Non-sterile examination gloves and sterile surgical gloves: Which are more sustainable?

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Keywords

Environmental sustainability – sustainability in healthcare – sterile surgical gloves – non-sterile gloves – life cycle assessment

Summary

Background: Healthcare professionals should consider environmental sustainability when using personal protective equipment (PPE). One of the most frequently used items of PPE in medical settings are gloves.

Aim: This study aims to quantify the environmental impact of sterile versus non-sterile gloves using the life cycle assessment (LCA) methodology.

Methods: This study used three glove types: non-sterile gloves and sterile gloves (latex and latex-free). Sixteen different environmental impact categories were used to demonstrate the impact of each glove type.

Findings: Non-sterile gloves had the least environmental impact in all categories. The two types of sterile gloves, non-latex (synthetic rubber) and latex (natural rubber), performed similarly, although the non-latex gloves had a greater impact on ozone depletion, mineral use and ionizing radiation. For climate change impact, sterile latex gloves were 11.6 times higher than non-sterile gloves. This study found that for both sterile type gloves (latex and non-latex), the manufacture of the gloves contributes to the most considerable environ- mental impact, with an average of 64.37% for sterile latex gloves and 60.48% for non-latex sterile gloves.

Conclusion: Using the LCA methodology, this study quantitatively demonstrated the environmental impact of sterile versus non-sterile gloves.

Introduction

Environmental sustainability continues to be one of the greatest challenges of this era. Multiple initiatives, goals and ambitious plans have been set in recent years to fight climate change [1-2].

The global healthcare sector is responsible for around 5% of global greenhouse gas (GHG) emissions [3]. Healthcare sectors that strive to improve individuals' health and quality of life are indirectly harming it. In the UK, the National Health Service (NHS) contributes to more than 4% of the overall GHG emissions produced in England (two-thirds of which comes from medical equipment and supply chains) [4]. The NHS has now set up an ambitious long-term plan towards sustainability [4]. One of the main goals to be reached is for the NHS to reduce its GHG emissions by 80% from 2028-2032 [4].

One way of increasing sustainability is through procurement of more sustainable consumables. Personal Protective Equipment (PPE) is an essential consumable used by the healthcare sector, with gloves accounting for a significant proportion [5]. It is estimated that, globally, more than 150 billion pairs of medical gloves are produced each year, with a market value of more than $5 billion [6]. During the coronavirus (COVID-19) pandemic, there was a surge in the PPE demand, with an estimated 11% increase in the global production of gloves [7]. According to recent statistics by the Department of Health and Social Care, nearly 6 billion gloves were distributed to health and social care services from February 2020 to March 2021 [8].

There are two main types of medical gloves used in healthcare, sterile and non-sterile gloves. According to the World Health Organisation (WHO) recommendations on medical glove use, sterile gloves are primarily used during surgical procedures, while non-sterile gloves are mainly used during contact with blood, body fluids, secretions and skin [9]. Whilst non-sterile gloves are not used for surgical procedures, sterile gloves can be used (and are used) sometimes for non-surgical procedures.

To assess the environmental impact of a specific product or item, the Coalition for Sustainable Pharmaceuticals and Medical Devices (CSPM) recommends the utilisation of the life cycles assessment (LCA) [10]. It assesses the environmental impact associated with all stages of a product's life from the extraction of raw materials, machinery used during manufacturing, distribution, transportation used to the disposal method.

In light of the quantity of gloves utilised in the medical field, this study aims to quantify the environmental impact of sterile versus non-sterile gloves using the LCA methodology.

Materials and methods

Functional unit

The functional unit in this study was an individual clinician using one pair of non-powdered, medium-sized gloves for a healthcare procedure. The following types of gloves were compared:

1. Medium, latex-free (nitrile), non-sterile gloves
2. Size 7 latex, sterile gloves
3. Size 7, nonlatex, sterile gloves

The products chosen were based on what is currently in use at University College Hospital London (UCLH). The exact brands have been anonymised.

System boundaries

The entire product system was considered, including the geographic location of the manufacture (Figure 1).
Information on raw materials and manufacture was obtained from the manufacturers. Estimates of power usage during manufacture were obtained from publicly available machinery specifications.

Assumptions and exclusions

Raw materials

Non-sterile gloves were made from latex-free nitrile, and sterile gloves were made from latex rubber and the nonlatex sterile gloves from EDPM synthetic rubber. Weights of the gloves and packaging materials were measured to the nearest 0.01g using an electronic weighing scale (Ascher Model CS).

Manufacture and packaging

Glove manufacture was estimated using the kWh for the machinery used to produce each type of glove. For the non-sterile nitrile gloves, it was assumed that 0.01267kWh were needed to produce one pair of gloves, and 0.01904762kWh for the sterile gloves as they undergo more rigorous manufacturing methods and sterilisation. For both types of gloves, the chemicals and oils used to clean and maintain the machinery were excluded from system boundaries.

European Standards EN455-1 (adopted into UK law) require medical disposable gloves to undergo air leak testing. An air leak testing machine uses 0.3833kWh to test 1 glove. For the sterile gloves, the manufacturer confirmed that every individual glove undergoes air leak testing therefore, 0.7666kWh was allocated for one pair of gloves. For non-sterile gloves, one quality testing service recommends four gloves per batch of non-sterile medical examination gloves were tested (0.02%); therefore, 0.0076kWh was allocated for a pair of non-sterile gloves. It was assumed that gloves failing the test were recycled back into the manufacturing process.

The packaging of non-sterile gloves was assumed to be in a printed cardboard box containing 100 gloves. The sterile gloves were packaged in pairs, wrapped in a sheet of printed greaseproof paper and a heat-sealed printed polyethylene film (it was assumed that 0.00738889 kWh were needed to heat seal one packet), and 50 pairs of wrapped gloves were packaged in one large printed cardboard box. All printing was assumed to be offset printing.

The manufacturers in China confirmed the manufacture location for the non-sterile gloves and Malaysia for the sterile gloves.

Transport and retail

The supply chain between the factory and the UCLH was assumed to go via a local supplier. Transport routes were assumed to be via the shortest land and sea routes, measured in kg*km. Distances for road transport were estimated using Google Maps and Ports.com website. Distances for sea transport were estimated and converted from nautical miles to km using Google Unit Converter.

The non-sterile gloves were assumed to be transported from the factory in China via lorry road transport to Qingdao port then by container ship to Port of London. The sterile gloves were assumed to be transported from the factory in Malaysia via lorry road transport to the Port of Penang, then by container ship to Port of London. From the Port of London, all gloves were assumed to be transported via a EUR06 engine lorry from the Port of London to the supplier depot in Kent, and from there to the Royal National ENT and Eastman Dental Hospitals on Huntley Street. ‘Retailing’ of the gloves by the supplier was excluded, as the impact was assumed to be negligible and the same for each type of glove (stored in a warehouse with no heat requirements).

Consumer use and disposal

After the use of the gloves by the clinician, it was assumed the gloves themselves were placed in clinical waste (for incineration). The packaging for both gloves was assumed to be recycled in plastic or paperboard waste.

Data collection and analysis

A life cycle inventory was produced using the assumptions above and a breakdown of the two products (Table I). The reference database Ecoinvent v3.7.1 was used alongside openLCA v1.10.3 for the life cycle analysis according to ISO and PEF standards [11,12]. The LCIA methods and impact categories were based on PEF standards, as described in Table II. Normalised results and contribution analysis were produced. Disability Adjusted Life Years (DALYs) were produced using ReCiPe H Endpoint and converted into minutes.

Results

Life cycle impact assessment (LCIA)

The LCIA results for each of the three gloves types are shown in Figure 2. Non-sterile gloves had the least environmental impact in all categories (colour coded in green), with the impact of the sterile latex gloves measuring at least five times the amount of the non-sterile gloves.

For climate change, the impact of a pair of sterile gloves was over eleven times greater than that of the non-sterile gloves (11.6 for latex, 11.8 for nonlatex).

Latex and nonlatex sterile gloves produced similar LCIA results (within 0-6% of each other) for all but three impact categories. The nonlatex (synthetic rubber) sterile gloves scored higher than latex (natural rubber) sterile gloves in ozone layer depletion (20%), mineral and metal depletion (34%) and ionising radiation (37%).

Normalised results

The raw LCIA results were normalised. Normalised results provide an impact of a product proportional to that of which an average person would be expected to contribute from their daily lives in one year. The normalised results are shown in Figure 3. The most notable categories for all types of gloves were carcinogenic effects, non-carcinogenic effects, freshwater eutrophication, and climate change. Using one pair of non-sterile gloves is equivalent to about 0.001% of the average person's annual climate change contribution (this figure was over 11 times greater for sterile gloves - approximately 0.01%).

Contribution analysis for each glove type

Figure 4 demonstrates how each life cycle stage contributed to the impact results for each type of glove. For the nonsterile nitrile gloves, the raw material was the largest contributing factor (20.23% - 72.28%), whereas for the sterile gloves, it was the manufacturing processes of the gloves that was the largest contributing factor (making up 18.18% – 89.17% for latex and 17.19% – 81.77% for the nonlatex).

Disability adjusted life minutes

The disability adjusted life minutes for each glove type are presented in Table lll. Nonlatex sterile gloves had the highest impact at the equivalent of 36 minutes, followed by latex-sterile gloves with 29 minutes and non-sterile gloves with 3 minutes. Ozone depletion and global warming contributed most to the overall impact for all types of gloves.

Discussion

In this study, the LCA methodology was utilised to quantify the environmental impact of sterile versus non-sterile gloves. Overall, non -sterile examination gloves had the least environmental impact in all categories. Substituting latex sterile to non-sterile gloves would save at least 80% of the environmental impact in all categories. The two types of surgical sterile gloves - nonlatex (synthetic rubber) and latex (natural rubber) - performed similarly, although the nonlatex gloves had a greater impact on ozone depletion, mineral use, and ionising radiation than sterile latex gloves. However, for climate change impact, sterile latex gloves were 11.6 times higher than non-sterile gloves.

This study found that for both sterile type gloves (latex and nonlatex), the manufacture of the gloves contributes to the most considerable environmental impact, with an average of 64.37% for sterile latex gloves and 60.48% for nonlatex sterile gloves. One of the main reasons for this increase is that sterile gloves must meet specific standards before production. To meet these standards, rigorous processes and machinery are utilised to test for glove surface and micro-holes, mechanical, biological, and shelf-life testing. For instance, extensive tests are performed to ensure that sterile gloves can form an effective barrier against micro-organisms. Moreover, each sterile glove undergoes an air leak test, unlike non-sterile gloves, where only a few gloves are randomly picked from the batch to be tested. As for the non-sterile nitrile gloves, the nitrile material accounted for an average of 40% of the overall impact.

Additionally, the packaging contributed more towards the overall impact of sterile gloves compared to non-sterile gloves. That is because 50 pairs of non-sterile examination gloves are packaged together in a printed cardboard box only, while individual pairs of sterile gloves are wrapped in a paper insert and polyethylene wrap, with 50 pairs then packaged in another cardboard box.

As stated earlier, LCA is an environmental assessment tool that evaluates inputs, outputs, and numerous potential environmental impacts associated with a product during its entire life cycle. Although the CSPM recommends using LCA analysis by the healthcare sector as a reliable tool to assess the product's environmental impact, it still holds some drawbacks. As previously demonstrated, the LCA assesses various environmental impact aspects, including climate change, acidification, water/fossil, or land usage. Some studies may rule out one of these impacts or processes as they may not fit their scope. Eventually, this will create a wide margin of variations which reflects in equivocal results. For instance, in this study, our calculations are based on several assumptions. We calculated the environmental impact on a single typical model of each type of gloves, but other products will have different environmental impacts. Nonetheless, the margin of these differences is likely to be small and may not contribute to a substantial change in the average environmental impact results. Moreover, to overcome these issues, LCA tools must follow stringent and widely accepted guidelines to reduce these variations. Recently, the European Union adopted the Product Environment Footprint (PEF) as a standardised and consistent method to utilising LCA [13], and PEF guidelines were followed in this study.

Besides the environmental impact of gloves, other aspects should be investigated, such as the cost and the environment in which they are manufactured. Out of all the PPE, disposable gloves are the most used by healthcare workers and are estimated to range from 85% to 95%. In England, the government spent over £15 billion on PPE for frontline staff during the pandemic. According to recent statistics by the Department of Health and Social Care, nearly 6 billion gloves were distributed to health and social care services from February 2020 to March 2021 [8]. The cost of the glove brands used in this study for non-sterile gloves with a box containing 100 gloves was an average of £4.21. On the other hand, one box of sterile gloves containing 50 pairs costs an average of £56, which is almost 14 times higher than non-sterile gloves.

The Sustainable Healthcare guidelines set by the WHO recommend that healthcare sectors choose their manufacturer correctly [14]. The guidelines suggest choosing an environmentally conscious manufacturer, who uses sustainable raw materials, runs on renewable energy for their machinery, and provides recyclable packaging. Although beyond the scope of this study, migrant rights abuse in glove producing factories is also common [8]. Gloves are mainly manufactured in Far East Asia in countries such as China, Malaysia, and Thailand, to name a few. Sadly, there may be labour abuses in some of these factories [15]. Recently, procurement agencies in Europe and worldwide, including the NHS, developed policies to protect labour rights. Any NHS supply chain follows the Supplier Code of Conduct and the Labour

Standards Assurance System (LSAS) when dealing with any manufacturer [16]. However, during the pandemic and the surge in PPE demand, parallel supply chains were required. The LSAS, the Supplier Code of Conduct, and the Modern Slavery policies may not have fully verified these supply chains [17] (S., 2021, P, 2020). A UK Green Paper plan is being investigated to simplify and speed up procurement, emphasising value for money and providing flexibility in adding new suppliers [18] (Office, 2020). However, it is not clear whether or not the risks of forced labour will be mitigated.

According to the sustainability guidelines, when it comes to single-use plastic items, the rule of the three Rs (reduce, recycle, or reuse) is always emphasised. According to the WHO guidelines on glove use, non-sterile gloves are used in the case of touching blood, body fluids, secretions, excretions, and items visibly soiled by body fluids. In contrast, sterile gloves are mainly used during a surgical procedure [9]. Considerations of which type of glove to use are principally in terms of cross-infection and cost. The inconsistency of guidelines increases the ambiguity of healthcare professionals concerning when to use certain types of gloves and where. Thus, it is essential for a healthcare professional to have standardised guidelines to follow to know when to use what type of glove and how often to reduce its use whenever possible. Moreover, as a rule, the guidelines state that the healthcare team should not consider single-use goods unless mandated through patient safety and/or legislation. Gloves do not need to be worn for all healthcare related interactions, as even these non-sterile examination gloves have an environmental cost. According to the WHO guidelines, the use of gloves would not be indicated when there is no potential for exposure to blood or bodily fluids. This includes direct patient exposure (e.g., taking blood pressure, checking temperature or providing intramuscular injections) or indirect patient exposure (e.g., using telephones, writing patient’s charts or during replacing or removing patient’s bed linens) [9]. In these situations, guidelines and policies should focus on hand hygiene and not wearing gloves.

To the best of the author's knowledge, no studies have demonstrated how often sterile gloves are used for non-sterile procedures. Studies like these (e.g., audits) will be essential to assess the healthcare sector's adherence to the guidelines regarding glove use.

Conclusion

In conclusion, medical PPE has an impact on the environment. Using the LCA methodology, this study quantitatively demonstrated the environmental impact of sterile versus non- sterile gloves.

Conflict of interest

The authors declare no conflict of interest.

Source of funding

No source of funding to declare.

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Figure 1. System boundaries

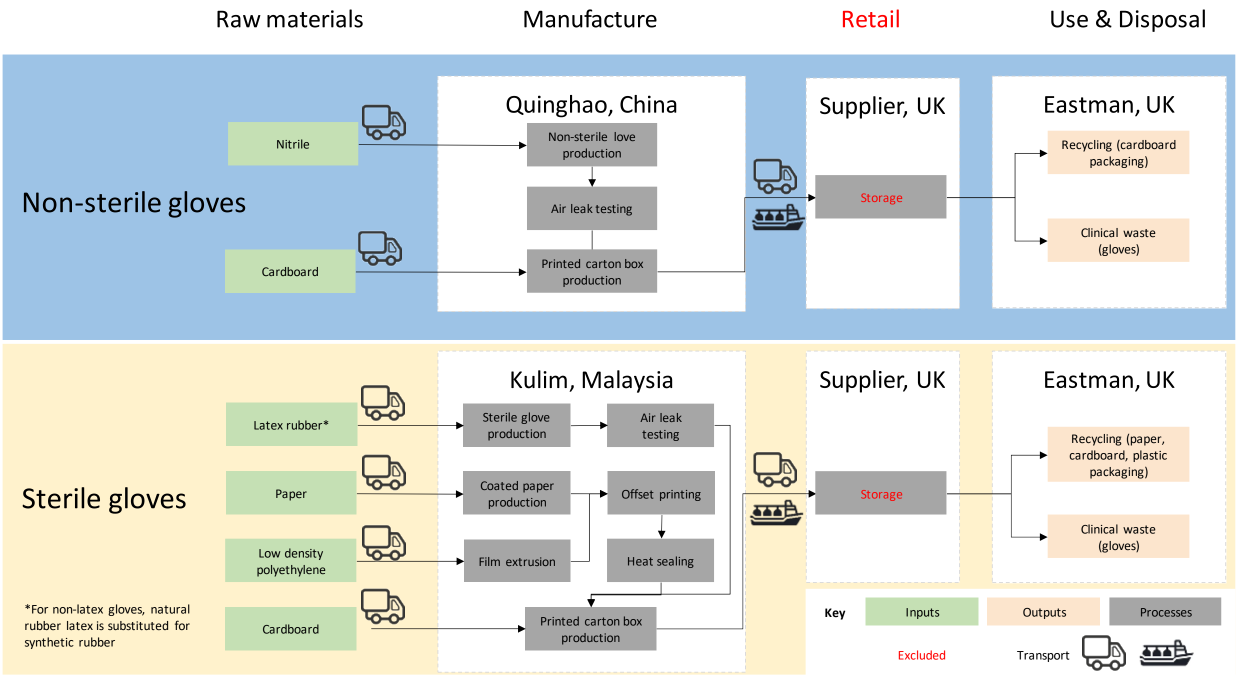

Figure 2. LCIA results

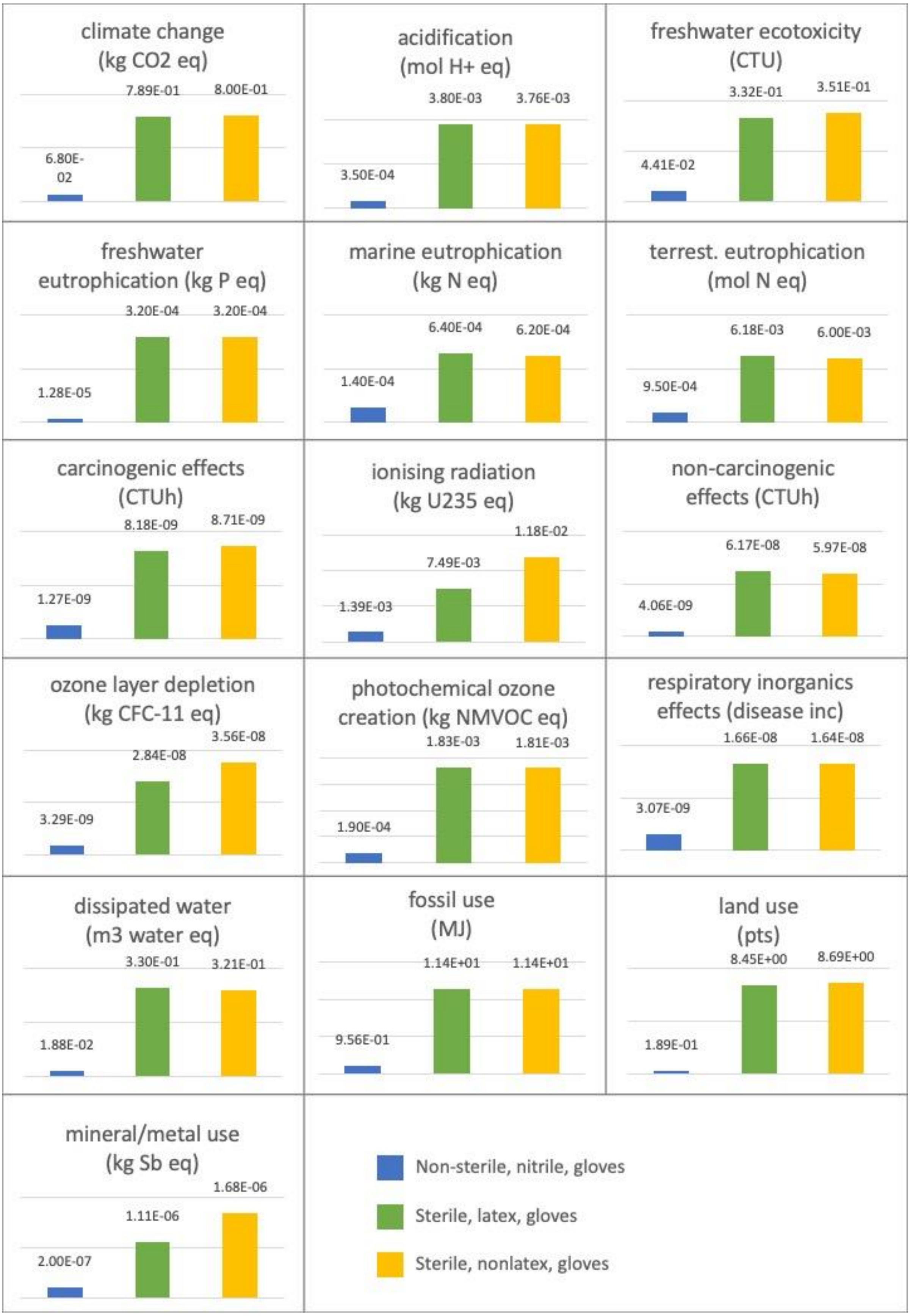

Figure 3. Normalised results

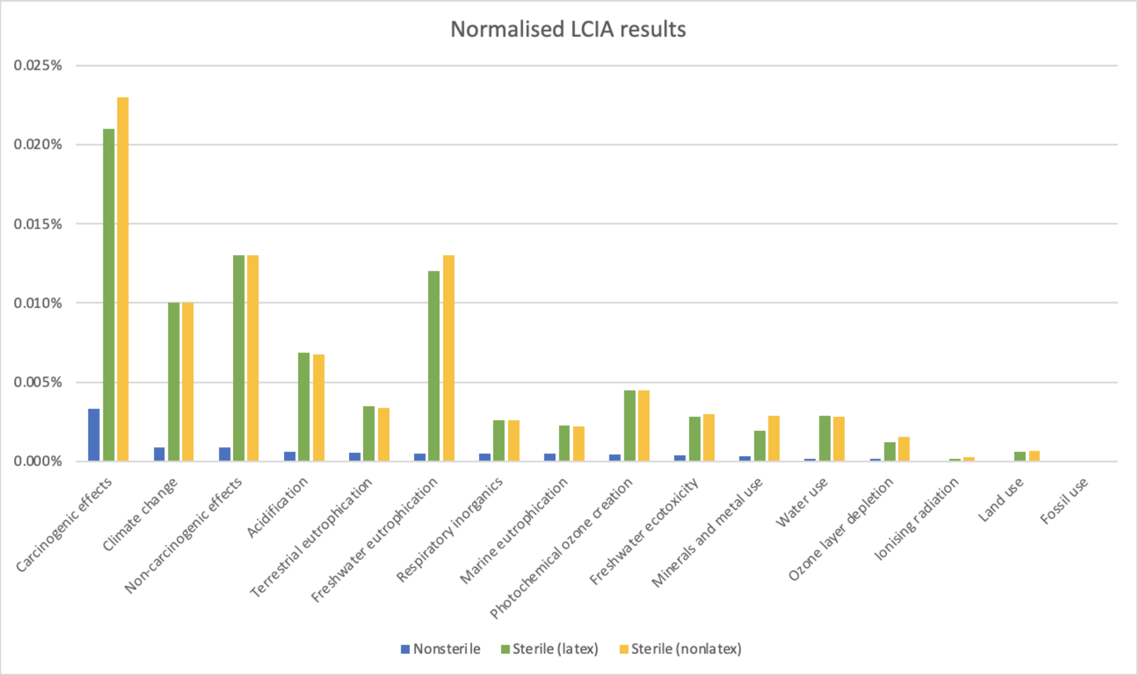

Figure 4. Contribution analysis for each glove type. A. Non-sterile nitrile gloves; B. Sterile latex gloves; C. Sterile nonlatex gloves.

Table I. Life cycle inventory for 1 pair of gloves

Description	**Amount**	**Unit**	**Provider**
Non-sterile nitrile gloves			
Nitrile material	6.88	g	Market for acrylonitrile, GLO
Manufacture gloves	0.01267	kWh	Market for electricity, medium voltage CN-SGCC
Air leak testing	0.0076	kWh	Market for electricity, medium voltage CN-SGCC
Packaging (cardboard box)	1.0354	g	Market for carton board box production with offset printing GLO
Road transport to Quingdao port	232km*(6.88 +1.0354)/1000kg	Kg*km	Market for transport, freight, lorry, unspecified, GLO
Sea transport to Port of London	22628km* (6.88+1.0354)/1000kg	Kg*km	Market for transport, freight, sea, containership GLO
Road transport to EDH via UK supplier	122.1km* (6.88+1.0354)/1000kg	Kg*km	Market for transport, freight, lorry >32 metric ton, EUR06 RER
Gloves in clinical waste	6.88	g	Market for hazardous waste, for incineration (Europe without Switzerland)
Cardboard box in recycling	1.0354	g	Market for waste paperboard GB
Sterile latex gloves			
Latex material	11.29	g	Market for latex GLO
Manufacture gloves	0.01904762	kWh	Market for electricity, medium voltage MY
Air leak testing	0.7666	kWh	Market for electricity, medium voltage MY
Packaging (paper insert)	5.62	g	Paper production, woodfree, coated, at integrated mill GLO
Packaging (plastic sleeve)	6.05	g	Market for packaging film, low density polyethylene GLO

Packaging (offset printing sleeve)	5.62+6.05	g	Offset printing, per kg printed paper GLO
Packaging (heat seal sleeve)	0.00738889	kWh	Market for electricity, medium voltage MY
Packaging (cardboard box)	4.1652	g	Market for carton board box production with offset printing GLO
Road transport to Penang port	23.5km*(11.29+5.62+6.05+4.1652)/1000 kg	Kg*km	Market for transport, freight, lorry, unspecified, GLO
Sea transport to port of London	16407km*(11.29+5.62+6.05+4.1652)/1000kg	Kg*km	Market for transport, freight, sea, containership GLO
Road transport to EDH via UK supplier	122.1 km*(11.29+5.62+6.05+4.1652)/1000kg	Kg*km	Market for transport, freight, lorry >32 metric ton, EUR06 RER
Packaging in recycling (paper insert)	5.62	g	Market for waste packaging paper GB
Packaging in recycling (polyethylene sleeve)	6.05	g	Market for waste polyethylene GB
Packing in recycling (cardboard box)	4.1652	g	Market for waste paperboard GB
Gloves in clinical waste	11.29	g	Market for hazardous waste, for incineration (Europe without Switzerland)
Sterile latex-free gloves			
Polyisoprene gloves	11.29	g	Market for synthetic rubber GLO

Table II. Impact categories and LCIA methods used in this study

Impact category	**LCA methods (Unit)**	**Description**
Human health - ozone layer depletion	ILCD 2011 Midpoint+ (kg CFC11 eq)	Air emissions causing stratospheric ozone layer destruction
Human health - non-carcinogenic effects	ILCD 2011 Midpoint+ (CTUh)	Harm to human health that is not related to cancer or ionising radiation
Resources – land-use	Soil quality index based on LANCA (points)	Depletion of natural resources, change in soil quality and reduction in biodiversity
Resources - minerals and metals	CML-IA baseline (kg Sb-eq)	Depletion of natural non-fossil fuel resources
Human health - photochemical ozone creation	ILCD 2011 Midpoint+ (kg NMVOC-eq)	Harm to human from gas emissions that contributes to smog in the lower atmosphere
Human health - respiratory effects, inorganics	PM method (disease incidence)	Harm to human caused by particulate matter emissions
Ecosystem quality - freshwater eutrophication	ILCD 2011 Midpoint+ (kg P-eq)	Changes in freshwater organisms and ecosystems caused by excess nutrients
Ecosystem quality - marine eutrophication	ILCD 2011 Midpoint+ (kg N-eq)	Changes in marine organisms and ecosystems caused by excess nutrients
Resources – fossils (energy carriers)	CML-IA baseline (MJ)	Non-renewable energy consumption
Resources - dissipated water	AWARE (m^3 deprivation)	Water taken from the environment
Climate change - climate change total	IPCC 2013 GWP 100a (kg CO2-eq)	Potential for global warming from GHG emissions
Ecosystem quality - freshwater and terrestrial acidification	ILCD 2011 Midpoint+ (mol N eq)	Acidification of soil and freshwater due to gas release

Human health - carcinogenic effects	ILCD 2011 Midpoint+ (CTUh)	Harm to human health that causes or increases cancer risk
Human health - ionising radiation	ILCD 2011 Midpoint+ (kBq U^{235} eq)	Potential damage to human DNA from ionising radiation
Ecosystem quality - freshwater ecotoxicity	ILCD 2011 Midpoint+ (CTUe)	Harmful effect of toxic substances on freshwater organisms
Ecosystem quality - terrestrial eutrophication	ILCD 2011 Midpoint+ (mol N-eq)	Changes in land organisms from excess nutrients in soil and air

Table III. Disability adjusted life minutes

Human health impact category	**Disability adjusted life minute impact (figures given to the nearest 2 decimal places)**		
	Nonsterile	**Sterile (latex)**	**Sterile (nonlatex)**
Stratospheric ozone depletion	3.25	28.13	35.27
Global Warming	0.03	0.38	0.38
Water consumption	0.01	0.13	0.12
Photochemical ozone formation	0.00	0.00	0.00
Ionzing Radiation	0.00	0.00	0.00
Fine particulate matter formation	0.00	0.00	0.00
Toxicity (cancer)	0.00	0.00	0.00
Toxicity (non-cancer)	0.00	0.00	0.00
Total disability adjusted life minutes	*3.29*	*28.63*	*35.77*