



Design Guidelines for Optimal Hospital Plastics Recycling

ABOUT HPRC

HPRC is a private technical coalition of industry peers across healthcare, recycling and waste management industries seeking to improve recyclability of plastic products within healthcare. To date, HPRC is made up of brand leading and globally recognized members including Baxter, BD, Cardinal Health, DuPont, Eastman Chemical Company, Halyard Health, Johnson & Johnson, Medtronic, Ravago Americas, and SABIC Innovative Plastics. The council convenes biannually at meetings hosted by an HPRC member that include facility tours to further learning and knowledge sharing opportunities through first-hand demonstration of best practices in sustainable product and packaging design and recycling processes.

HPRC MEMBER COMPANIES



Healthcare Facility Advisory Board



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EXECUTIVE SUMMARY

“To collaborate across the value chain to inspire and enable the healthcare community to implement viable, safe, and cost-effective recycling solutions for plastics products and packaging used in the delivery of healthcare.” – Mission of Healthcare Plastics Recycling Council

Pilot Studies

The findings from two hospital recycling pilot studies have been used to evaluate the recyclability and best practices for hospital plastics waste. The first study (2009-2010) with Cleveland Clinic, Waste Management, and Engineered Plastics Inc., in conjunction with HPRC, evaluated pre-patient operating room wastes specifically. The second study (2012-2013) conducted at Stanford University Medical Center evaluated a broad range of clinical and pre-clinical hospital settings, including procedural, patient care, and ancillary clinical areas. In both pilot studies, only non-contaminated, non-regulated plastics waste materials were aggregated for recycling. Both pilot studies found that a broad range of waste plastics can be diverted from the municipal waste stream and safely and economically recycled. Other significant challenges still remain throughout the other steps of the plastics lifecycle.

Design Guidelines

These guidelines are very specific for healthcare applications and have been developed considering recycling conditions prevalent in the United States. While the current efforts have been focused on recycling infrastructure in the US, there are likely significant similarities between the infrastructure in the US and in others parts of the world including Europe. These design guidelines are specifically intended for medical device and packaging engineers and will refer to certain aspects of product and packaging design unique to medical devices and their packaging. As such, these design guidelines are intended as a supplement to other plastics and packaging recycling and sustainability guidelines, which have applicability to a broader range of products.

While the most critical requirement for all medical applications is patient safety and product efficacy, design considerations to improve recovery and recycling of healthcare plastics are important. HPRC’s design guidelines have been developed based on the findings from two pilot studies as well as input from industry experts, including resin manufactures, device and packaging designers, healthcare sustainability professionals, and recycling experts. These findings concentrate on the context of recyclability, but also consider the broader context of product functional requirements, hospital operations and protocols, overall business requirements and many other design and manufacturability requirements. Medical device and packaging designers and engineers should prioritize product performance and functionality, sterility, efficacy, safety, and ease of use when there is a conflict between these requirements and the ability to recycle.

Other audiences may also find these guidelines of interest, although these groups are not the focus: Some of the guidelines touch on the ‘product use’ phase on the further recyclability of a product or packaging. and would enable improvements in “Use for Recyclability”, Likewise, waste haulers and recyclers interested in expanding their businesses to include this waste stream, may learn more about the types of plastics in the healthcare plastics waste stream. This document explains design guidelines that can be used in healthcare product design in order to improve the recyclability of plastics post-use. Therefore,

while HPRC is also studying other barriers to recycling in the “downstream” lifecycle of healthcare plastics (i.e. within the healthcare facility, waste consolidation and transportation, and within the recycling facility), those impediments are not the focus of this document. While discussed later in more detail, a summary of guidelines for desirable design and less desirable design are as follows:

Desirable Design Practices

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

Less Desirable Design Practices

- Using a rubber seal on a polypropylene bottle
- Combining incompatible bioplastics and petroleum-based plastics into one product
- Welding, gluing or molding two components of unlike plastics
- Combining plastic film with paper in packaging
- Using metalized plastics, metals screws, grommets in plastic
- Using lead
- Using PVC

INTRODUCTION

This guidance document, Design Guidelines for Optimal Hospital Plastics Recycling, articulates product and packaging design which could possibly enhance recycling potential and value. Process steps by recyclers may include separation, blending, compounding, and other steps to enable the highest value with reuse of the materials. To ensure economic viability of recycling programs it is critical to create purer material streams that limit contamination.

The findings for this study are derived from pilot programs at the Cleveland Clinic and Stanford University Medical Center, as well as interviews of experts in the field. We anticipate that these guidelines will be of value to product and packaging designers in order to raise awareness of practices that will decrease recyclability or contaminate healthcare plastics and eliminate their value as a recyclable material stream. These guidelines may also be of use for hospital staff and waste haulers and recyclers interested in recycling these materials.

Pilot Study with Cleveland Clinic, Waste Management and Engineered Plastics

Cleveland Clinic, Waste Management, Inc., and Engineered Plastics Inc. performed a pilot study to evaluate the recyclability and best practices for capturing operating room plastics. The initial steps for the pilot involved characterizing the materials, plastic types, and volumes of waste plastics generated from the Operating Room (OR). The study looked at which operating room plastics could be safely and economically collected and diverted from the solid and medical waste collection into the mixed healthcare plastics recycling. Plastic materials were collected from the operating rooms and preparatory rooms, prior to the presence of patients (i.e., "pre-patient"). Contaminated materials, regulated medical waste, gloves, and devices with multiple plastic materials were specifically excluded. This source separation is required in order to minimize risk.

The pilot study showed that labor, storage space and logistics are all limiting factors preventing separation of plastics at the point of generation. A single point of mixed plastics collection was the optimal solution for the generator, placing the burden of separation on the waste handler and plastics processor. This "single stream" approach to collecting mixed plastics into readily identifiable bags offered the highest collection opportunity for the healthcare staff, and the easiest means for the housekeeping staff to properly handle and segregate the collection at the dock. Another outcome of the study was the determination that compression or baling of the collected materials had to occur in order to offer efficiencies in the storage of material onsite and during the handling and logistics of transporting materials offsite.

Based on the results of the pilot study and with the test batches which were processed through the recycling facility, the guidelines for recyclability outlined below were developed.

Pilot Study at Stanford University Medical Center

HPRC and Stanford Health Care conducted a six-month pilot study that analyzed data related to recyclable material types, volumes and flow through nine hospital departments as well as documented clinical recycling processes and lessons learned. The study developed comprehensive waste profiles across procedural, patient care and ancillary areas including operating room, ambulatory surgery, cardiac cath lab, interventional radiology, pre- and post-anesthesia, pharmacy and radiology at Stanford Health Care facilities in Palo Alto, California.

Stanford Health Care's clinical recycling program to-date will divert more than 110 tons of non-infectious packaging material from landfill annually, with plastics representing nearly 70 percent of that material. This will add an additional 9% of diversion to their 2012 diversion of 2,846 tons. In addition, Stanford has realized significant financial benefit associated with the program, as recycling collection offered a 75 percent cost savings compared to municipal waste collection. The pilot study was fully funded and implemented by Stanford Health Care with technical support provided by HPRC.

The complete pilot study report is available at <http://www.hprc.org/stanford-pilot-study>.

DESIGN GUIDELINES FOR RECYCLING

These guidelines have been developed based on the findings from the pilot studies, during which separation was done manually. Furthermore, these findings, which concentrate on the context of recyclability, also need to be considered in the broader context of product functional requirements, hospital operations and protocols, overall business requirements and many other design and manufacturability requirements. Overall environmental impact, which can be determined using life cycle assessment (LCA), should also be considered. Recycling may reduce environmental impacts by reducing the need for virgin resin production, which usually requires more energy than recycling processes.

These guidelines are specific to healthcare applications, and are intended as a supplement to other plastics and packaging recycling and sustainability guidelines^{3,4,5} which have broader applicability. These other sources are relevant for the general plastics industry, and include guidelines from Association of Plastic Recyclers and Sustainable Packaging Coalition. The table below includes a checklist to provide a comparison between the guidelines provided by those organizations and the recommendations included in this document.

TOPIC	HPRC	SPC	APR
PRODUCT FUNCTIONALITY	√	√	
PACKAGING REGULATIONS		√	
MULTIPLE MATERIALS	√		√
MATERIAL SELECTION/TYPE	√	√	√
CONTENT ID FOR POST USE RESIDUE	√		
PIGMENT	√	√	
BIODERIVED RESINS	√		
RESIN ID	√	√	
METAL IN PLASTICS	√	√	
NON-RECYCLABLE			√

Table 1: Guideline comparison between Healthcare Plastics Recycling Council, Sustainable Packaging Coalition and Association of Plastics Recyclers.

Elimination of Multiple Material Types within One Discrete Healthcare Product

One of the major issues identified at EPI during the Cleveland Clinic pilot study was the combination of mixed plastics within one product. The study determined that it was not economically viable to remove cross-linked rubber seals from plastic bottles, like those containing saline; it required too much labor for a manual separation process or for specialized separation methods. A viable alternative is to incorporate a thermoplastic elastomer (TPE) seal during the product design stage.

TPE seals would not have to be removed from the bottle prior to recycling because TPE seals are melt-processible alongside the plastic bottle and can be pelletized to form a recycled resin material without additional separation processes.

Similarly, product designers need to be conscious of utilizing bioderived polymers such as poly lactic acid (PLA) in conjunction with the more common thermoplastic polymers like polyester, polyethylene, and polypropylene when designing for recyclability. Due to differences in processing temperatures, these materials may require different recycling processes. At the current time, obvious labeling will be essential for enabling effective manual separation or manual segregation of these plastics from a mixed plastic stream. Products that contain biopolymers are still very few, but are likely to have a detrimental effect on plastic recycling economics unless care is taken to ensure that they can be processed with chemically compatible materials.

A best practice is to utilize mono-material designs wherever possible. Currently, the most marketable recycled plastics are thermoplastics, such as polyester, polyethylene, polypropylene, and high impact polystyrene. If a healthcare product can be made with just one of those polymer types, there will be less labor (and resulting expense) at every level in the plastics lifecycle. If multiple material types must be used, materials that can be separated easily (e.g. in a sink / float tank, optical sorter, air jet, etc.) are more desirable than those which cannot.

The goal is for a healthcare facility not to have to do any material separation other than to place the product into a commingled healthcare plastics recycling bin. The consolidator, waste removal company, and plastics recycler can then choose to separate and isolate these mono-material products for a higher recycled polymer value or they can keep them with other thermoplastic polymer types to sell as a mixed plastic recycle. While the mixed plastic recycling stream has a lower value, it also takes less labor to produce because of fewer separation and segregation steps.

A good practice, while not the best, is to only use thermoplastics if mono-material options are not available; the TPE seal on a PP bottle is a good example of this practice. While it does not provide the value of a mono-material recycled polymer stream, it still avoids any necessary labor of separation and the recycled material can be utilized for a good number of future applications.

Another good practice is to label a healthcare plastic package or product with the appropriate resin identification code⁶, from 1 to 7, if the package or product could reasonably be recycled given appropriate plastics recycling collection capabilities and would not be expected to enter a regulated waste stream (e.g., sharps waste, infectious waste, etc). With current recycling

practices, polyethylene terephthalate (resin type 1), high-density polyethylene (resin type 2), low-density polyethylene (resin type 4), polypropylene (resin type 5), and polystyrene (resin type 6) are frequently recycled.



Certain material classes, like rubber, poly vinyl chloride (resin type 3), and resin type 7 (all other plastics not described in resin types 1-6) can potentially be problematic for pelletizing equipment if not caught and removed from the materials stream prior to being processed for recycling. Therefore, these materials should be avoided to promote a design for recycling. As an example, when saline bottles with rubber seals are processed (i.e., ground up and repelletized for reuse), the rubber material will not melt, which clogs filters in the equipment and could result in downtime.

Figure 1: Resin Identification Codes

Marketable* Thermoplastic Recycled Resins & Recycled Resin Blends**

- Polyethylene terephthalate and variants (PET, PETE, PETG)
- High density polyethylene (HDPE)
- Low density polyethylene (LDPE)
- Polypropylene (PP)
- Polystyrene (PS)
- Blends of polypropylene and polyethylene (PP and PE)
- Blends of polypropylene and thermoplastic elastomers (PP/TPE)

* In 2011

** Relevant to Hospital Plastics Recycling

Eliminating Multiple Material Types within Healthcare Packaging

The use of multiple materials in packaging has some unique challenges and opportunities. Much of the sterile product used in operating rooms is packaged in a thermoplastic film laminated to a micro-porous label made of paper. The paper provides two functions in that it allows for printing of the product information on the packaging and it allows the sterilant to enter and exit the package during gaseous sterilization processes. A breathable thermoplastic, such as DuPont's TYVEK®, could be used as a replacement for the cellulose-based label. Some sterilization packaging designs such as this were found in the Cleveland Clinic pilot study, and EPI had no issues processing the entire thermoplastic packaging. Additionally, some sterilization methods, such as gamma radiation and e-beam radiation methods, do not require breathable films and could also be potential alternatives for certain products. There are issues in that not all product and product materials are compatible with the radiation methods of sterilization. Overall, both alternative films and alternative sterilization methods may also provide solutions to this design issue.

Other considerations for material choices include:

- Using water based adhesives when necessary. Water based adhesives are more easily dissolved, enabling separation of dissimilar materials from the recycling stream during material preparation than other, non-water based adhesives.
- PVC in any form requires special considerations in the recovery and reprocessing equipment.
- Multilayer structures may result in a lower value material stream if the layers are dissimilar materials. It is recommended to use materials that contain same family or compatible materials (e.g. polyolefin's) in these layers. For more information on the effects of blending multilayer materials please see the results of a collaborative study by HPRC and Penn State University, visit <http://www.hprc.org/materials-testing>.
- Designing a product with both paper and plastic materials or introducing paper to a plastic product during the use of a product can be a minor concern with recycling.



FIGURE 2: Blue Wrap with Paper and Paper-Based Tapes Attached

Avoiding Metal in the Plastics Recycling Stream

Metal in the plastic recycling stream can potentially be an issue in the pelletization process. Without the proper equipment in place, packaging and healthcare supplies that contain metal can damage the equipment at a recycler. Most recyclers have a metal detector in their pelletization equipment that will separate out the metal or shut down the process in the event that metal is found. Much of the metal that EPI encountered during the pilot study was metallized plastics, which are commonly used to improve the barrier properties of the packaging. Metallized plastic packaging is commonly found on supplies where there is a liquid substrate inside, i.e. a betadine swab or a pre-moistened wipe. Packaging designers should take care to only use metal packaging when necessary, e.g. when thermoplastic films cannot provide the barrier properties required.

Preventing contamination can include education at the healthcare facility to not recycle those types of materials as well as implementation of metal detection / removal procedures and equipment at the recycling facility. To minimize the amount of metal in medical products the healthcare industry could seek an economically viable barrier plastic packaging material that is compatible with plastics recycling processes from its packaging film suppliers.

Designers also need to minimize the introduction of metal to materials that are otherwise wholly plastic through the introduction of staples or other metal items that may be sorted into the plastic recycling stream.



FIGURE 3: Examples of Foil Based Wrap in the Recycled Material Stream

One final area of significance is the use of heavy metals in medical products and packaging. Heavy metals (for example lead as a sterility indicator in packaging, cadmium as a pigment, etc.) are contaminants that are difficult to safely remove and dispose of and should be avoided if at all possible. These materials can be particularly problematic for recyclers as they can contaminate an otherwise clean recycled material stream, and can also contaminate wastewater during the cleaning / sorting process.

Allow for the Identification and Removal of Product Residue in Healthcare Supplies

Product design to allow for easy drainage before disposal for recycling appears to be an area that has not been greatly utilized by the healthcare product industry. However, if it were easier for operating room (OR) staff to drain non-contaminated bottles, bags, etc. with ease, the recycling compliance of these items in an OR environment would be likely to increase. Designs to accomplish this will vary widely by product, but an example would be a bottle that has a hook to hang on a sink so that the bottle can drain while other work is done in the OR.

Another area that may require work by healthcare product manufacturers, pharmacies, and hospitals is labeling on liquid supplies that indicates products that should never be recycled. Certain liquids in the healthcare facility will safely evaporate in the pelletization process, like saline solutions. If the liquids are potentially hazardous, are regulated, or will create unnecessary worker exposure issues in the recycling value chain, the products should be appropriately labeled and handled accordingly in other waste streams. It is the healthcare facility's responsibility to ensure its compliance of all local regulatory requirements.

Minimization of Pigments

Where possible, minimization of mineral-based pigments within the plastics will also increase recyclability. One criterion closely associated with the usability and salability of recycled plastics is the ash content (as percentage points), which is the amount of residue remaining after all the resin is burnt off. Typically, contributors to the ash content will be mineral-based pigments, which are commonly found as colorants in plastics. In addition, the greater the level of pigmentation of the material, the more likely that the resulting recycled resin would only be suitable for a second life in a black colored product, further limiting the marketability of the resin. Typically the amount of pigment found in inks associated with text on packaging and devices will be a very small contributor to the total ash content of a recycled resin materials stream. In general, non-pigmented components are preferred; if pigmentation is required then white is more desirable than other colors.

Summary

Overall, products designed to limit the use of multiple plastics without sacrificing their intent for use, could increase their recyclable potential. Additionally, a standardized labeling system for all recyclable healthcare plastics products could further optimize yields at the hospital and increase the effectiveness of manual sorting capabilities of the workers handling and sorting this material. Finally, the largest challenge to optimum yield of a viable, economic mixed plastic commodity is the reduction or elimination of common contaminants, such as paper, metals, rubber seals, liquids, etc. Some of these contaminants are introduced at the hospitals. Elimination of these contaminants would increase the end product value and increase processing and separation equipment capacity and efficiency. More study is required for optimization for automated sorting methods.

ENVIRONMENTAL BENEFIT OF RECYCLING

Healthcare facilities in the United States generate approximately 14,000 tons of waste per day, most of which is being disposed of in landfills or by incineration. It is estimated that between 20 and 25 percent of that 14,000 tons can be attributed to plastic packaging and plastic products². In addition, 85 percent of the hospital waste generated is non-hazardous, meaning free from patient contact and contamination³.^{7,8,9}

Recycling plastic waste not only reduces the amount of waste sent to landfill or incineration but also reduces the environmental impacts from producing virgin plastics. In most cases this results in a net reduction of greenhouse gas emissions, as the energy required for recycling is less than the energy required to make new, virgin plastic. The overall environmental impacts may be quantified using life cycle assessment (LCA), a methodology for quantifying all impacts associated with a product from the time raw materials are removed from the earth, through manufacturing, use, and disposal.

In a literature review conducted by HPRC, Life Cycle Assessment (LCA) studies comparing recycling to other disposal methods concluded that recycling had a lower environmental impact than landfill or incineration with energy recovery, particularly due to the benefits of avoiding virgin plastic production.¹⁰ The Life Cycle Assessment literature review is available at <http://www.hprc.org/environmental-impacts-of-recycling>.

The EPA's Waste Reduction Model (WARM) uses life cycle inventory data to allow comparison of waste management practices of different materials, including recycling of PET. For example, if just 1% of 1,320 tons of plastic waste (assuming PET) from hospitals were recycled instead of landfilled each day, it would reduce greenhouse emissions by over 15 tons of CO₂ equivalent each day, which is equivalent to consuming 1,600 gallons of gasoline or 30 barrels of oil.^{11,12}

Previous and Future Efforts

The pilot studies at Cleveland Clinic and Stanford Hospital and Clinics have provided the baseline for a number of guidelines that will enable manufacturers and users of hospital products and packaging to enable future recycling of the waste products. In addition, HPRC has published a Healthcare Plastics Value Chain Map to aid users in understanding all steps of the value chain. We also intend to pursue additional studies to further characterize and understand opportunities and processes required for effective and viable commingled healthcare plastics recycling programs. This work is intended to map out key attributes of recycling for healthcare plastics stakeholders as well as identify issues and barriers along the value chain that affect plastics recycling. It will also seek to demonstrate the economic benefits associated with healthcare plastics recycling.

HPRC CONTACT

For information about HPRC and current activities please visit www.hprc.org.

ACRONYMS

HPRC	Healthcare Plastics Recycling Council
APR	Association of Plastics Recyclers
SPC	Sustainable Packaging Coalition
LCA	Life Cycle Assessment
EPI	Engineered Plastics, Inc.
SPI	Society of Plastics Industry
OR	Operating Room
EPA	Environmental Protection Agency
WARM	Waste Reduction Model
PET	Polyethylene terephthalate
PETG	Glycol-modified polyethylene terephthalate
HDPE	High density polyethylene
LDPE	Low density polyethylene
PP	Polypropylene
PS	Polystyrene
TPE	Thermoplastic elastomer
PLA	Polylactic acid
PVC	Polyvinyl chloride

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DISCLAIMER

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