization containers (RSCs) is another promising option, as studies have shown that adopting RSCs can reduce carbon footprints by up to 85 percent and yield notable improvements in other environmental metrics.[13] Additionally, optimizing sterilization procedures to minimize the quantity of blue wrap used can further reduce its environmental impact, while exploring alternative materials, such as biodegradable or compostable options, presents a promising pathway for long-term sustainability.

Ultimately, expanding and improving recycling programs for blue wrap holds the greatest potential for reducing its environmental footprint on a large scale. By increasing collection, improving sorting and processing infrastructure, and supporting markets for recycled polypropylene, hospitals can significantly cut greenhouse gas emissions, conserve resources, and move toward a more sustainable, circular system for medical plastics.

Through such efforts, hospitals can reduce their reliance on blue wrap and make meaningful strides toward mitigating its environmental impact. This work aims to understand the impact of current blue wrap disposal methods to highlight the impact of adopting a recycling program to divert blue wrap from landfill/incineration.

Landfills remain the primary destination for municipal solid waste (MSW) in the United States, receiving about 75–86% of discarded plastics, including a significant portion of polypropylene waste[14]. In 2018, U.S. landfills accepted 27 million tons of plastic, representing 18.5% of all landfilled MSW.[14,15] While plastics themselves do not readily decompose, over time they can release microplastics and leachate into the environment. Limited landfill capacity is an increasing concern in some regions, leading to higher costs and the need to transport waste farther, particularly in urbanized areas. Although plastics do not generate methane directly, methane emissions from organic waste decomposition in landfills contribute significantly to global warming.[16,17] The global warming potential (GWP) impact from landfilling plastic waste is relatively low compared to incineration but contributes indirectly through landfill gas emissions.

Incineration, or waste-to-energy combustion, is used for about 9–16% of U.S. plastic waste.[18] Some blue wrap waste is incinerated, especially in medical settings where contamination is a concern. Incineration reduces waste volume and can generate energy, but it also produces significant greenhouse gas emissions-burning one ton of plastic emits approximately one ton of CO_2-and releases toxic ash and air pollutants like dioxins and heavy metals.[19] These emissions raise environmental and health concerns, and the ash must be landfilled, perpetuating some environmental impacts. The GWP for incineration is substantially higher than landfilling due to direct CO_2 emissions.

Recycling rates for plastic in the U.S. remain low, with only about 5–9% of plastics recycled as of 2021.[20] Polypropylene recycling is particularly challenging due to contamination and lack of consistent collection infrastructure. The recycling process involves collecting, sorting, cleaning, and reprocessing plastics into new materials. Recycling significantly reduces environmental impacts by lowering greenhouse gas emissions by approximately 18–23% compared to producing virgin plastics and uses 65–70% less fossil energy and 48–55% less water.[21] While some programs target hospital blue wrap for recycling, the majority is still landfilled or incinerated. Efforts to improve recycling include advanced sorting technologies, policy initiatives mandating recycled content, and education to reduce contamination. Strengthening extended producer responsibility (EPR) policies and increasing government investment in domestic recycling infrastructure could also improve outcomes. Programs like the U.S. Plastics Pact aim to boost recycling rates and promote circular economy principles, but significant barriers remain, including economic viability and market demand for recycled materials.[22]

This comparison highlights that while landfilling is currently the dominant method, it poses long-term environmental risks and space limitations. Incineration reduces waste volume and produces energy but at the cost of high greenhouse gas emissions and toxic pollutants. Recycling offers the greatest environmental benefit by reducing greenhouse gas emissions and conserving resources but requires significant improvements in infrastructure and market demand to scale effectively (Table. 2).

Table. 2. Environmental Impact of Plastic

Waste Management Method	Approximate GWP per Ton of Plastic	Energy Use	Other Environmental Impacts	U.S. Plastic Waste Share
Landfilling	Low (indirect methane emissions)	Low	Microplastic pollution, leachate, land use	75–86%
Incineration	High (~1 ton CO_2 per ton plastic)	Moderate (energy recovery possible)	Toxic emissions (dioxins, heavy metals), ash disposal	9–16%
Recycling	Lowest (18–23% less than virgin plastic)	65–70% less than virgin production	Reduced resource extraction and pollution	5–9%

Processing Rate Experiment

We found that recycled blue wrap must undergo processing before it can be repurposed. This includes removing sterilization indicator tape and labeling stickers, as well as evaluating the material's overall quality (e.g., presence of contaminants, size, or tears). These steps are essential because leftover adhesives, composed of different materials with varying melting points, can weaken the composition and durability of the melted plastic and cause air bubbles to form. To better understand the requirements and efficiency of processing, we conducted experiments to assess the rate at which blue wrap can be processed and to evaluate different melting approaches for reuse.

The first experiment investigated the pre-processing rate of blue wrap, aiming to quantify workload to inform process standardization. We began by counting stickers and tape on several sheets of blue wrap. On average, each sheet had about 7 pieces of tape, regardless of size, and about 2-3 stickers with labeling. Three participants then completed two ten-minute trials to see the rate at which the stickers could be removed and binned along with the blue wrap. The rate of removal was measured in pounds per minute (lbs/min), and the weight of processed blue wrap was recorded.

In Trial 1, participants processed an average of .9675 lbs of blue wrap, while in Trial 2, it increased to 1.6207 lbs, with standard deviations of .5593 and .2434, respectively. The corresponding average rates were .0968 lbs/min and .1621 lbs/min, with the increased rate in Trial 2 suggesting that participants developed a more efficient technique for adhesive removal and worked with greater focus. Across both trials, the combined weight of the removed stickers and tape was 0.44 lbs. This highlighted the importance of worker attentiveness and consistency, as some labels and tapes were small, torn, or difficult to identify, increasing the risk of contaminating the final product.

The second experiment tested the melting process. In the first trial, we used a large rectangular tray (10in x 13in) containing 163.4 grams of blue wrap sheets and 82 grams of rigid #5 plastic from shredded pipette tip boxes. The sample was prepared to be melted at 384°F, just below the melting point of polypropylene, which is approximately 340°F.[23] After 21 minutes, approximately half of the material had melted. To encourage full melting, we added 159.6 grams of rigid plastic and continued heating for 23 more minutes. Finally, after cooling for 28 minutes, the material was removed from the tray.

The second melting trial used two smaller rectangles (4.125in x 4.125in; 3.5in x 6.125in) and a slightly lower temperature of 382°F. The mold had a combined 83.9 grams of blue wrap and 35.2 grams of rigid plastic. The materials fully melted in 22 minutes and, after being placed under a sheet press, cooled and set in just 6 minutes. This trial was more successful, with shorter melt and cool times and noticeably easier mold extraction.

During experimentation, we observed two types of sterilization indicator tape – blue and yellow– indicating a lack of standardization in blue wrap packaging and sterilization preparation. The yellow tape was significantly easier to peel off despite breaking more and was less likely to catch as much blue wrap in removal as the blue tape did. This variation, along with inconsistent sticker sizes and adhesive types, made pre-processing more labor-intensive and posed risks to the structural integrity of the final melted material. Trial participants need to develop a useful technique to quickly and efficiently remove tape and should be focused on efficiency when completing the task.

Based on our findings, we recommend considering alternatives for sticker labels, such as embossing or imprinting. This would reduce processing time and labor intensity, making implementing large-scale applications easier. Standardizing tape application and removal methods (e.g., using the same indicator tape, starting from a corner, and peeling back cleanly) could also improve efficiency. Finally, it may be worth considering melting blue wrap sheets in smaller sizes since it appeared to improve melting time and consistency, reduce cooling time, and simplify extraction, factors that are critical when considering large-scale implementation or in-house manufacturing.

These findings support our primary goal of repurposing blue wrap by demonstrating that with proper preprocessing and optimized melting methods, it's feasible to transform waste material into usable, durable products. Our experiments identified key barriers, such as adhesive removal, and offered strategies to address them through design changes or process standardization. The smaller mold trials also suggest practical directions for scalable, in-house recycling, strengthening the hospital's potential cost-benefit case for reusing this material. We believe that items such as trinkets, trays, storage containers, or non-sterile medical accessories could be produced using methods like injection molding. With further refinement, this approach could help reduce waste, lower material costs, and support circular practices within hospital operations.

Material Testing

Fourier Transform Infrared Spectroscopy

To confirm that the chemical composition of the blue wrap material matched the manufacturing labeling of #5 plastic, polypropylene, we conducted Fourier Transform Infrared Spectroscopy (FTIR) analysis. FTIR is an analytical technique for identifying materials based on their infrared absorption spectra, which reflect the vibrational modes of molecular bonds. Two blue wrap samples were selected, one for the blue side and one for the white side. As well as one recycled sample, our pilot sample of blue wrap mixed with shredded #5 plastic from pipette boxes and melted into a sample sheet as experiment two describes. The resulting spectra were compared to those of reference polymer data. A hit quality index (HQI), scaled out of 1000, was used to quantify the similarity between each sample and the reference; a higher HQI indicates a closer match to the original polypropylene spectrum.

Both blue wrap samples showed general spectral agreement with the original polypropylene reference. However, an absorption spike was observed around 2300 cm^{-1} in both samples, suggesting the presence of an additive. The HQIs for the two samples were 632 and 642, respectively, indicating moderately strong spectral matching to polypropylene (Fig. 1 & 2).

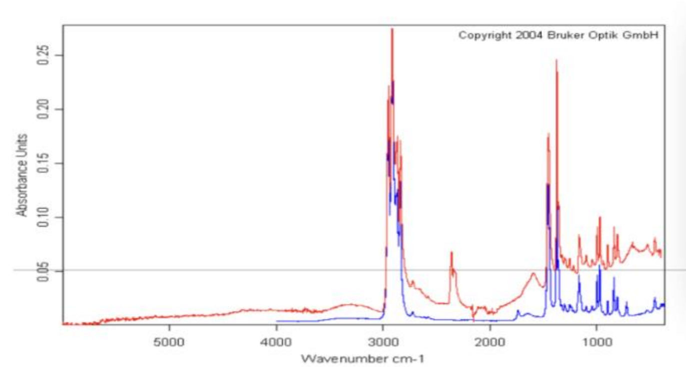

Fig. 1. FTIR Spectrum of Blue Wrap (White Side) Sample. Hit quality index: 632.

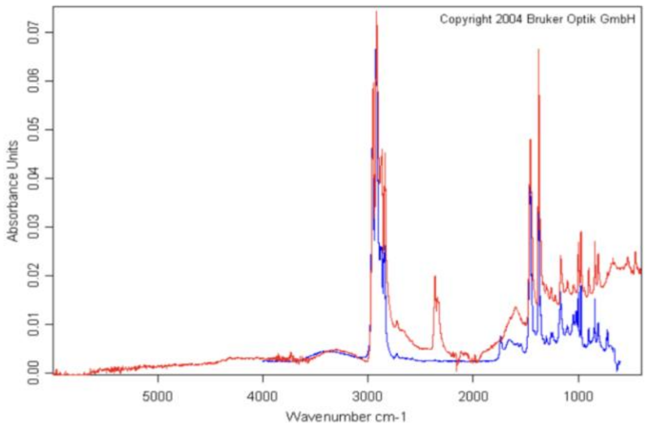

Fig. 2. FTIR Spectrum of Blue Wrap (Blue Side) Sample. Hit quality index: 644.

The blue wrap-pipette box mixture sample exhibited a higher HQI of 803, indicating stronger spectral matching to polypropylene reference data compared to the blue wrap samples. However, the absorption spike around 2300 cm^{-1} was still present in this sample. This suggests that the addition of the recycled pipette box material may enhance the overall material resemblance to the original material, while the unknown components require further analysis (Fig. 3).

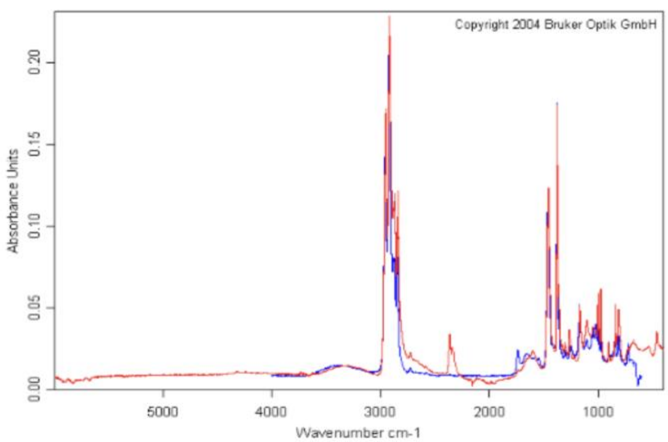

Fig. 3. FTIR Spectrum of the Blue Wrap-Recycled Pipette Box Mixture. Hit quality index: 803.

Tensile Strength Testing

In addition to confirming material composition, tensile strength testing was conducted to evaluate the mechanical integrity of the blue wrap material, which reflects a material's ability to resist breaking under tension, especially crucial when considering potential repurposing and remanufacturing applications. Two Dog bone-shaped specimens were prepared using a recycled pipette box to a blue wrap ratio of 6:4. The sample was sheet pressed, as injection molding was not available. The measured load and elongation data from the tensile testing machine were utilized to generate the stress-strain curve (Fig. 4).

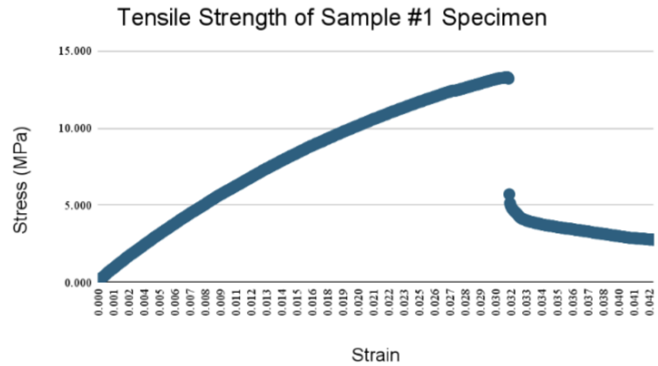

Fig. 4. Stress-Strain Curve of the First Specimen. The first specimen is composed of a recycled pipette box-to-blue wrap mixture in a 6:4 ratio.

From this curve, Young's modulus and ultimate tensile strength (UTS) were determined. These values were then compared to standard values for virgin polypropylene.

Table. 3. Mechanical Properties of Original Polypropylene and the Samples

Material	Young's Modulus (GPa)	Ultimate Tensile Strength (MPa)
Original Polypropylene	2	29
Sample #1	0.68	13.29
Sample #2	1.11	24.81

Compared to the original polypropylene, which typically exhibits a Young's modulus of 2 GPa, the tested samples displayed significantly lower values, with Sample #1 showing 0.68 GPa and Sample #2 showing 1.11 GPa. These results indicate that the samples are more flexible, and the mechanical rigidity of the recycled material is lower. The UTS of the tested samples was lower than that of the original polypropylene. Sample #2 showed a value closer to the original, with a UTS of 24.81 MPa, while Sample #1 displayed a significantly lower value of 13.29 MPa. The overall lower UTS suggests a decrease in the material's ability to withstand high mechanical tension, potentially limiting its ability to be repurposed in applications that require high durability (Table. 3). The variation in UTS values between the two samples may be attributed to the flawed creation of the specimens. Historical testing of recycled #5 plastic from the pipette box shreds showed a more promising material result, with high resemblance to virgin polypropylene. Due to the lack of access to an injection molder, a sheet press was utilized instead, which likely caused inconsistencies in the samples.

Future testing using injection molding is necessary to obtain more accurate and reliable results.

Current Recycling Process

At UVA Hospital there is currently no blue wrap recycling process. However, there is currently a collection initiative by UVA's Medical Equipment Recovery of Clean Inventory (MERCI) program. This group receives collected clean blue wrap and is not present in the OR during surgery. From shadowing Dr. Meyer, an anesthesiologist at UVA Hospital, we learned that the success of collection efforts is contingent on the initiative of operating room nurses. The hospital has dedicated bins from UVA's Medical Equipment Recovery of Clean Inventory (MERCI) program that are meant to collect clean blue wrap, however, this is not a standardized process. A barrier in standardization is the tightly scheduled workflow in operating rooms, leaving little time for extra responsibilities like collecting clean blue wrap for recycling. These bins can be brought in by nurses on a case-by-case basis and what they deem as "clean" gets collected. However, this poses several challenges. Not only is the full burden of recycling on the nursing staff, but due to the fast-paced nature of their job, the current process is not practical for every procedure. Additionally, this information may not be presented to them during onboarding and is often something learned by word of mouth.

Once received by MERCI, clean blue wrap is manually sorted by size and bagged. MERCI currently receives an estimated 7.8 tons of blue wrap per year, equivalent to about 15 bags (each weighing about 20 pounds) per week. Of these, 10–12 bags are distributed to community members, amounting to approximately 5 tons annually. This leaves an estimated 2–3 tons of blue wrap discarded due to overflow. From shadowing at MERCI, we learned that blue wrap sent to community members is sewn into reusable bags and dog beds which puts blue wrap back into a second cycle of use. Rather than truly recycling the material, this adds an extra step before it ultimately becomes waste. This is not a scalable process and is currently not regulated or standardized. Because the reuse process relies on proper sorting and handling of the blue wrap from the nurses, any lapses in cleanliness can undermine its safety and effectiveness. In a processing rate experiment done by our team, several samples labeled as 'clean' were found to contain contaminants, raising further concerns about the feasibility and safety of reuse or recycling pathways. Because there are no clearly established standards for what constitutes as "clean" blue wrap, the reliability and scalability of the current system are limited. Given these findings, our team proposes a scalable pilot program that can be implemented at UVA Hosptial and expanded to other hospitals.

Pilot Program

The UVA Hospital Blue Wrap Recycling Pilot Program builds on existing collection and sorting efforts by introducing a comprehensive process to repurpose blue wrap into useful products and track impact. From our findings we propose a pilot to focus on Dr. Meyer's operating rooms to test collection methods, evaluate preprocessing techniques, and develop end uses for the recycled material. A visual overview of the pilot program structure is shown in Figure 5. The goal is to establish a closed-loop, circular system in which blue wrap waste is not just diverted from landfills but transformed into useful products for the hospital itself.

Step 1: Blue Wrap Collection

A major barrier to effective blue wrap recycling is the lack of a standardized collection process. Currently, OR nurses must manually bring in MERCI bins from elsewhere in the facility and sort and collect them. This puts a burden on them and disrupts the workflow of the OR. To address this, the first step of the pilot will focus on improving collection at the source by reintroducing clearly labeled MERCI bins inside Dr. Meyer's operating rooms, making the process more accessible and intuitive. By bringing the bins into the OR environment, we aim to integrate recycling into the surgical workflow with minimal disruption.

However, to determine whether this approach is truly effective, we need to collect input directly from OR nurses as they will be using this program the most. Surveys will be used to assess optimal bin placement for visibility and accessibility, evaluate which types of signage or labeling are most intuitive, and identify what kinds of training, reminders, or feedback mechanisms would best support consistent participation. This co-creation process ensures that the collection system is designed with the staff to increase the likelihood of participation and long-term success. Pilot data will also include observations of bin usage and the quantity and condition of collected wrap over several weeks.

Step 2: Blue Wrap Sorting

Once blue wrap is collected from Dr. Meyer's operating rooms, it will be transported to the MERCI facility. While MERCI currently estimates that it receives approximately 7.8 tons of blue wrap annually, there is no precise system for measuring how much is collected. To better evaluate the environmental impact of this program, the pilot will implement a standardized measurement system for every bag of blue wrap received. Each bag will be weighed, logged, and tagged with its origin and date of arrival. Key metrics such as total weight, number of bags per week, and proportion of bags deemed acceptable for recycling will be recorded consistently throughout the pilot period. This will provide quantifiable data on the volume of blue wrap successfully diverted from landfills and trends in weekly collection volumes.

The pilot will also explore creating a baseline metric for blue wrap use per surgical procedure, by tracking the number of procedures performed in Dr. Meyer's ORs and correlating this with the amount of wrap collected. By establishing a system of measurement and accountability at this stage, the pilot aims to make blue wrap recycling a trackable and scalable part of hospital operations. Blue wrap will be sorted by size and shipped to be recycled by our proposed recycling system.

Step 3: Preprocessing

Before the blue wrap can undergo reprocessing to be melted and reformed, it must be cleaned of non-polypropylene elements such as tape, stickers, and other contaminants. This step is also where blue wrap will be checked again to ensure that no bodily fluids have contaminated the material. This step is both labor-intensive so during the pilot program, shredding techniques and alternatives to stickers will concurrently be explored. Some possible techniques include manual removal using tools such as scrapers, heat-based or solvent-based methods to ease sticker removal, or semi-automated sticker-removal device. Additionally, preprocessing may include shredding the wrap to get rid of air bubbles in melted plastic when whole sheets of blue wrap were melted. This step is an opportunity to collaborate with other teams working on developing these technologies.

Step 4: Reprocessing/Recycling

Once preprocessing is complete, the cleaned blue wrap will undergo reprocessing by being melted into raw material blocks or pellets. This will be done using a Polyvora SheetPress V4 X which will melt the blue wrap at range that we found in our experiments. The product of this process is rigid plastic sheets measuring 3 ft x 3 ft x 0.5 in, which can serve as raw materials ready for manufacturing. The primary goals of this step are to validate the quality of the resulting recycled material by re-running material property tests to ensure it is consistent with known polypropylene standards. This step is also where different melting temperatures and times will be tested to optimize material quality. Additionally, blends of blue wrap with other polypropylene sources, such as pipette tip boxes, will be evaluated to determine how different ratios affect the durability and flexibility of the repurposed material. The insights gained from this pilot and pressing process will inform scaling efforts, enabling broader implementation of blue wrap recycling programs within hospital systems. By standardizing sheet production and validating recycled material performance, this step lays the groundwork for a sustainable circular pathway for polypropylene waste.

Step 5: New Product Manufacturing

The recycled blue wrap will then be used to make new products. This pilot phase will focus on making simple, low-risk products that have clear internal use cases at UVA Hospital such as bedpans, bins, and key chains. At the same time, we will begin establishing partnerships with both manufacturers and UVA Health to identify internal needs that can be met with recycled blue wrap. This includes exploring opportunities to supply raw material or finished products to different departments. The long-term goal is to develop a circular economy within UVA Health where materials that were previously discarded are transformed into tools, equipment, or even gift shop merchandise to support hospital sustainability.

Step 6: Redistribution

The recycled products will be distributed back to UVA Hospital for use. This redistribution is essential to closing the loop and allows the hospital to visibly benefit from its own waste reduction efforts. In addition to promoting environmental sustainability, these products serve as educational and advocacy tools to engage staff, patients, and visitors in the initiative. Pilot feedback from nurses, patients, procurement officers, etc. will be gathered to evaluate product effectiveness and expand to more complex items.

Step 7: Data Collection

Throughout every stage of the pilot, data will be collected and analyzed to inform future decisions. Currently, estimates of blue wrap usage, disposal, and recycling are based on rough counts, and there are significant data gaps particularly from UVA Health Procurement and MERCI. Procurement lacks clear records on the volume of blue wrap purchased by the department, and MERCI does not consistently track the quantities received, rejected, or redistributed. To address these gaps, the pilot will introduce structured tracking systems. This includes categories such as the total number of wraps collected, accepted, and rejected, estimated weight diverted from landfills per week or month, number of products manufactured and used internally, and staff compliance levels. This data can then be used to quantify landfill diversion and based on the findings of the pilot program, offer recommendations for scaling the program to other departments.

Fig. 5. University of Virginia Proposed Pilot Program for Blue Wrap Recycling

Discussion

Research Summary

This project aimed to quantify UVA's blue wrap waste and to develop a sustainable and scalable recovery solution. An LCA was conducted to evaluate the total annual environmental impact associated with UVA blue wrap waste disposal. The analysis revealed that blue wrap disposal contributes approximately 22,901.12 kg of CO_2 emissions, 5,248.04 MJ of energy consumption, and 169.38 m^3 of water usage per year. These findings highlight the significance of implementing a recovery pathway to reduce the environmental footprint of blue wrap waste. To explore potential recovery methods, a manual processing experiment, including the removal of adhesive labels and the melting of blue wrap, was conducted. On average, one person was able to process 0.13 pounds of blue wrap per minute, with each sheet containing approximately seven adhesive tapes. Melting experiments were performed at 380°F, taking roughly 22 minutes to achieve full melting. These experiments revealed that manual processing of blue wrap is slow and labor-intensive, which could present a significant barrier to large-scale implementation.

Material testing provided further insight into the feasibility of blue wrap repurposing. FTIR analysis indicated the presence of additives or impurities not consistent with the labeling of the material as solely #5 polypropylene. Mechanical testing showed that both Young's modulus and UTS of the recycled material were lower than those of the original polypropylene, suggesting that the mechanical integrity of the material is compromised. Based on the findings, the pilot program was suggested. The pilot program aims to explore pathways for remanufacturing blue wrap in the UVA Hospital, potentially serving as a scalable model for sustainable blue wrap management across larger healthcare systems.

Implications of the Work

Since this research focuses on waste stream mitigation, its implementation could inform more sustainable and standardized disposal practices in hospitals around the U.S. Targeting blue wrap – a high-impact, often overlooked material – our project offers a replicable model for integrating sustainability into healthcare without compromising patient safety, sterilization standards, or operational efficiency. These changes affirm broader sustainability initiatives and contribute to reducing carbon emissions, minimizing toxic incineration byproducts, and diverting waste from landfills, addressing the urgent need for climate-conscious solutions in the medical field. In doing so, this research may also inspire the creation or expansion of plastic repurposing programs, stimulate cross-sector collaboration, and influence institutional and governmental waste management policies nationwide. While the project is not a direct intervention in clinical procedures, it demonstrates how efforts rooted in research and systems thinking can meaningfully contribute to environmental conservation, advancing long-term health and sustainability goals for human communities and the ecosystems they depend on.

Limitations & Future Work Directions

While the project successfully developed a framework for addressing blue wrap waste management at UVA Hospital, several areas remain for future development. First, future work should explore alternatives to the current labeling stickers, such as directly embossing information onto the blue wrap, to improve recyclability. Additionally, future material testing is necessary to enhance the material integrity of recycled blue wrap. To reduce the variability across test samples, future studies should adopt standardized manufacturing techniques, such as injection molding. Moreover, further research is needed to improve the mechanical properties of the recycled material, specifically Young's modulus and UTS, and to investigate the discrepancies observed in the FTIR spectra between the blue wrap and the original polypropylene. Due to the time constraints, the implementation of the proposed pilot program was not feasible. As a result, a key direction for future work is the implementation and evaluation of the pilot program within a selected department at UVA Hospital. This will allow for real-time data collection that can be utilized to obtain essential feedback for refining the program and assessing its potential for long-term scalability. Finally, establishing collaboration with the University of Virginia's Schools of Arts and Architecture could offer new pathways for repurposing recycled blue wrap in creative and functional ways. It could further promote innovative repurposing strategies and extend the materials' lifecycle through design-oriented solutions.

End Matter

Author Contributions and Notes

Katia Almeida, Jennie Kang, Sharanya Nagendra, and Nylaa LaRose designed and performed research, analyzed data, designed the poster, and wrote the paper.
Dr. Matthew Meyer led hospital shadowing and guided data collection.
Zackary Landsman and Dr. Lisa Colosi-Peterson advised the undergraduate team throughout the project.

Conflicts of Interest

The authors declare no conflict of interest.

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References

1. Hospital Waste Characterization. Healthcare Plastics Recycling Council. Accessed May 5, 2025. https://www.hprc.org/resources/hospital-waste-characterization/
2. How Much Medical Waste is Produced Each Year? TriHaz Solutions. Accessed May 5, 2025. https://www.trihazsolutions.com/how-much-medical-waste-is-produced-each-year/
3. Waste generation by hospital emergency departments is highlighted for first time in a Mass General study. Accessed May 5, 2025. https://www.massgeneral.org/news/press-release/waste-generation-by-hospital-emergency-departments-is-highlighted-for-first-time-in-a-mass-general-study
4. Clark L. Recycling Surgical Blue Wrap Promotes Sustainability - Blue Wrap. MERI, Inc. April 10, 2024. Accessed May 5, 2025. https://www.meriinc.com/recycling-surgical-blue-wrap-promotes-sustainability/
5. Reusable Totes, Blue Wrap Recycling, and Composting, Environmental Best Practices for Health Care Facilities.
6. Blue Wrap and the Circular Economy | Practice Greenhealth. Accessed May 6, 2025. https://practicegreenhealth.org/about/news/blue-wrap-and-circular-economy
7. Blue Wrap and the Circular Economy | Practice Greenhealth. Accessed May 6, 2025. https://practicegreenhealth.org/about/news/blue-wrap-and-circular-economy
8. Is Polypropylene Eco-Friendly? Stats & Trends. GreenMatch.co.uk. Accessed May 6, 2025. https://www.greenmatch.co.uk/polypropylene-environmental-impact
9. (PDF) Design for Recycling Strategies Based on the Life Cycle Assessment and End of Life Options of Plastics in a Circular Economy. ResearchGate. Published online December 9, 2024. doi:10.1002/macp.202200046
10. Hospital Sustainability with BLUE RENEW | HALYARD. HALYARD Global Products. Accessed May 6, 2025. https://www.halyardhealth.com/sustainability
11. Iron Mountain® sterilization wrap recycling service. Accessed May 6, 2025. https://www.ironmountain.com/resources/solution-

guides/i/its-time-to-unwrap-your-medical-facility-recycling-program

12. Repurposed surgical blue wrap project reduces medical waste | Innovation & Grants. Northern Arizona Healthcare. Accessed May 5, 2025. https://www.nahealth.com/innovation-grants/blue-wrap-project/
13. Friedericy HJ, van Egmond CW, Vogtländer JG, van der Eijk AC, Jansen FW. Reducing the Environmental Impact of Sterilization Packaging for Surgical Instruments in the Operating Room: A Comparative Life Cycle Assessment of Disposable versus Reusable Systems. Sustainability. 2022;14(1):430. doi:10.3390/su14010430
14. US EPA O. Plastics: Material-Specific Data. September 12, 2017. Accessed May 5, 2025. https://www.epa.gov/facts-and-figures-about-materials-waste-and-recycling/plastics-material-specific-data
15. Complexities of the global plastics supply chain revealed in a trade-linked material flow analysis | Communications Earth & Environment. Accessed May 5, 2025. https://www.nature.com/articles/s43247-025-02169-5
16. Elevation D. The Hidden Climate Polluter: Plastic Incineration - GAIA. GAIA -. May 15, 2019. Accessed May 5, 2025. https://www.no-burn.org/the-hidden-climate-polluter-plastic-incineration/
17. Green TS. Burning Plastic Waste: What are the Consequences? Source Green. July 9, 2024. Accessed May 5, 2025. https://www.sourcegreen.co/end-of-life/burning-plastic-waste-what-are-the-consequences/
18. The Real Truth About The U.S. Plastics Recycling Rate. Beyond Plastics - Working To End Single-Use Plastic Pollution. Accessed May 5, 2025. https://www.beyondplastics.org/publications/us-plastics-recycling-rate
19. The Plastic Recycling Process. Association of Plastic Recyclers (APR). Accessed May 5, 2025. https://plasticsrecycling.org/how-recycling-works/the-plastic-recycling-process/
20. US EPA O. Recycling Basics and Benefits. April 16, 2013. Accessed May 5, 2025. https://www.epa.gov/recycle/recycling-basics-and-benefits
21. U.S. Plastics Pact | Working together to end plastic waste. Accessed May 5, 2025. https://usplasticspact.org/
22. US EPA O. Plastics: Material-Specific Data. September 12, 2017. Accessed May 5, 2025. https://www.epa.gov/facts-and-figures-about-materials-waste-and-recycling/plastics-material-specific-data
23. Chen F. Polypropylene (PP) Melting Point: Practical Insights & Tips. BOYI. August 8, 2024. Accessed May 6, 2025. https://www.boyiprototyping.com/materials-guide/polypropylene-pp-melting-point-practical-insights-tips/