EPA Assistance Identification Number: X9-00E00871-0

Reducing Solid Waste in Surgical Centers by Replacing Blue Wrap

Priority area addressed:
Reduce hazardous and solid waste in the health care sector with reusable containers

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Report on the Life Cycle Assessment for Mayo Clinic
Project Sponsor: U.S. Environmental Protection Agency X9-00E00871-0

Abstract: Life cycle assessment (LCA) is a tool used to quantify environmental impacts for products, systems, and/or services throughout their entire life cycle. An LCA was performed comparing two forms of medical sterilization protection: disposable polypropylene blue wraps and reusable aluminum hard cases. The GaBi 5 Software-System Life Cycle Engineering has been used to conduct the LCA, and information from various life cycle inventory (LCI) databases has been used, including ecoinvent v2.2 and the U.S. LCI database. Additional information was taken from the Emissions & Generation Resource Integrated Database, the 1994 Manufacturing Consumption of Energy Survey, PlasticsEurope, PE International, and the European Reference Life Cycle Database. The Tool for the Reduction and Assessment of Chemical and Other Environmental Impacts (TRACI) 2.0 life cycle impact assessment methodology was used. The impact category assessed was global warming potential, characterized in kilograms of carbon dioxide-equivalent. The functional unit for this study was sterilization protection for 100 surgical toolsets used 365 times per year over 10 years. This study found that the reusable hard cases have roughly half the greenhouse gas (GHG) emissions impact than the disposable polypropylene blue wraps annually. The most impactful phase for both the hard cases and the blue wrap was the use phase; the size of this impact was largely due to the high amounts of energy consumed during the pre-surgery sterilization and post-surgery decontamination processes. While the hard cases have a significantly lower emissions impact, there are additional considerations that must be included when deciding what type of sterilization protection to use such as storage space and decontamination requirements.

Life Cycle Assessment of Medical Sterilization Protection: Disposable Polypropylene Blue Wrap vs. Reusable Aluminum Hard Cases

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Abstract

Life cycle assessment (LCA) is a tool used to quantify environmental impacts for products, systems, and/or services throughout their entire life cycle. An LCA was performed comparing two forms of medical sterilization protection: disposable polypropylene blue wraps and reusable aluminum hard cases. The GaBi 5 Software-System Life Cycle Engineering has been used to conduct the LCA, and information from various life cycle inventory (LCI) databases has been used, including ecoinvent v2.2 and the U.S. LCI database. Additional information was taken from the Emissions & Generation Resource Integrated Database, the 1994 Manufacturing Consumption of Energy Survey, PlasticsEurope, PE International, and the European Reference Life Cycle Database. The Tool for the Reduction and Assessment of Chemical and Other Environmental Impacts (TRACI) 2.0 life cycle impact assessment methodology was used. The impact category assessed was global warming potential, characterized in kilograms of carbon dioxide-equivalent. The functional unit for this study was sterilization protection for 100 surgical toolsets used 365 times per year over 10 years. This study found that the reusable hard cases have roughly half the greenhouse gas (GHG) emissions impact than the disposable polypropylene blue wraps annually. The most impactful phase for both the hard cases and the blue wrap was the use phase; the size of this impact was largely due to the high amounts of energy consumed during the pre-surgery sterilization and post-surgery decontamination processes. While the hard cases have a significantly lower emissions impact, there are additional considerations that must be included when deciding what type of sterilization protection to use such as storage space and decontamination requirements.

Introduction

In the medical industry, the highest priority is maintaining the cleanliness and sterility of the hospital and medical instruments to maintain a healing environment for patients. Reducing waste is a secondary priority. In order for hospitals to effectively serve their purpose, these priorities must not change. However, some hospitals are making product choices that satisfy their sterility requirements while simultaneously reducing significant waste streams. One example of this type of choice is the selection of reusable aluminum surgical tool sterilization cases, often called “hard sides” or “hard cases,” to replace a portion of their disposable polypropylene sterilization wraps, known as “blue wrap” for its blue color.

Blue wrap and hard cases are both used to enclose and protect baskets of surgical tools during sterilization processes. Blue wrap is folded around the tool baskets, the folds are taped in place with a special sterilization indicator tape, and the entire package is placed in the autoclave. The blue wrap is a single-use product, however, and so it is disposed of after just one sterilization instance, often by incineration or landfilling and occasionally by recycling. The disposable nature of the blue wrap means that a large amount of blue wrap waste is created every day. Conversely, the reusable nature of the hard case means that very little waste is created. During use, the tool basket is placed in the hard case, a small piece of nonwoven polypropylene is attached as a steam vent, the lid is snapped in place, and the case is placed in the autoclave. The hard case does generate waste from the disposable steam vent and sterilization indicators consumed, but the amount of waste generated from hard cases is extremely small compared to the amount of waste generated from blue wrap.

Life cycle assessment (LCA) is a tool that can compare the environmental impact of products, systems, and services throughout their life cycles. By tracing the paths of the blue wrap and the hard cases all the way from their beginnings as petroleum and bauxite (an aluminum precursor) through the actual blue wrap and hard case manufacture to use and blue wrap incineration/hard case repair at the end of the product lifetime, we can quantify and compare the overall GHG emissions impacts for the two sterilization containment systems, as well as identify the major emission sources for each. This is considered a cradle-to-grave LCA, as it considers the impacts from the very beginning of product creation to the very end of product disposal.

This LCA compares disposable polypropylene blue wrap with reusable aluminum hard cases on the basis of GHG emissions impact. The intent of this work is to provide the information to enable informed decision-making for healthcare facilities on the environmental impact of sterilization protection and the sterilization process in general. Use of this information might influence hospital equipment and purchasing choices in such a way that the overall environmental impact of the hospital is reduced, even if only to a small extent.

Goal, Scope & Methods

Goal

The goal of this study is to compare the overall environmental impact of disposable polypropylene blue sterilization wraps with that of reusable aluminum hard sterilization cases.

Scope

The scope of this study is defined as a cradle-to-grave assessment, accounting for the environmental impacts of blue wrap and hard cases from raw material extraction through product manufacture and use to end-of-life disposal. The impact categories for this study are greenhouse gas emissions, characterized in kilograms of CO_2-equivalents, and solid waste, characterized in kilograms of solid waste. The functional unit is defined as 10 years of surgical kit sterilization protection for 100 kits each used 365 times per year. Blue sterilization wrap is a single-use product, and wraps are disposed of after one use; a hard sterilization case is a multi-use product, and cases are cleaned and reused after use. The lifetime of a hard sterilization case is estimated at 10-20 years as indicated by a hard case manufacturer and a major hospital that uses hard cases. This lifetime includes minor repairs of the case, and these repairs are included in the scope of the study. Some necessary accessories are consumed during the use of both the blue wrap (BW) and the hard cases (HC), and the following accessories are included in the scope of this study: sterilization indicator tape (BW), tray liner (BW), sterilization indicator tabs (HC), steam vent (HC), polypropylene wipes (HC).

Methods

This study uses comparative attributional LCA to compare 10 years of surgical kit sterilization protection for 100 kits, each used 365 times per year, for disposable polypropylene blue sterilization wrap and reusable aluminum hard sterilization cases. The process flow diagram method was used to model the commodity flows between processes (Suh & Huppes, 2005) for the entire process of production, use, and disposal of both blue wrap and hard cases. Life cycle inventory (LCI) data was drawn from the U.S. LCI database and ecoinvent (ecoinvent, 2012). Additional information was taken from the Emissions & Generation Resource Integrated Database (eGRID) model (EPA, 2010), the 1994 Manufacturing Consumption of Energy Survey (EIA, 1997), State Electricity Profiles 2010 (EIA, 2012), PlasticsEurope, PE International, the European Reference Life Cycle Database (ELCD), CareFusion, the manufacturer of V.Mueller brand Genesis™ containers, Mayo Clinic who uses both blue wrap and hard cases, and product specification datasheets (Getinge, 2012). The GaBi 5 Software-System was used to manage all data and create detailed models for the life cycles of the blue wrap and hard cases. TRACI 2.0 (Bare, 2011) impact assessment methodology was used within GaBi to calculate the final environmental impact for each product’s life cycle.

System Boundary

Table 1 (next page) provides a summary of the system considerations for this analysis of disposable blue polypropylene sterilization wrap and reusable aluminum hard sterilization cases. These considerations include impacts for raw material production & primary processing, product manufacture, product use, and product end-of-life disposal.

Materials Production & Manufacture, Description of Product Use, and End-of-Life Scenarios

Raw Material Production

Information on processes from raw material extraction until consumption at the blue wrap or hard case manufacturer (excluding transportation of raw materials from extraction to primary processing) was taken from the LCI databases mentioned above. The information in these databases generally does not include impact of travel from raw material extraction to primary processing, and so those impacts are excluded from this study.

Blue Wrap and Accessory Production, Packaging, and Transport

Blue wrap is produced by transforming raw polypropylene resin via a spunbond-meltblown-spunbond (SMS) process. No direct manufacturer information on blue wrap production was available, so the nine plastics transformation processes available in the ecoinvent database (stretch blow molding, blow molding, thermoforming & calendaring, calendaring of rigid sheet, extruding film, extruding pipe, foaming & expanding, injection molding, and fleece production) were utilized as proxy data to generate average values for electricity and natural gas consumption (per kilogram of transformed plastic) for the SMS process; a 99% polypropylene utilization ratio was assumed. Using the weight of a single blue wrap, the average values were converted to electricity and natural gas consumption per piece of blue wrap. The electricity generation GHG emission factors were based on values from the EPA's eGRID model (EPA, 2010) with exact proportions for each type of electricity generation modified to match the proportions of those types of power found in North Carolina (a location for a major blue wrap manufacturer). Production of one piece of blue wrap was estimated to consume approximately 0.216 kWh of electricity and 347 Btu of natural gas. A single piece of two-ply, 1.22 meters by 1.22 meters blue wrap weighs approximately 0.111 kg.

For this study, the raw polypropylene resin was modeled as traveling 735 kilometers from production to the blue wrap manufacturer; transportation estimates are based on distances between potential producers and manufacturers. Blue wraps were assumed to be packaged 24 per case. (http://www.kchealthcare.com/us/healthcare/home/products/product-catalog/surgi/q00-steri/rux-steri/ruxso3-kimgu/62148-kc500.aspx
The packaging for each case is composed of corrugated cardboard and polyolefin shrink wrap. For this study, low density polyethylene resin was used as a proxy for the production of polyolefin shrink wrap. Transport of the packaging materials was set at 161 kilometers to be consistent across the model (actual distances for transport of packaging materials were unavailable for this study). The packaged blue wrap case was modeled as traveling 1730 kilometers from manufacturer to distributor to use at the hospital.

Table 1: Products, materials, processes, and transportation included in the system boundary.

Product	Blue Wrap (BW)	Hard Cases (HC)
Raw material(s)	Polypropylene (PP)	5005-O Anodized aluminum (AA) Stainless steel (SS) Silicone (Si) Ultem high-performance plastic (UP)
Total manufactured	365,000	100
Packaging materials	Corrugated cardboard (CC)[1] Polyolefin shrink wrap (PSW)[2]	Corrugated cardboard[1]
Accessories required for product use	Sterilization indicator tape (STa) Tray liner (TL)	Sterilization indicator tabs (two) (STb) Steam vent Polypropylene wipes
Accessory raw materials	Cellulose Acrylate copolymer Polyisoprene Butylated urea-formaldehyde resin Zinc oxide Titanium dioxide Lithium carbonate Polyurethane (PU)	Paper Salicylamide Polypropylene Corrugated cardboard Polyolefin shrink wrap
Process impacts	Polypropylene production Blue wrap manufacture (SMS process) Cellulose production Acrylate copolymer production Polyisoprene production Butylated urea-formaldehyde resin production Zinc oxide production Titanium dioxide production Lithium carbonate production Polyurethane production	Aluminum production Aluminum anodization Stainless steel production Silicone production Ultem plastic production Hard case manufacture Cardboard production Paper production Salicylamide production Polypropylene production Steam vent manufacture (SMS process)
Transportation	PP from plant to BW manufacturer CC from plant to BW manufacturer PSW from plant to BW manufacturer BW from BW manufacturer to hospital BW from hospital to landfill STa from STa manufacturer to hospital PU from plant to TL manufacturer PSW from plant to TL manufacturer CC from plant to TL manufacturer TL from manufacturer to hospital	AA from plant to HC manufacturer SS from plant to HC manufacturer Si from plant to HC manufacturer UP from plant to HC manufacturer CC from plant to HC manufacturer HC from HC manufacturer to hospital STb from STb manufacturer to hospital PP from plant to SV manufacturer SV from SV manufacturer to hospital CC from plant to SV manufacturer PSW from plant to SV manufacturer HC repair materials from plant to hospital
End-of-life scenario	Incineration & ash to landfill	Repair

[1] Corrugated cardboard basis weight: 19.1 kg/92.9 m^2 (Twede & Selke, 2005)
[2] Polyolefin shrink wrap assumed thickness: 0.015 mm

The production impact of the blue wrap accessories was estimated by the production impact of the constituent raw materials for each respective accessory. Production impact of the sterilization indicator tape, weighing 1.3 grams, was estimated by the production impact of 0.066 grams of cellulose fiber, 0.045 grams of silicone product (proxy for acrylate copolymer), 0.049 grams of polyurethane (proxy for polyisoprene), 0.0098 grams of urea formaldehyde resin (proxy for butylated urea-formaldehyde resin), 0.0098 grams of zinc oxide, 0.0027 grams of titanium dioxide, and 0.00029 grams of lithium carbonate as found in the Ecoinvent database. Indicating tape used at Mayo Clinic does not contain lead salts in the color changing strips. Transport of the sterilization indicator tape was set at 161 kilometers from manufacture to the hospital. Production impact of the tray liner was estimated by the production impact of polyurethane foam. Tray liner weight was assumed to be 20 grams, and the polyurethane utilization ratio was assumed to be 95%. The raw polyurethane was modeled as traveling 777 kilometers from production to tray liner manufacture, and 1730 kilometers from tray liner manufacture to use at the hospital.

Hard Case and Accessory Production, Packaging, and Transport

A hard case starts as aluminum alloy coils and blanks and is formed by hydroforming and stamping processes. A complete hard case is composed of 2.73 kg of anodized aluminum, 0.526 kg of stainless steel, 0.136 kg of silicone, 0.0136 kg of Ultem plastic, and a negligible mass of Mylar (excluded from this study based on its negligible weight). For this study, hard case production was modeled by the production of exactly the amount of raw materials found in the cases; no manufacturing losses were accounted for in the hard case portion of this study. Total anodization area for the case was estimated at 0.53 square meters. The electricity generation GHG emission factors were based on values from the EPA's eGRID model (EPA, 2010), with exact proportions for each type of electricity generation modified to match the proportions of those types of power found in Ohio (EIA, 2012) (a location for a major hard case manufacturer). Exact electricity and natural gas consumption values were unavailable, so estimates of per-case energy consumption were based on facility square foot area and monthly case output for a major hard case manufacturer, and on energy consumption per facility square footage data from the 1994 Manufacturing Energy Consumption Survey (EIA, 1997) (no more recent data was available for energy consumption per square foot). Production of one hard case was estimated to consume approximately 15.4 kWh of electricity and 92,200 Btu of natural gas.

For all materials used in the hard case, transport distances are set at 161 kilometers (no actual distances from raw material primary processing to hard case manufacture were available to model). The hard cases were assumed to be packaged in corrugated cardboard, with one case per cardboard box and each cardboard box weighing approximately 0.114 kg. Distance from hard case manufacturer to the hospital was modeled as 1102 kilometers.

The production impact of the hard case accessories was estimated by the production impact of the constituent raw materials for each respective accessory. The production impact of the sterilization indicator tabs, assumed to weigh five grams each, was estimated by the production impact of 4.6 grams of paper and 0.4 grams of benzoic compounds (proxy for salicylamide) per tab (two used per case per sterilization). Indicating tabs for V. Mueller brand containers by CareFusion do contain an extremely small amount of lead salt that reacts during the autoclave process to change color. Transport of the sterilization indicator tabs from manufacture to the hospital was set at 161 kilometers. Production impact of the steam vent was assumed to be similar to that of blue wrap but scaled down to the size of a steam vent, 229 millimeters by 229 millimeters; the same assumptions made of the blue wrap concerning packaging, transport, and transport of packaging materials are made of the steam vent scaled proportionally to the size of the steam vent. Production impact of the polypropylene wipes used to wipe clean the cases was estimated by the production impact of raw polypropylene; a 95%utilization ratio was assumed. No information on packaging of the sterilization indicator tabs or the polypropylene wipes was available, and so no packaging or packaging transport considerations were made for those accessory products.

Description of Product Use

Prior to use, surgical tools must be sterilized. In this study, sterilization is accomplished by the steam sterilization method. Baskets containing surgical tools are secured within either blue wrap or a hard case and placed in the autoclave for sterilization.

Before the blue wrap is wrapped around the tool basket, a tray liner is placed in the bottom of the tool basket to help absorb residual moisture from sterilization. Then, blue wrap is folded around the tool basket, the folded fabric is secured in place with sterilization indicator tape, and the entire packaged is placed in the autoclave for sterilization; for this study, 10 blue-wrapped toolsets are assumed to fit in the autoclave simultaneously. Post-sterilization, the sterilization indicator tape serves to maintain the integrity of the wrapped package and also indicate successful sterilizations through the activation of color-changing stripes on the surface of the tape. Blue wrap is designed to allow the sterilant (steam) to penetrate and sterilize the instrument(s) but microbes are filtered out or prevented from passing through.

Once the blue wrap has gone through the sterilization process, it is not able to be reused because it is indicated for single use only. When the package is opened, the blue wrap is held up to the light and inspected for damage. If damage is found on the wrap or moisture is found in the tool basket, the packages is re-wrapped with new blue wrap and re-sterilized; this re-processing occurs at a rate of approximately 3% according to data from Mayo Clinic, leading to an increase in the amount of blue wrap and accessories consumed. Regardless of damage status, the blue wrap and attached sterilization indicator tape is disposed of immediately following damage inspection. Following surgery, the tools are washed by hand and by machine; for this study, 10 toolsets are assumed to be washed simultaneously in the washing machine.

For hard case sterilization, tool baskets are placed in the bottom of the case. A steam vent is placed in the case lid, locked in place by a metal grate and pivoting latch, and the case lid is held in place by the locking handles. Sterilization indicator tabs are placed through both handles of the case and the case is placed in an autoclave for sterilization; for this study, seven hard cases are assumed to fit in the autoclave simultaneously. During sterilization the steam vent behaves as a small piece of blue wrap allowing sterilant to penetrate and sterilize the instruments but microbes are prevented from passing through. Post-sterilization, the sterilization indicator tabs serve to indicate successful sterilizations and the integrity of the case seal. When the case is opened to use the enclosed tools, the sterilization indicator tabs are broken and discarded. The tool basket is taken out of the case, the steam vent is inspected for punctures, and the case is removed from the operating room prior to patient entry to avoid contamination. The single-use steam vent is inspected for tears and discarded. The cases themselves are wiped down with a polypropylene wipe moistened with sanitizing solution and returned to use. If the steam vent is found to be punctured or moisture is found within the case, the case is cleaned and the tools are re-sterilized. Reprocessing of the hard cases occurs at a rate less than 1%. For the purposes of this study, the difference in reprocessing for the blue wrap relative to the hard cases is applied to the process with the higher rate; in this case, blue wrap has a reprocessing rate of 3% and hard cases have a reprocessing rate of 1%, so only a 2% reprocessing rate is applied to the blue wrap process. Following surgery, the tools are washed by hand and by machine; for this study, 10 toolsets are assumed to be washed simultaneously in the washing machine.

Electricity generation GHG emissions impacts for the energy consumed during sterilization and decontamination were based on the EPA's eGRID model (EPA, 2010), with exact proportions for each type of electricity generation modified to match the proportions of those types of power found in Minnesota, the site of the Mayo Clinic facility engaged in this study (EIA, 2012) . For this study, 10 blue-wrapped cases or seven hard cases fit in an autoclave simultaneously. Based on product specification information for the autoclave (Getinge, 2012), one run of the autoclave consumes about 72,800 Btu of natural gas, 3.85 kWh of electricity, 22.7 kilograms of steam water, and 18.1 kilograms of cooling water. During machine-washing decontamination, for both the blue wrap and the hard cases, 10 toolsets fit in the machine washer simultaneously. Based on product specification information for the machine washer (Getinge, 2012), one run of the washing machine consumes about 53,200 Btu of natural gas, 2.55 kWh of electricity, 130 kilograms of tap water, and 37.6 kilograms of deionized water.

Given the functional unit of sterilization protection for 100 medical kits used 365 times per year for 10 years, and the respective reprocessing rates for each type of sterilization protection, 375,950 pieces of blue wrap and 100 hard cases are produced. Each piece of blue wrap is used once and disposed of, and each hard case is used once per day and reused for a total of 3,650 uses per case. The amounts of the required accessories total 375,950 tray liners, sufficient sterilization indicator tape for 365,000 blue wrapped packages (approximately 1,890 kg worth of tape), 365,000 steam vents, 730,000 sterilization indicator tabs, and sufficient polypropylene wipes to clean hard cases 365,000 times (approximately 1,830 kg worth of wipes).

End-of-Life Scenarios

After a single use, the blue wrap, tray liner, and attached sterilization indicator tape is incinerated. The ash produced is then transported to a nearby landfill. Energy consumption and emissions from incineration were based on information direct from the Mayo Clinic waste management facility. The incineration of one piece of blue wrap consumes 0.0272 kWh of electricity and 97.7 Btu of natural gas and produces approximately 0.00243 kg of ash.

As a reusable product, the hard cases are not incinerated after use and are instead cleaned (as detailed above) and recirculated. Over time, however, repairs to the case may be necessary due to daily wear and tear. This commonly includes silicone gasket replacement or case lid repair. Repairs are assumed to replace the equivalent (in material consumption) of 12 gaskets and five cases per year. A repair worker comes to the hospital with new parts and materials and uses hospital electricity to power the repairs. The repairs are assumed to consume 1.5 kWh per day over the 30 hours assumed worked per week by the repair worker.

Results

Figure 1 shows the greenhouse gas emissions from the production, use, and end-of-life disposal for both disposable polypropylene blue wrap and reusable aluminum hard cases. Even in the first year of use, the disposable blue wrap has roughly twice the impact of the reusable hard cases. Given the assumptions detailed above, this relationship maintains a linear progression over the 10-year time span of the functional unit.

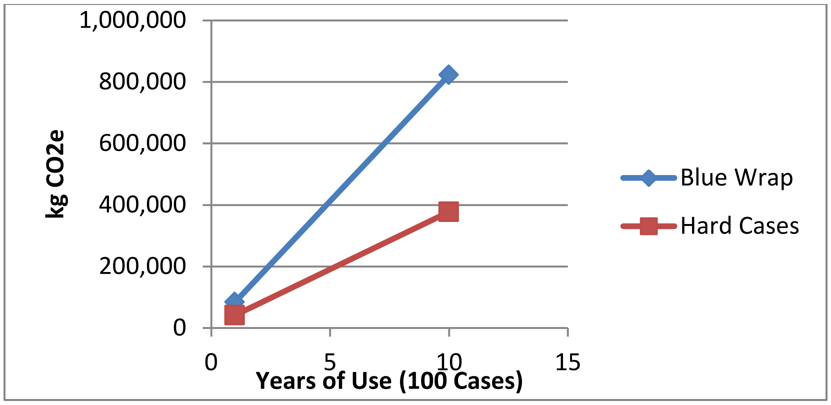

Figure 1: GHG emissions from blue wrap and hard cases from 1-10 years.

Figure 2 shows the 10-year emissions totals for blue wrap and hard cases, as well as the breakdown of emission impact by phase of the life cycle, including manufacturing, use, and end-of-life phases. Figure 2 also emphasizes the approximate 2:1 ratio of emissions impact for blue wrap to hard cases; the life cycle of blue wrap over 10 years generates around 823,000 kilograms of CO_2e whereas the life cycle of hard cases over the same time period generates around 377,000 kilograms of CO_2e. In terms of impact by life cycle phase, for both blue wrap and the hard cases, the use phase has the greatest impact of all phases by a very large margin; this is due to the large amount of energy consumed during the sterilization and decontamination processes and emissions associated with that energy production. For the hard cases, manufacturing phase impact is about 1.6% of the total impact, end-of-life phase impact is only 0.9% of the total impact, and the use phase is about 97.5% of the total impact. Of the total impact for the blue wrap, manufacturing phase impact is about 22.2%, end-of-life phase impact is about 2.5%, and use phase impact is about 77.3% of the total impact.

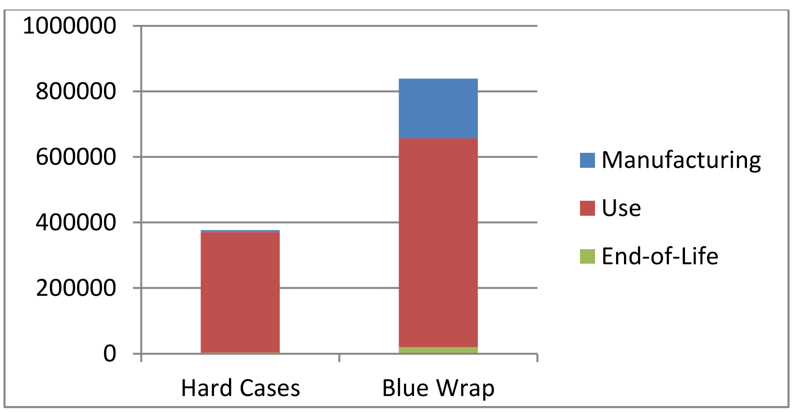

Figure 2: 10-year totals and proportions of manufacturing, use, and end-of-life phases.

Discussion

This study investigated the greenhouse gas emissions related to medical sterilization waste for disposable polypropylene blue wraps and reusable aluminum hard cases. It found the hard cases have roughly half the emissions impact of the blue wrap, even in the first year of use. This result shows the advantage of reusable sterilization containers over disposable sterilization wrappings. However, in actual practice, there are other factors that influence the decision whether to use hard cases or blue wrap, such as storage space and wrapping of variable sized tools. In instances where storage space is a concern, the larger volume of space occupied by a rigid hard case rather than a flexible flat blue wrap may be an issue. In addition, blue wrap can be easily trimmed to wrap individual tools of various sizes, providing a flexibility that is not afforded by the unchanging size of the hard cases. While purchasing smaller cases may be possible, it may not be a cost- or space-effective option. Time required for product use is another area in which there may be differences between blue wrap and hard cases. Hard cases may be faster to assemble during preparation, however, they also require an additional decontamination wipe down. These other factors beyond the GHG emissions impact have been excluded from the system boundary of the current study. Ultimately, while the GHG emissions impact of the hard case is significantly lower than that of the blue wrap, it is only one area for the hospital to consider when choosing one sterilization protection product over another, and other considerations may take precedence for any given situation.

Another significant finding from this study was that the majority of the impact, for either blue wrap or hard cases, was found during the use phase. During the use phase, the energy consumption required for the pre-surgery sterilization and post-surgery decontamination processes was far greater than the energy consumption for blue wrap or hard case production or disposal. This shows that while disposable vs. reusable product issues are not insignificant, the manner in which the product is used often has the largest area of impact. Use procedures vary between hospitals suggesting the results obtained from analysis of the procedures used at Mayo Clinic may not be the same at another facility. Hospital procedures must first manage sterilization and decontamination, as cleanliness and sterility are paramount in the medical industry. Minimizing the existing use phase impact may be possible through sharing optimized procedures between facilities. Information derived from this study may contribute to developing best practices recommendations that manage both sterilization and decontamination requirements as well as optimize environmental impact.

The most evident area of improvement for this study would be to obtain energy consumption and emissions data directly from blue wrap and hard case manufacturers. This would provide the most accurate estimate of per-wrap and per-case energy consumption and emissions, which in turn would enable the most accurate modeling and results. In addition, interacting directly with manufacturers would minimize the number of assumptions necessary to generate a working model, further improving model accuracy.

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