The impact on global warming potential of converting from disposable to reusable sharps containers in a large US hospital geographically distant from polymer and container manufacturer

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Background. Sustainable purchasing can reduce greenhouse gas (GHG) emissions at healthcare facilities (HCF). A previous study found that converting from disposable to reusable sharps containers (DSC, RSC) reduced sharps waste stream GHG by 84% but, in finding transport distances impacted significantly on GHG outcomes, recommended further studies where transport distances are large. This case-study examines the impact on GHG of nation-wide transport distances when a large US health system converted from DSC to RSC.

Methods. The study examined the alternate use of DSC and RSC at a large US university hospital where: the source of polymer was distant from the RSC manufacturing plant; both manufacturing plants were over 3,000 km from the HCF; and the RSC disposal plant was considerably further from the HCF than was the DSC disposal plant. Using a "cradle to grave" life cycle assessment (LCA) tool we calculated annual GHG emissions (CO_2, CH_4, N_2O) in metric tonnes of carbon dioxide equivalents ($MTCO_2eq$) to assess the impact on global warming potential (GWP) of each container system. Primary energy input data was used wherever possible and region-specific impact conversions used to calculate GWP of each activity over a 12-month period. Unit process GHG were collated into Manufacture, Transport, Washing, and Treatment & disposal. Emission totals were workload-normalized and analysed using CHI^2 test with $P \leq 0.05$ and rate ratios at 95% CL.

Results. The hospital reduced its annual GWP by 168 MTCO2eq (-64.5%; $p < 0.001$), and annually eliminated 50.2 tonnes of plastic DSC and 8.1 tonnes of cardboard from the sharps waste stream. Of the plastic eliminated, 31.8 tonnes were diverted from landfill and 18.4 from incineration.

Discussion. Unlike GHG reduction strategies dependent on changes in staff behaviour (waste segregation, recycling, turning off lights, car-pooling, etc), purchasing strategies can enable immediate, sustainable and institution-wide GHG reductions to be achieved. Medical waste containers contribute significantly to the supply chain carbon footprint and, although non-sharp medical waste volumes have decreased significantly with avid segregation, sharps wastes have increased, and can account for 50% of total medical waste volume. Thus converting from DSC to RSC can assist reduce the GWP footprint of the medical waste stream. This study confirmed that large transport distances between polymer manufacturer and container manufacturer; container manufacturer and user; and/or between user and processing facilities, can significantly impact the GWP of sharps containment systems. However, even with large transport distances, we found that a large university health system significantly reduced the

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Abstract

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This study confirmed that large transport distances between polymer manufacturer and container manufacturer; container manufacturer and user; and/or between user and processing facilities, can significantly impact the GWP of sharps containment systems. However, even with large transport distances, we found that a large university health system significantly reduced the GWP of their sharps waste stream by converting from DSC to RSC.

Keywords: sharps containers, greenhouse gases, reusable, global warming potential, life cycle assessment, sustainable purchasing, healthcare

Introduction

Healthcare activities account for 5.4% of greenhouse gas (GHG) emissions in the U.K. (NHS, 2016; DBEIS, 2017) and 7.6% in U.S. (Chung and Meltzer, 2009) and in hospitals, more than half of GHG emissions are derived from supply chain goods and services (Chung and Meltzer, 2009; NHS, 2016). Many hospitals are adopting green purchasing strategies to reduce their GHG (Chung & Meltzer, 2009; NHS, 2017) – a position supported by the Alliance of Nurses for Health Environments (ANHE, 2017). Replacing disposable products with reusables is such an example (WHO-HCWH 2009, Unger et al., 2016; Karrlson and Ohman, 2005) and, as clinical waste containers are in the top 20 contributors to the supply chain carbon footprint (NHS, 2017), replacing disposable sharps containers (DSC) with reusable sharps containers (RSC) is recommended (PGH, 2013). One life cycle assessment (LCA) study found RSC achieved a significant reduction in GHG over DSC however the hospital was close to where both containers were manufactured and the authors' sensitivity analysis found that transport distances could significantly affect results and recommended that scenarios with large transport distances be investigated (Grimmond and Reiner, 2012). Our study compares the annual impact on the global warming potential (GWP) of converting from DSC to RSC at a large U.S. teaching hospital system sited at nation-wide distances from RSC manufacturing and processing plants.

Materials and Methods

Study Overview, Data Sources and Statistical Analysis

Using established principles for assessment of the life cycle GHG emissions of goods and services (British Standards Institute, 2011) we utilised a cradle-to-grave life cycle inventory (LCI) and a product-system LCA tool developed specifically for sharps containers and containing some 750 data cells (Grimmond and Reiner, 2012). In a before-after intervention study, we compared the annual GWP of DSC and RSC usage at Loma Linda University Health

(LLUH), an 1100 bed university healthcare system with 5 general acute care hospitals and an expansive outpatient clinic system, in Loma Linda, California.

The LCI itemised all energy-using processes required by each containment system life-cycle as implemented at LLUH. Scope 1, 2 and 3 processes were included in both study years. Unit process GHG were collated into the following life-cycle stages: manufacture (of polymer and containers); transport; washing (RSC); and treatment & disposal. The LCA assessed the GWP of all energy used in these processes (vehicle fuel, gas, electricity, water supply and treatment) and in the manufacture and life cycle of ancillary products (pallets, transport cabinets, cardboard boxes, wash products).

The following data sources were used in calculating GHG: American Chemistry Council data (American Chemistry Council, 2010) for DSC and RSC resin manufacture; primary energy input data for DSC and RSC container manufacture (Clarion 2011) and RSC washing; industry-specific data for DSC autoclaving; DEFRA transport conversions for RSC and DSC transport (DEFRA, 2015); USEPA eGrid values for California, Michigan and Illinois power generation (USEPA eGRID 2014); GaBi data for energy inputs for water supply and treatment, and manufacture of wash product, cardboard and transporters (GaBi, 2006); DEFRA for pallet LCA (DEFRA and Consortium, 2010): and USEPA WARM values for incineration of DSC (USEPA WARM, 2016. The same database and values were applied to the relevant unit processes in both container systems. In the RSC study-year, the manufacture, treatment and disposal of 412 chemotherapy DSC were included. The RSC is certified for 500 uses and 2% required dismantling and repair with 80% of parts reused and 20% recycled. RSC manufacturing emissions were divided by their anticipated life expectancy of 41.7 years (British Standards Institute 2008). Although it is theoretically possible for RSC to be recertified for a further period when they reach their certified reuse expiration, for this study their "end-of-life" was taken to be 41.7 years. The GHG associated with manufacture of ancillary reusables (transport cabinets and pallets) were included and calculated using their expected life span. The DSC were not recycled; 1 of 17 DSC product-lines contained recycled polymer but GHG credit was excluded as it was less than 1% of total DSC manufacturing GHG). Data on size, brand and number of containers, and APD were obtained from LLUH. Tare weights of DSC were determined by weighing an example of each model. The conversion-transition period (2 years) was excluded to avoid data overlap. Emission totals for each system's annual use were workload-normalized using total Adjusted Patient Days (APD) for the two study years. Rate ratios with 95% confidence limits were analysed using CHI^2 with P set at ≤ 0.05.

System Function, Boundary, Allocation and Classification

The system function provided by the alternative products (DSC, RSC) was the supply and disposal of sharps waste within a specified healthcare system. The functional unit was the supply of each system for a one-year period. Sharps waste is a sub-category of medical waste and comprises items capable of penetrating human skin (e.g. needles, scalpels) which may have the potential to transmit infectious disease or pose a physical or chemical hazard. Because of these hazards, at disposal, all sharps must be safely contained in either DSC or RSC and transported to a treatment facility. With DSC the container is used once and the intact container and contents are subjected to treatment (commonly autoclaving or incineration) prior to landfill. With RSC, the container is automatedly decanted of its contents, cleaned and decontaminated and reused a defined number of times, and contents subjected to treatment as with DSC. The boundary of the system studied included all unit processes used for raw material extraction and polymer manufacture and transport, container manufacture and transport; transport of full containers to treatment facility, RSC processing (including water supply, water treatment, and wash products), treatment of DSC, transport of treated DSC to landfill, and energy required for electricity generation for all relevant processes. Transport fuel processes were calculated from well to wheel. Excluded from the system boundary were treatment of contents (remained the same in both DSC and RSC), infrastructure and assets, and any inputs and outputs that comprised less than 1% of mass or energy.

Allocations for emissions were based on a mass basis for polymer production, container production, carton and transporter production and DSC treatment. Other allocations for emissions were as follows: transport (truck size and utilization by tonne.km); electricity generation (kwH); water supply and treatment (Litre); RSC washing and washing products (container); and pallets (trip).

Global warming potential was the impact assessment category to which all inventory data was allocated as it is well-known and is commonly used and understood by healthcare facilities. A table listing the raw data for all unit processes in the LCI, including flow, units, emission factors, total GWP, data sources and data-representativeness, accompanies this publication.

Results

DSC were manufactured in Crystal Lakes IL from US-sourced polymer, nested in cardboard containers, transported 3,200km to the hospital on wooden pallets, and autoclaved and landfilled without shredding at Vernon CA, 130km from the hospital. The RSC were manufactured in Greenville MI from polymer sourced in Korea, transported 3,500km in reusable transporter cabinets to LLUH, and decanted and processed at Fresno CA, 440km from the hospital.

A summary of results is presented in the Table. To service LLUH in the baseline year, 48,460 DSC were manufactured from 50.6 tonnes of polymer and required 8.2 tonnes of corrugated cardboard packaging for transport (see Table). In California, only biological sharps can be treated (autoclaved) then landfilled; chemotherapeutic and pharmaceutical sharps must be incinerated (then ash landfilled). With DSC, this resulted in 31.8 tonnes of plastic DSC being landfilled and 18.8 tonnes of DSC being incinerated (Table 1).

In the RSC year, 2,780 RSC were manufactured from 9.6 tonnes of polymer and 0.4 tonnes of cardboard were used for packaging of 412 chemo DSC that were continued to be used (no cardboard is used for RSC packaging). During the RSC study year, approximately 60 RSC required repair with 30 kg parts being recycled or reused (nil to landfill), and, with recycling credit, an equivalent of 2.3 RSC were manufactured as replacement containers (2,782 RSC total for year). The RSC, certified for 500 uses, were reused an average of 12.0 times/year, giving an "end-of-life" lifespan of 41.7 years. Total GHG emissions and GHG differences between DSC and RSC life cycle stages are shown in the Figure.

Adjusting for the 0.3% APD workload increase in the year of RSC use, sharps management GWP using DSC was 260.5 MTCO2eq, and with RSC use, decreased to 92.5 MTCO2eq, a 168 MTCO2eq (64.5%) reduction in GWP (See Table and Figure).

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Discussion

Background and impact of distances

Commercial RSC, first used in US and Australia in 1986, now represent approximately 50% and 75% respectively of the sharps containers used in these countries, and since 1999 have been increasingly used in Canada, UK, Ireland, New Zealand, South Africa and South America. Generally, RSC are reused many times per year and, with rugged construction and effective inspection and repair, may last several decades. Prior to sale in the US, RSC and DSC are required by the Federal Drug Administration to pass identical performance tests and RSC are required to undergo lifespan processing simulation and transport simulation prior to testing. Likewise, the Canadian sharps container standard does not distinguish between DSC and RSC in its performance test requirements and requires lifespan simulation of RSC prior to testing (CSA, 2014).

One reason healthcare facilities adopt RSC is for environmental sustainability (PGH, 2013) but quantitative studies confirming this fact are rare (Unger et al 2016, Karrlson & Ohman 2005). Although the same RSC may be reused several hundred times, energy is required for their robotic washing between uses and, being heavier than DSC; their greater weight means more energy is required per unit for transport and manufacture. One study found that when polymer-source and container-manufacturing plant are close to the healthcare facility (HCF), the conversion to RSC resulted in an 83.5% reduction in GWP (Grimmond and Reiner 2012). In our study, the HCF was 3,500km from the RSC manufacturing plant, and, more importantly (because of daily delivery), the RSC processing plant was 440km from the HCF. This resulted in transport being the largest contributor to RSC life-cycle GWP (see Figure). Ali et al also noted the increased GHG when medical waste is transported longer distances (Ali et al, 2017). We found transporting RSC longer distances does lessen the differential between DSC and RSC GWP, and, unlike the 2012 study by

Grimmond and Reiner, transport then becomes the greatest contributor (86.3%) to GWP. Notwithstanding these impacts, even with long-distance transport, the conversion to RSC significantly reduced total sharps waste management GWP by 64.5% when compared to DSC. This reduction in sharps management GWP with RSC use, while only a small component of the total supply chain emissions at LLUH, has been a positive step in the institution's sustainability strategies. Unlike GHG reduction strategies dependent on changes in staff behaviour (waste segregation, turning off lights, car-pooling, etc), our study confirms that purchasing strategies can enable immediate, sustainable and institution-wide GHG reductions to be achieved.

Impact on GHG over 10 years

The impact of repeated DSC manufacture and one-off RSC manufacture is best illustrated over multiple years. In the LLUH scenario over a 10-year period, 484,600 DSC would need be manufactured compared to 6,900 with RSC use (includes 4,120 chemo DSC), and would divert 502 tonnes of plastic from landfill or incineration. The reduced number of container exchanges with RSC (with associated labor reduction) is also noteworthy.

Sensitivity analysis

Manufacturing (of resin and containers) gave the largest differential between the two systems (See Figure) and is predominantly a function of the energy required for the higher total polymer weight needed to be annually manufactured and molded for DSC. Although many more DSC required transportation from the distant manufacturing plant, the daily transport of RSC from the distant processing plant resulted in a similar transportation GWP for both systems over the year (see Figure).

Electricity "cleanliness" across US grids (e.g. windfarm, coal, hydro) is a key variable in comparative GWP analyses (Unger et al., 2016) and the sensitivity analysis in our study showed that differing US electricity sources can alter processing and manufacturing GHG by 76% and, when extrapolated to the total life-cycle GWP of each system, can alter DSC GWP by 22% and RSC GWP by 9%. Optimization of reusability of medical products is recommended to lower GHG (Unger et al., 2016) and, as water usage in this study was found to account for 60% of the GHG associated with RSC washing, less water usage would lower GHG of this stage. Also, energy and material reclamation will markedly reduce manufacturing GWP particularly if reclaimed plastic is used to offset virgin resin use (Grimmond and Reiner, 2012, Unger et al., 2016).

Other impacts of RSC

The focus of this study was GWP however cost reduction (Grimmond and Reiner, 2012) and sharps injury reduction (Grimmond et al., 2010) have also been associated with RSC use and these factors, together with sustainability and frontline staff evaluation, were considered prior to adoption of the RSC system by LLUH.

Study Limitations and strengths

One limitation of the study was the assumption made in the location of manufacture of polymer for the DSC. To limit the impact of this assumption, the location was assumed to be a United States polymer supplier close to the point of manufacture of the DSC. A second limitation was the use of the UK DEFRA database for transport energy inputs. This was necessary as no relevant United States database using tonne.km was available; however, all databases were applied equally for both DSC and RSC systems. Study strengths were in the availability of 12 months of usage data for both systems; the large transport distances compared to previous studies; and the primary and region-specific availability of energy input data for unit processes in both systems.

Conclusions

- Large RSC transport distances lessen the differential between DSC and RSC GWP, however, RSC still achieve significant GWP reductions over DSC.
- Transport & electricity cleanliness are key factors in GWP of sharps waste management.
- Purchasing decisions can significantly contribute to HCF GWP-reduction strategies.
- Institution-wide adoption of RSC can reduce GWP with minimal staff behavior-change.

Declaration of Interest

BM and MS declare no conflict of interest. TG is an international consultant in sharps injury prevention and waste management to the healthcare and associated industries and Daniels Health, the manufacturer of the reusable device studied in this paper, is one of his clients. The manufacturer did not review, sight or have input into the conduct, content, methodology, results, write-up of the study or choice of journal for publication.

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Table 1(on next page)

Annual sharps waste stream and GHG: comparison of disposable vs reusable sharps containers at LLUH.

Annual sharps waste stream and GHG: comparison of disposable vs reusable sharps containers at LLUH.

	DSC	RSC
Containers Manufactured	48,460	3194[a]
Containers landfilled annually	35,925[b]	0[c]
Weight plastic landfilled (tonnes)	31.8	0[c]
Weight plastic incinerated (tonnes)	18.8	0.4[d]
Weight cardboard boxes (tonnes)	8.2	0.1[e]
Container exchanges	48,460	33,356[f]
MTCO2eq GWP[g]	259.8	92.5
Adjusted Patient Days (APD)	296,205	297,056
$MTCO_2eq$ GWP per 10,000 APD[h]	8.77	3.11[i] (-64.5%)

GHG, Greenhouse Gas; LLUH, Loma Linda University Health; $MTCO_2eq$, metric tonnes carbon dioxide equivalent; DSC, disposable sharps container; RSC, reusable sharps container; GWP, Global Warming Potential.

[a] 2,780 RSC manufactured in year one only, plus 2.3 replacement RSC (allowing for reuse and recycling credits), plus 412 chemotherapy/pharmaceutical DSC annually.

[b] 8,245 Chemotherapy/Pharmaceutical DSC are incinerated/yr.

[c] No RSC were landfilled as all parts were either reused or recycled.

[d] Tonnes of chemo DSC incinerated (412 chemo DSC were used during RSC year)

[e] Chemotherapy DSC packaging.

[f] RSC were larger in fill-line capacity (25.7L vs DSC 18.5L) and exchanged less often than DSC.

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[g] Emissions of GHG expressed in terms of global warming potentials, defined as the radiative forcing impact of one mass-based unit (kg) of a given GHG relative to an equivalent unit of carbon dioxide over a given period of time (100 years) (British Standards Institute 2008).

[h] 10,000 APD used as workload denominator to normalize base year comparison and facilitate inter-hospital comparisons.

[i] 64.5% reduction; $P < 0.001$; Rate Ratio = 0.36; CL(95%) = 0.28-0.45.

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Figure 1 (on next page)

Annual greenhouse gas emissions by life stage of disposables and reusable sharps containers at Loma Linda University Hospital, normalised to Adjusted Patient Days.

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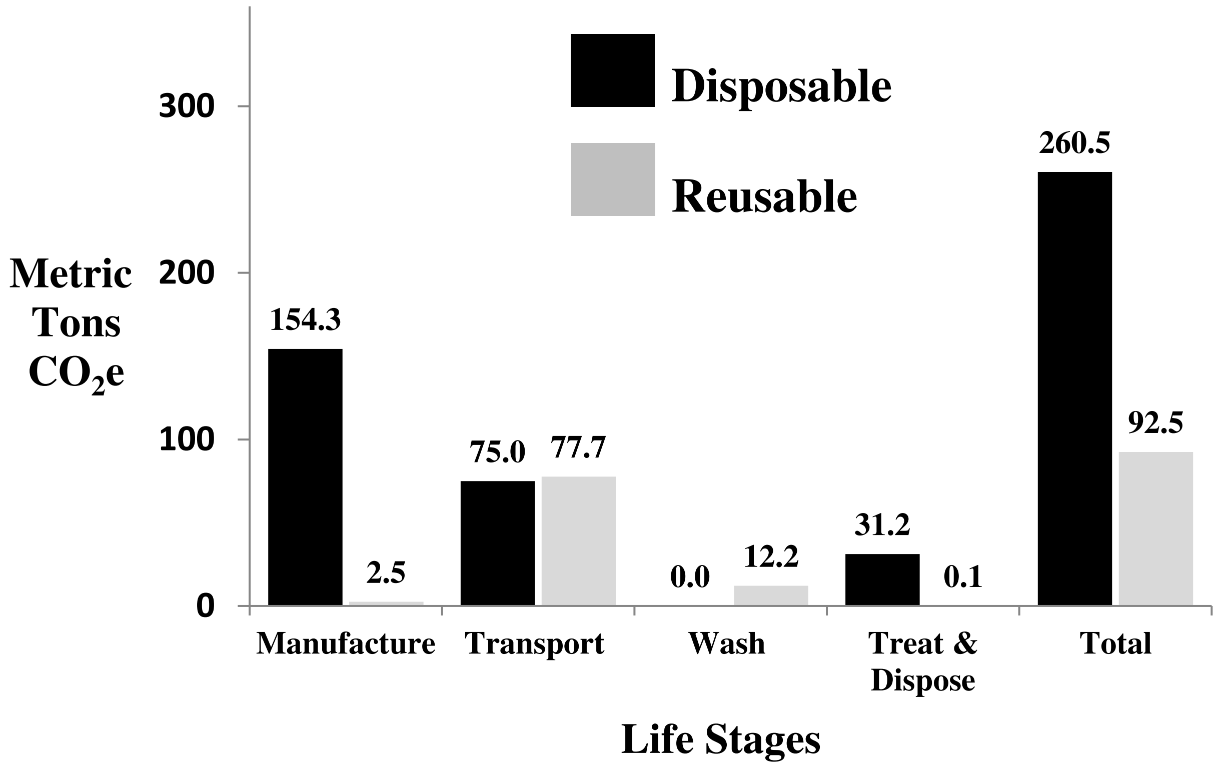

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