Comparative Carbon Footprint of Pre-Wash for Decontamination of Medical Devices

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Abstract

The aim of this study is to compare the environmental impacts of three different pre-wash methods (manual, Tiny Air and Medisafe SI PCF Ultrasonic machine) for the decontamination of surgical medical devices at the Central Decontamination Centre, NHS Greater Glasgow and Clyde at Cowlairs. The functional unit is the set of contaminated medical devices that are kept together in ½ DIN Baskets (250 x 500 mm) throughout the decontamination processes.

This study follows ISO14040, ISO14044 standards and more specifically the International Life Cycle Data System (ILCD), the EU guidance. The system boundary is on the pre-wash process of the decontamination processes. The main wash & disinfection which are the decontamination process after pre-wash are included in the system boundary only when rewashing is considered in the sensitivity study**.**

Attributional Lifecycle analysis (LCA) model is employed for this study. Open LCA (Version 2.2) is used as the software and Ecoinvent database (Version 3.10) is utilised as the lifecycle inventory database. EF v3.1 impact assessment method is used to report the environmental impacts against various categories (including but not limited to climate change) which are normalised and weighted to produce single-score environmental impacts (a mandatory step in ILCD, but an optional step in ISO standards)

Employing the electricity supplier in the Ecoinvent database that is based on the UK average for lifecycle inventory and without considering rewash rate, the overall environmental impacts of Tiny Air rewash is **45% of manual pre-wash and 10% of the Medisafe SI PCF Ultrasonic machine pre-wash**, demonstrating significant environmental gains. There are around 728,000 ½ DIN baskets that are decontaminated per year in Scotland for which, employing the **Tiny Air pre-wash to replace manual and ultrasonic machine pre-washes avoids 230 tonnes of Co2 Eq, and 1,034 tonnes of Co2 Eq emissions respectively.** Since no Scottish lifecycle inventory data is available in the Ecoinvent database, the lifecycle inventory data for electricity is based on the UK average. Considering Scotland has a higher percentage of renewable energy, the environmental benefits of the Tiny Air pre-wash are likely to be much higher than these results. This report also summarises the sensitive analyses considering the impacts of the rewash rate and regional composition of energy sources on the environmental impacts of the pre-wash.

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1. Scope and goals

1.1. Background

The National Health Service (NHS) is the world's first national health service that is committed to Net Zero through legislation [1]. NHS aims to reach Net Zero by 2040 for the emission they can control, with an ambition to reach an 80% reduction by 2028 to 2032 and reach net zero by 2045 for the emissions they can influence with an ambition to reach an 80% reduction by 2036 to 2039 [1]. The use-phase of surgical medical devices is the largest contributor to the environmental impacts of reusable items (dominated by decontamination processes); thus, the methods of decontamination should be explored [2]. In response to this, three different pre-wash methods, the first step for decontamination, are evaluated in this study to assess their corresponding environmental impacts.

This report has been written to be consistent with the international standards for Lifecycle analyses, notably ISO 14040:2006 [3] and ISO 14044:2006 [4], and more specifically the ILCD, 2010 (EU guidance) [5] that was developed based on ISO standards but with more specific requirements to ensure consistency, comparability, and transparency of the LCA results [5].

1.2. Goals of the study

The goal of this study is to:

Calculate and compare the environmental impacts of the three pre-wash methods including manual, Tiny Air and Medisafe SI PCF Ultrasonic machine for decontamination of reusable surgical medical devices at the Central Decontamination Centre, NHS Greater Glasgow and Clyde at Cowlairs.

The intended applications are to:

- *Understand the environmental impacts of various pre-wash to facilitate informed decisions*.

The intended audiences include health care practitioners, NHS procurement and the general public. The results are intended to support comparative assertions and may be disclosed to the public once this report has been verified by independent third parties. Note that when communicated publicly, this report (or a version of this report) should be available as supporting information.

1.3. Different pre-washing methods

The first pre-washing method is a purely manual process, in a sink with warm water and detergent. The second pre-washing method is an automated process using the Tiny Air machine (supplied by Tiny Air Limited). The third pre-washing method is an automated process using the Medisafe SI PCF ultrasonic machine. The three methods can be seen below (Figure 1).

(a) Manual (b) Tiny air (c) Ultrasonic

Figure 1 –Three Different pre-washing methods

1.4. Functional unit

In LCA, a functional unit quantifies the function provided by a product system and serves as a basis of comparison between systems, therefore it is an important factor. In this study, the environmental impacts of three different pre-washes are compared. The function of these three different pre-washes is, in each case, to provide the function of precleaning for the decontamination process, compliant to the relevant standards [6]. The functional unit for this study is defined as: "*a set of contaminated medical devices are kept together throughout the decontamination processes in a ½ DIN Basket (250 x 500 mm) as shown in Figure 2 (a) (b) at the Central Decontamination Centre, NHS Greater Glasgow and Clyde at Cowlairs*."

(a) (b)

Figure 2 - Contaminated medical devices in a ½ DIN Basket

1.5. System boundaries

This study is **not a full cradle-to-grave lifecycle analysis**. Instead, this study is a **gate-to-gate** study focusing on the pre-wash stage of the decontamination of reusable medical devices at the use stage of these devices. As shown in Figure 3, the decontamination includes pre-wash, wash & disinfection, inspection, and then if passed, sterilisation and packaging, otherwise, the set of medical devices are sent back for rewash and go through pre-wash and wash & disinfection processes again. Since the environmental impacts of sterilisation and packaging are the same for these three different pre-washes in this comparative study, and inspection is undertaken manually, having no environmental impacts. Therefore, inspection, sterilisation and packaging are not included in the system boundary of this study. Different pre-wash methods may lead to different rewash rates, therefore, **the system boundary includes three types of pre-wash only if rewash is not considered, otherwise the system boundary covers pre-wash and wash & disinfection which is discussed in detail in the sensitivity analysis section.**

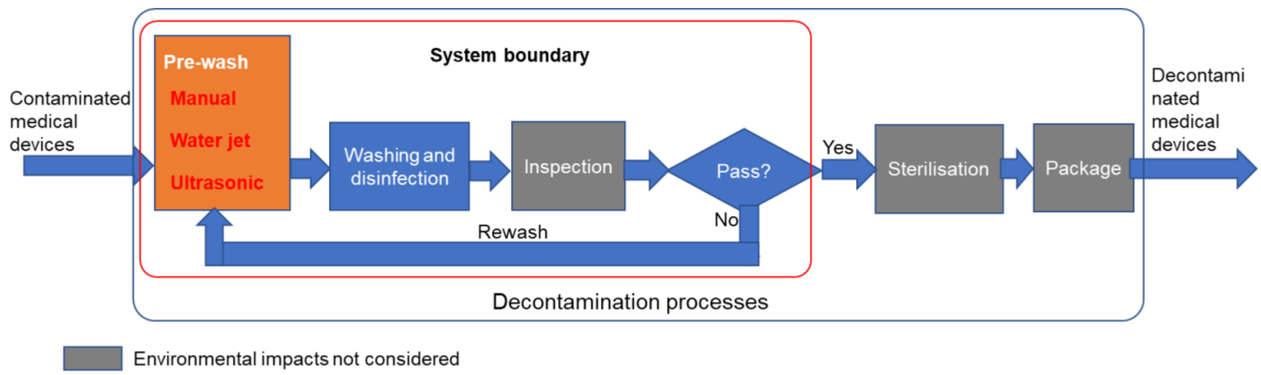

Figure 3 - System boundary of the study

1.6. System modelling

This study is an attributional LCA. Open LCA (Version 2.2) is used as the software for LCA. Ecoinvent database (Version 3.10, APOS unit process) is utilised as the lifecycle inventory database because datasets in Ecoinvent database have been audited by EU Life Cycle Data Network [7]. EF v3.1 impact assessment method [8] recommended by the European Commission for conducting Product Environmental Footprint (PEF) analysis for products sold in the EU is used for the study to report the environmental impacts against various categories (including but not limited to climate change). These are normalised and weighted to produce single-score environmental impacts which is a mandatory step in ILCD, but an optional step in ISO standards.

In the process of building a life cycle inventory (LCI), it is typical to exclude items considered to have a negligible contribution to results. To do this consistently and robustly, there must be confidence that the exclusion is fair and reasonable. To this end, cut-off criteria can be defined based on mass, energy or environmental significance. In this study, **no flow was cut-off**, but the following assumptions are applied:

- Emissions from the material extraction and manufacturing, transport and end of life of reusable medical devices and the machines used for the decontamination are not included in this study;
- When the Ecoinvent database does not contain UK-specific datasets, we use the closest available data, e.g. European/Global average data where necessary. For instance, the specific detergent is not available in the Ecoinvent database, instead, generic soap is used;
- Inputs related to overheads are not included in this study such as lighting and heating of buildings, furniture, computers, printers, paper and pencils etc.

2. Data collection

In LCA, quantitative and qualitative input and output foreground data are collected for all processes within the system boundary and these data are used to compile the LCI. Primary data are values obtained from a direct measurement or a calculation based on direct measurements at its original source. In this study, the environmental impacts of the three pre-washing methods are modelled using primary data that was collected at Cowlairs by RDH Scotland Limited between April to June 2024. This input data includes: the water consumption for each pre-wash and wash & disinfection, the electricity consumption (electricity used to run the pre wash and wash & disinfection machines and to dry the reusable medical devices during the wash & disinfection processes), the consumption of natural gas energy used to heat the water, the amount of detergent used by pre-wash and wash & disinfection. The output data is the wastewater of pre-wash and wash & disinfection the amount of which is the same as the input water consumption. Each input and output are also assigned a ‘provider’ which is derived from the Ecoinvent database to connect lifecycle inventory data with each input and output primary data thus to calculate the overall environmental impacts.

2.1. Data for pre-wash - Manual

For manual pre-wash, the sink is filled with water up to mark as shown in Figure 1 (a). The volume of water is 32.5 litre which is calculated based on the size of the sink, and 150ml detergent (Neodisher MediClean forte) is used per wash. Since the specific environmental impacts of the detergent is not in the Ecoinvent datasets, 150ml general soap is used for the LCA model. The water is heated from 12 degrees (mean) Celsius to 35 degrees, the energy needed for which is calculated as below:

$$Q=mc\Delta T \qquad \textit{Eq. 1}$$

where:

- Q is the energy in joules (J),
- m is the mass of the water in kilograms (kg),
- c is the specific heat capacity of water (approximately 4186 J/kg°C),
- ΔT is the change in temperature in Celsius degrees (°C).

Based on Eq. 1, for m=32.5 kg for 32.5 litre water, ΔT is 23 which is the temperature different between 11 degree to 35 degree

$$Gas\ Energy\ Q=32.5kg \times 4186\ J/kg°C \times 23 = 3129035\ \text{(joules)} = 0.869\ \text{kwh}$$

The energy Q is the net energy. Since the water is heated by steam which is powered by gas boiler. Assuming average 80% of the energy efficiency for steam heating [9] and 80% efficiency of gas boilers [10], then the overall efficiency is 0.80*0.80=0.64 and the energy required for heating the water.

Gas Energy for heating water for manual pre-wash: 0.869kwh/0.64=1.36 kwh

In Ecoinvent database, the source of energy selected is "Heat, central or small-scale, natural gas". Based on [11], "Water, deionised" is selected for the water.

2.2. Data for pre-wash-Tiny Air

The machine is supplied by Tiny Air, the electric energy consumption of which is on average 7.2kw with a cycle time of 2 minutes, the electric energy consumption Q is

Electric energy Q=(7.2kw).(2minuts) = 0.24kwh

The energy source is electricity. Thus "Electricity, low voltage" in Ecoinvent is selected as the energy source. Low voltage is used when the voltage is less than 1000 volts[12]. The water consumption is 30 litres. Detergent is not required and there is no need to heat the water in this pre-wash method.

2.3. Data for pre-wash - Medisafe SI PCF Ultrasonic machine

The ultrasonic machine is supplied by is Medisafe SI PCF Ultrasonic machine. The average power is 2kw and the cycle time is 30mins. Therefore, the electric energy consumption Q is:

Electrical energy Q=(2kw).(33mins)=(2kw)(33/60 hours)=1.01kwh

84 litres water and **125ml detergent** are consumed per wash. The 84 litres water is heated from 12°C to 40°C. Employing the formula in Eq.1, the net energy is

$$Q=84kg \times 4186\ J/kg°C \times 28 = 9845472\text{(joules)}=2.735\text{kwh}.$$

Again, the water is heated by steam which is generated via gas boilers, assuming 80% efficiency for steaming and 80% efficiency for gas boilers, the overall efficiency is 0.64 and the energy required is

Gas Energy= 2.735/0.64=4.276 kwh

2.4. Data for wash & disinfection

Steelco TW3000/2 is the machine used for both wash & disinfection. It can process 7 functional units (7 standard ½ Din baskets) during each cycle. The Washer Disinfector uses 8.6kWh of electric energy to run the machine per cycle. The energy consumption for washing and disinfection per ½ Din basket is 8.6kWh /7= **1.228 kWh**.

The washing processes for 7 functional units include

Pre-wash: 38 Litre water, no heating

Wash: 38 Litre water which is heated from 12 degrees to 55 degrees, and the net energy per functional unit is

$$Q=38kg\times 4186\ J/kg^{\circ}C\times(55-12)/7 = 0.271\ \text{kwh}$$

Rinse1: 38 Litre water which is heated from 12 degrees to 60 degrees, and the net energy per functional unit is

$$Q=38kg\times 4186\ J/kg^{\circ}C\times(60-12)/7 = 0.303\ \text{kwh}$$

Rince 2: 38 Litre water which is heated from 12 degrees to 60 degrees. The energy consumption for washing is

$$Q=38kg\times 4186\ J/kg^{\circ}C\times(60-12)/7 = 0.303\ \text{kwh}$$

The total energy required to heat the water per functional unit for wash, rinse 1 and rinse 2 is

$$Q=0.271+0.303+0.303=0.877kwh$$

Again, the water is heated by steam which is powered by a gas boiler. Considering 0.64 overall efficiency, the total energy required per functional unit is

$$\text{Gas energy}\quad Q=0.877\text{kwh} /0.64=1.37\text{kwh}$$

The total water consumption for the wash of 7 functional units is the sum of the water for pre-wash, wash, rinse 1 and rinse 2, totalling 38X4=152 litres, thus the water consumption per functional unit is 152 litres/7=**21.71 litres**.

The detergent used is 342 ml for 7 functional units, thus, the detergent used per functional unit is 342/7=**48.86ml**

For disinfection, 38 litres Reverse Osmosis (RO) water is used for 7 functional units, thus **5.43 litres** (38 litres/7) is consumed per functional unit. Since RO water is not available in the Ecoinvent database, standard ionised water in Ecoinvent database is selected instead.

The RO water is heated from 12 degrees to 91 degrees, thus, the net energy required is

$$Q=5.43kg\times 4186\ J/kg^{\circ}C\times(91-12)=1795668\ \text{joules}=0.499\ \text{kwh}$$

With 0.64 efficiency for gas boiler for steam heating,

Gas energy required for disinfection is 0.499/0.64=0.780kwh.

After the disinfection, the functional units are dried at 120 degrees. This is heated by electricity and is already included in the electricity consumption; thus it is not calculated separately to avoid double counting.

The detailed input and output primary data for the three pre-washes, wash & disinfection is shown in Table 1.

Table 1 - Detailed input and output primary data and providers in Ecoinvent

Stage/Flow	Type	Quantity	Unit	Provider (Ecoinvent)	Data Quality	Time Range	Region of data provider (Ecoinvent)
Manual pre-wash							
Heat, central or small-scale, natural gas	Input	1.36	kWh	market for heat, central or small-scale, natural gas | heat, central or small-scale, natural gas | APOS, S - Europe without Switzerland	1.4	01/01/2011 - 31/12/2023	EU
Soap	Input	125	ml	soap production | soap | APOS, S - RoW	1	01/01/1992 - 31/12/2023	Global
Water, deionised	Input	32.5	litre	market for water, deionised | water, deionised | APOS, S - Europe without Switzerland	1	01/01/2011 - 31/12/2023	EU
Wastewater, average	Output	32.5	litre	market for wastewater, average | wastewater, average | APOS, S - Europe without Switzerland	1	01/01/2010 - 31/12/2023	EU
Tiny Air pre-wash							
Electricity, low voltage	Input	0.24	kWh	market for electricity, low voltage | electricity, low voltage | APOS, S - GB	1	01/01/2020 - 31/12/2023	GB
Soap	Input	0	ml	soap production | soap | APOS, S - RoW	1	01/01/1992 - 31/12/2023	Global
Water, deionised	Input	30	l	market for water, deionised | water, deionised | APOS, S - Europe without Switzerland	1	01/01/2011 - 31/12/2023	EU
Wastewater, average	Output	30	l	market for wastewater, average | wastewater, average | APOS, S - Europe without Switzerland	1	01/01/2010 - 31/12/2023	EU
Medisafe SI PCF Ultrasonic machine							
Electricity, low voltage	Input	1	kWh	market for electricity, low voltage | electricity, low voltage | APOS, S - GB	1	01/01/2020 - 31/12/2023	GB

Heat, central or small-scale, natural gas	Input	4.277	kWh	market for heat, central or small-scale, natural gas | heat, central or small-scale, natural gas | APOS, S - Europe without Switzerland	1.4	01/01/2011 - 31/12/2023	EU
Water, Deionised	Input	84	l	market for water, deionised | water, deionised | APOS, S - Europe without Switzerland	1	01/01/2011 - 31/12/2023	EU
Soap	Input	125	ml	soap production | soap | APOS, S - RoW	1	01/01/1992 - 31/12/2023	Global
Wastewater, average	Output	84	l	market for wastewater, average | wastewater, average | APOS, S - Europe without Switzerland	1	01/01/2010 - 31/12/2023	EU
Wash with Steelco TW3000/2 machine							
Electricity, low voltage	Input	1.43	kWh	market for electricity, low voltage | electricity, low voltage | APOS, S - GB	1	01/01/2020 - 31/12/2023	GB
Heat, central or small-scale, natural gas	Input	1.37	kWh	market for heat, central or small-scale, natural gas | heat, central or small-scale, natural gas | APOS, S - Europe without Switzerland	1.4	01/01/2011 - 31/12/2023	EU
Soap	Input	48.86	ml	soap production | soap | APOS, S - RoW	1	01/01/1992 - 31/12/2023	Global
Water, deionised	Input	21.71	l	market for water, deionised | water, deionised | APOS, S - Europe without Switzerland	1	01/01/2011 - 31/12/2023	EU
Wastewater, average	Output	21.71	l	treatment of wastewater, average, wastewater treatment | wastewater, average | APOS, S - Europe without Switzerland	1	01/01/2010 - 31/12/2023	EU
Disinfection with Steelco TW3000/2 machine							
Heat, central or small-scale, natural gas	Input	0.78	kWh	market for heat, central or small-scale, natural gas | heat, central or small-scale, natural gas | APOS, S - Europe without Switzerland	1.4	01/01/2011 - 31/12/2023	EU

Water, ultrapure	Input	5.43	l	market for water, ultrapure | water, ultrapure | APOS, S - RoW	1	01/01/2009 - 31/12/2023	Global
Wastewater, average	Output	5.43	l	treatment of wastewater, average, wastewater treatment | wastewater, average | APOS, S - Europe without Switzerland	1	01/01/2010 - 31/12/2023	EU

2.5 Data quality

ISO 14044 provides detailed guidelines and introduces specific **data quality criteria** for conducting LCA. The standard specifies that LCA data must meet the following criteria:

- **Reliability**: Ensuring that data is accurate, consistent, and trustworthy. It should come from credible sources and allow for reproducibility.
- **Completeness**: All relevant data, processes, and elements must be included, ensuring no significant gaps or missing information in the LCA.
- **Temporal Correlation (Temporal Representativeness)**: The data should represent the time frame relevant to the study. Data should align with the period during which the process or product is being analysed. If older data is used, the time difference must be justified and, if necessary, adjustments should be made to account for changes over time.
- **Geographical Correlation (Geographical Representativeness)**: Data must reflect the geographical location of the processes and systems being studied. The standard recognizes that environmental impacts can vary significantly based on geographic differences (e.g., regional energy mixes, climate, regulations), so the data used must be representative of the actual locations of the system or product lifecycle.
- **Technological Correlation**: Ensuring that the data matches the specific technology or processes involved in the lifecycle under consideration.

The details of the scores for the 5 criteria of data quality according to ILCD is shown in Table 2. The scores were (1,1,1,1,1) for the five criteria including reliability, completeness, temporal correlation, geographical correction and technological correction for electricity, water, detergent data for pre-wash and wash & disinfection respectively as they were measured directly from the site of the study only a few months ago, thus the overall score of data quality for the primary data electricity, water and detergent is 1. However, for the gas energy calculation, average efficiency has been used, thus the scores are (3, 1,1,11) for the five criteria, thus, the overall score is 1.4. The overall data quality scores for each of the primary data are presented in Column of “Data quality” in Table 1.

Table 2 - Data quality scores according to ILCD

Data Quality Indicator	Corresponding ISO requirement	Score				
		1	2	3	4	5
Reliability	Precision Completeness	Verified data based on measurements	Verified data partly based on assumptions OR non-verified data based on measurement	Non-verified data partly based on qualified estimates	Qualified estimates; data derived from theoretical information	Non-qualified estimates
Completeness	Completeness Representativeness	Representative data from all sites relevant for the market considered over an adequate period to even out normal fluctuations	Representative data from > 50% of the sites relevant for the market considered over an adequate period to even out normal fluctuations	Representative data from only some sites (<< 50%) relevant for the market considered OR > 50% of sites but for shorter periods	Representative data from only one site relevant for the market considered OR some sites but for shorter period	Representativeness unknown or data from a smaller number of sites AND from shorter period
Temporal correlation	Time related coverage Representativeness	< 3 years difference to the reference year*	< 6 years difference to the reference year*	< 10 years difference to the reference year*	< 15 years difference to the reference year*	Age of data unknown OR > 15 years difference to the reference year
Geographical correlation	Geographical coverage Representativeness	Data from the area under study**	Average data for larger area in which the area under study is included	Data from smaller area than area under study		Data from unknown OR distinctly different area (e.g., Europe)

Technological correlation	Technology coverage Representativeness	Data from enterprises, processes and material under study (i.e., identical technology)	Data from processes and materials under study but from different technology	Data on related processes or material but same technology OR Data from processes and materials under study but from different technology	Data on related processes or materials but different technology OR data on laboratory scale processes and same technology	Data on related processes or materials but on laboratory scale of different technology

3. Environmental impact results

The environmental impact assessment results of each pre-washing method and main wash & disinfection per functional unit against the impact categories required for ILCD are reported as shown in Table 3 assuming 0% rewash with the EF v3.1 impact assessment method used for the study.

Table 3 - Environmental impacts of pre-wash per functional unit against various environmental categories

Impact category	Reference unit	Pre-wash			Main Wash & Disinfection
		Manual	Tiny Air	Medisafe SI PCF Ultrasonic machine	
Ecotoxicity: freshwater, inorganics	CTUe	3.04E+00	2.80E+00	8.74E+00	2.65E+00
Climate change: fossil	kg CO2-Eq	3.91E-01	7.48E-02	1.49E+00	9.94E-01
Climate change: biogenic	kg CO2-Eq	1.82E-03	2.12E-03	6.90E-03	4.86E-03
Human toxicity: carcinogenic	CTUh	8.11E-10	3.62E-10	3.44E-09	2.51E-09
Human toxicity: carcinogenic, organics	CTUh	7.92E-10	3.40E-10	3.33E-09	2.42E-09
Water use	m3 world Eq deprived	1.79E-02	2.39E-02	1.28E-01	1.32E-01
Human toxicity: non-carcinogenic	CTUh	2.70E-09	2.95E-09	1.21E-08	9.77E-09
Human toxicity: non-carcinogenic, organics	CTUh	1.07E-10	6.63E-11	5.71E-10	5.06E-10
Ecotoxicity: freshwater, organics	CTUe	1.92E-01	1.09E-01	9.13E-01	7.44E-01
Eutrophication: marine	kg N-Eq	6.15E-04	5.33E-04	1.87E-03	9.72E-04
Eutrophication: terrestrial	mol N-Eq	1.19E-03	7.77E-04	6.11E-03	5.30E-03
Land use	dimensionless	2.26E-01	1.15E+00	5.18E+00	6.77E+00
Climate change: land use and land use change	kg CO2-Eq	2.39E-04	9.95E-05	7.27E-04	6.64E-04
Eutrophication: freshwater	kg P-Eq	6.83E-05	6.42E-05	2.35E-04	1.29E-04

Human toxicity: carcinogenic, inorganics	CTUh	1.91E-11	2.14E-11	1.02E-10	9.12E-11
Photochemical oxidant formation: human health	kg NMVOC-Eq	6.95E-04	2.08E-04	2.86E-03	2.07E-03
Ionising radiation: human health	kBq U235-Eq	7.50E-03	6.17E-02	2.71E-01	3.67E-01
Ecotoxicity: freshwater	CTUe	3.24E+00	2.91E+00	9.66E+00	3.39E+00
Climate change	kg CO2-Eq	3.93E-01	7.70E-02	1.50E+00	1.00E+00
Human toxicity: non-carcinogenic, inorganics	CTUh	2.59E-09	2.88E-09	1.15E-08	9.26E-09
Energy resources: non-renewable	MJ, net calorific value	6.10E+00	1.85E+00	2.63E+01	1.98E+01
Material resources: metals/minerals	kg Sb-Eq	4.76E-07	1.17E-06	6.03E-06	7.24E-06
Particulate matter formation	disease incidence	2.54E-09	2.21E-09	1.40E-08	1.26E-08
Ozone depletion	kg CFC-11-Eq	1.53E-08	3.35E-09	6.15E-08	4.32E-08
Acidification	mol H+-Eq	3.60E-04	3.02E-04	2.12E-03	1.98E-03

The value in Table 3 may look insignificant, however, considering that that there are around 728,000 ½ Din baskets decontaminated per year (data provided by Tiny air), the environmental impacts are significant. For instance, the climate change of 728,000 functional units using three pre-washes is shown in Table 4 which shows the employing **Tiny Air pre-wash could save 230 tonnes Co2 Eq, and 1,034 tonnes Co2 Eq** emissions compared to manual and Medisafe SI PCF Ultrasonic machine pre-washes respectively.

Table 4 – Impacts of three pre-wash on climate change per year in Scotland

Manual Pre-Wash	Tiny Air Pre-Wash - Low Voltage	Medisafe SI PCF Ultrasonic machine Pre-Wash
286 tonnes Co2 Eq	56 tonnes Co2 Eq	1,090 tonnes Co2 Eq

Table 3 shows the breakdown environmental impacts against various environmental categories according to ILCD requirements. The relative environmental impacts are illustrated in Figure 4 from which the pre-wash in which the prewash with the highest impact in an environmental category is viewed as 100%, with the other methods being scaled relative to it. This allows for each of the methods to be compared to each other in terms of percentage in each environmental impact category, from which it could be seen that ultrasonic pre-wash has the maximum environmental impacts against all 14 environmental categories.

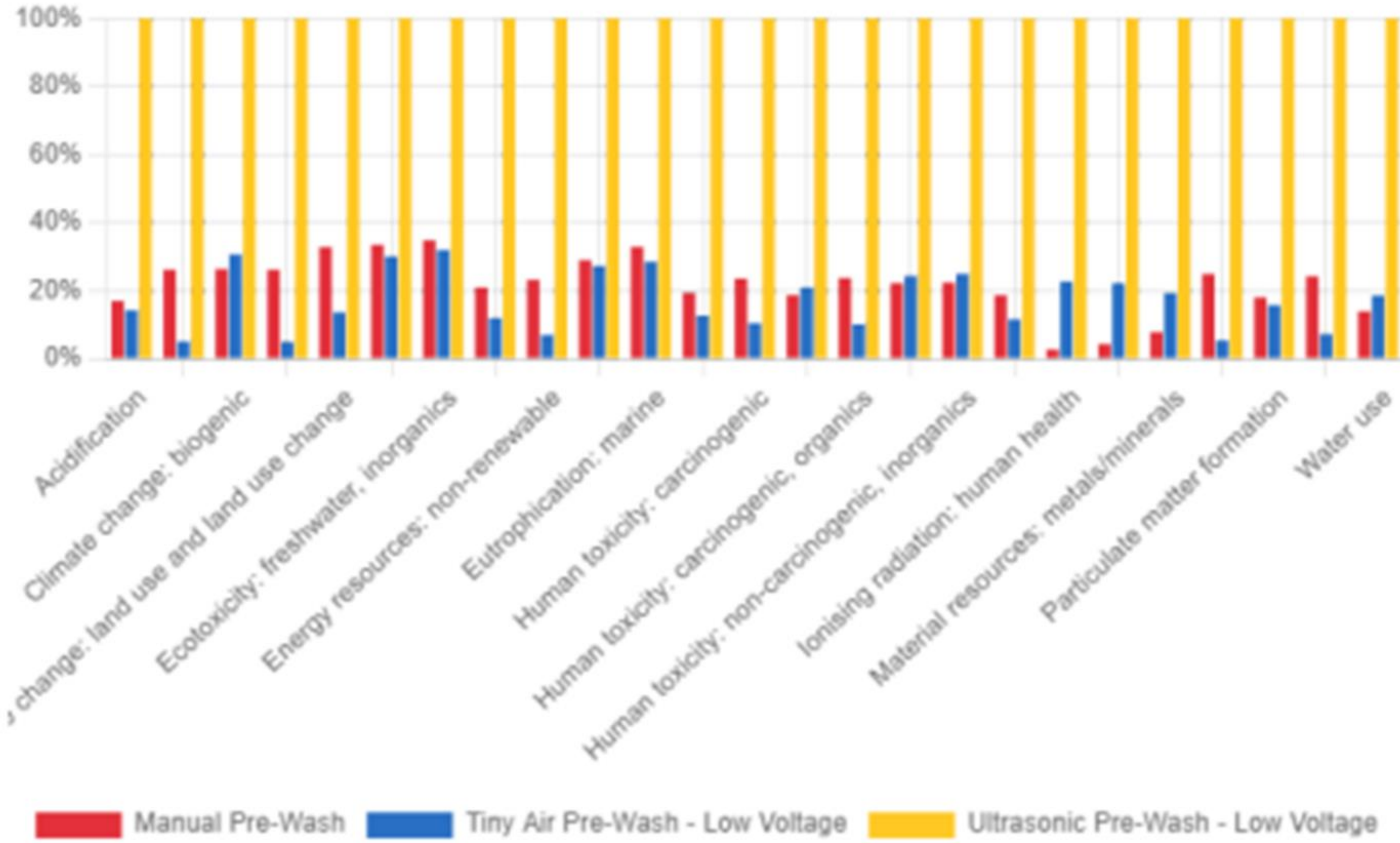

Figure 4 - Relative results for each pre-wash methods

Subsequently, the breakdown environmental impact data in Table 3 is normalised and weighted using the parameters set in the EF v3.1| Global Reference 2010 for the comparison in terms of single score representing the overall environmental impacts of pre-washes combining the breakdown environmental impacts of the individual categories as required by ILCD. This single score of environmental impacts avoids the danger of focusing on a single element of environmental impacts, e.g. climate change and neglecting the impacts of other environmental categories. The results of the single score are shown in Table 5.

Table 5 - Single score of the environmental impacts of the three pre-wash methods per function unit

Single score		
Manual pre-wash	**Tiny Air pre-wash**	**Medisafe SI PCF Ultrasonic machine pre-wash**
2.61E-05	1.18E-05	1.13E-04

The parameters used for normalisation and weighting for single score are shown in Table 6.

Table 6 - EF v3.1| Global Reference 2010

EF v3.1| Global Reference 2010		
Impact category	**Normalization value**	**Weighting factor**
Ecotoxicity: freshwater, inorganics	0	0
Climate change: fossil	0	0
Climate change: biogenic	0	0
Human toxicity: carcinogenic	1.73E-05	0.0213
Human toxicity: carcinogenic, organics	0	0
Water use	11468.70864	0.0851
Human toxicity: non-carcinogenic	1.29E-04	0.0184
Human toxicity: non-carcinogenic, organics	0	0
Ecotoxicity: freshwater, organics	0	0
Eutrophication: marine	19.54518155	0.0296
Eutrophication: terrestrial	176.7549998	0.0371

Land use	819498.1829	0.0794
Climate change: land use and land use change	0	0
Eutrophication: freshwater	1.606852128	0.028
Human toxicity: carcinogenic, inorganics	0	0
Photochemical oxidant formation: human health	40.85919773	0.0478
Ionising radiation: human health	4220.16339	0.0501
Ecotoxicity: freshwater	56716.58634	0.0192
Climate change	7553.083163	0.2106
Human toxicity: non-carcinogenic, inorganics	0	0
Energy resources: non-renewable	65004.25966	0.0832
Material resources: metals/minerals	0.063622615	0.0755
Particulate matter formation	5.95E-04	0.0896
Ozone depletion	0.052348383	0.0631
Acidification	55.56954123	0.062

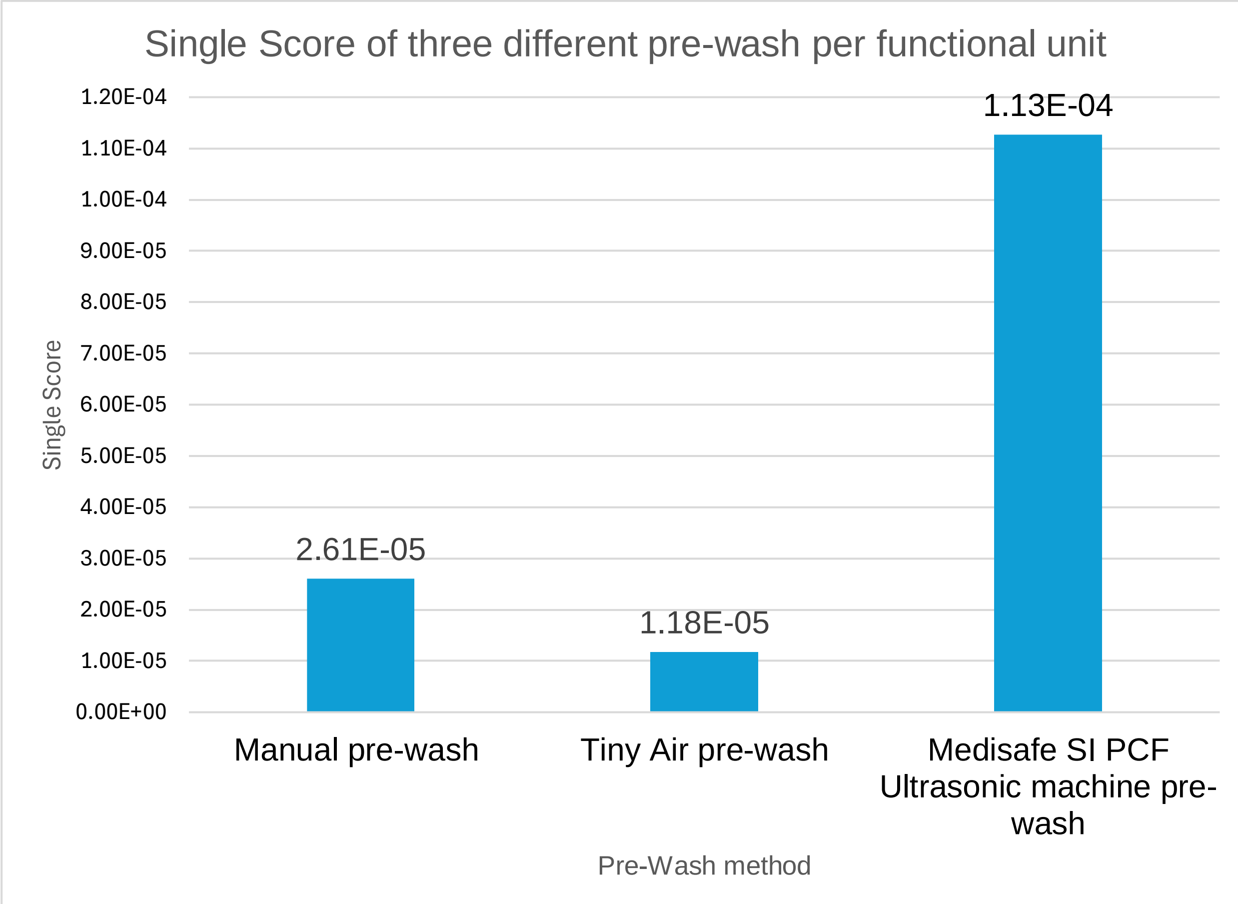

Figure 5 The single score environmental footprint of the three pre-wash

The resultant single score of the three pre-washes is illustrated in Figure 5. **This showed that the overall environmental impacts of Tiny Air is 45% of the manual pre-wash and 10% of the Medisafe SI PCF Ultrasonic machine pre-wash**. Since there is no Scottish lifecycle inventory data available, the lifecycle inventory data for electricity in Ecoinvent is based on the UK average. Considering Scotland has a higher percentage of renewable energy, thus the actual environmental benefits of Tiny Air (tiny air) pre-wash are likely to be much higher than these results. When the rewash rate is considered, the overall environmental benefits of Tiny Air are likely to be further increased. This is discussed in detail in the sensitivity sector of this report.

4. Sensitivity analysis

1. Impacts of rewash

The environmental impacts of rewash could have effects on the overall environmental impacts of the decontamination. Different pre-wash methods may have different rewash rates. This sensitivity analysis investigates the impacts of rewash on the overall environmental impacts of pre-wash in response to different rewash rates.

Assuming X% rewash rate, for Y functional units (each refers to an 1/2 contaminated DIN basket), there will be :

(X%).(Y) functional unit rewashed and

(1-X%). (Y) functional units passing the inspection and going through the sterilisation and package process (See Figure 3 for the system boundary).

However, if we need Y functional units passing the inspection and going through the sterilisation and packaging processes, we will need Z contaminated functional units that go through the pre-wash and wash & disinfection.

$$Z= Y/(1-X\%) \qquad \text{Eq (2)}$$

In other words, in order to get Y functional units going through decontamination processes (pre-wash, washing & disinfection, sterilisation and package), we need to pre-wash and wash & disinfection of Y/(1-X%) functional units.

Based on the primary data in Table 1, the environmental impacts of wash & disinfection only against various categories are shown in Table 3. The single score of pre-wash and wash & disinfection for 0% rewash rate is shown in Table 7.

Table 7 - Single score environmental impacts of pre-wash and wash & disinfection

0% rewash rate	Manual + wash & disinfection	Tiny Air +Wash & Disinfection	Medisafe SI PCF Ultrasonic machine + Wash & Disinfection
Single Score Environmental impacts	1.10E-04	9.66E-05	1.90E-04

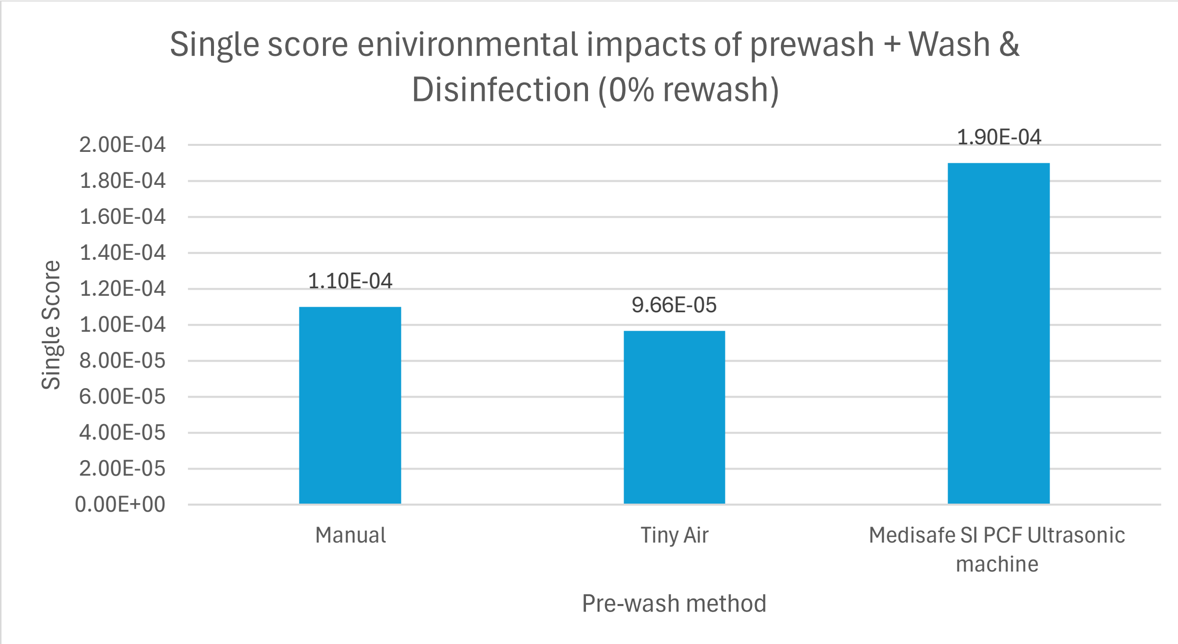

Figure 6 - Single score environmental impacts of wash & disinfection

From Figure 6, the Tiny Air + Wash & Disinfection which has the lowest overall environmental impacts is **88% of that of Manual + Wash & Disinfection and 51% of that of the Medisafe SI PCF Ultrasonic machine + Wash & Disinfection**.

Let Y in Eq (2) be the single score of the overall environmental impacts of pre-wash and wash & disinfection for 0% rewash, using the Eq (2) the overall environmental impacts considering rewash rate is shown in Table 8 and is illustrated in Figure 7.

Table 8 - Rewash rate and the environmental impacts

Rewash Rated	Single Score (manual)	Single Score (Tiny Air)	Single Score (Medisafe SI PCF Ultrasonic machine)
0%	1.10E-04	9.66E-05	1.90E-04
1%	1.11E-04	9.76E-05	1.92E-04
2%	1.12E-04	9.86E-05	1.94E-04
3%	1.13E-04	9.96E-05	1.96E-04
4%	1.15E-04	1.01E-04	1.98E-04
5%	1.16E-04	1.02E-04	2.00E-04
6%	1.17E-04	1.03E-04	2.02E-04
7%	1.18E-04	1.04E-04	2.04E-04

8%	1.20E-04	1.05E-04	2.07E-04
9%	1.21E-04	1.06E-04	2.09E-04
10%	1.22E-04	1.07E-04	2.11E-04

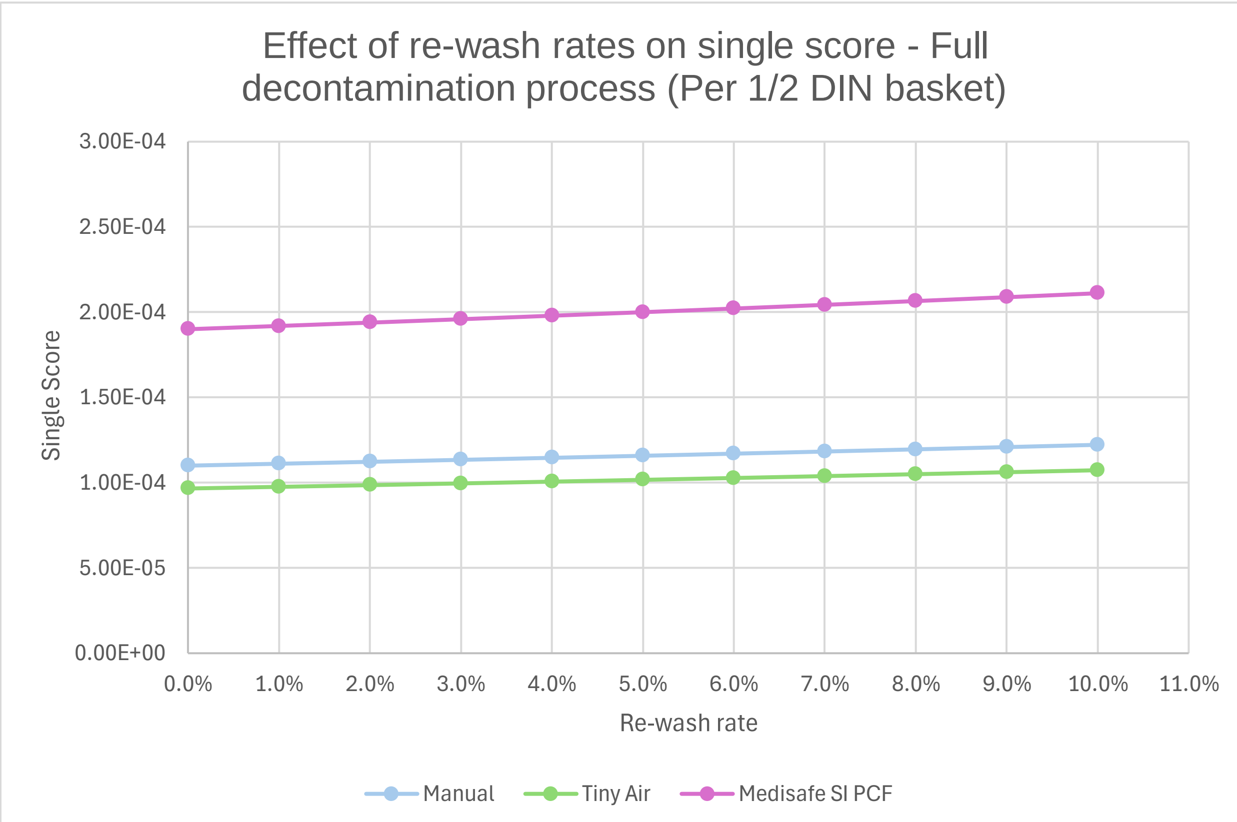

Figure 7 Impacts of re-wash rate on the single score

From the data provided, the average rewash rate (3%, data collected between the week commencing 1st April to the week commencing 24th June, in total 2331 out of 73437 rewashed). The rewash rate for Tiny is only 0.93% (12912 sets processes and 12 non-compliant). The single score of three different pre-wash plus wash & disinfection is shown in Table 9.

Table 9 - Impacts of rewash rate

	Manual pre-wash + Wash & Disinfection	Tiny Air pre-wash + Wash & Disinfection	Medisafe SI PCF Ultrasonic machine + Wash & Disinfection
Single Score Environmental impacts (0% rewash)	1.10E-04	9.66E-05	1.90E-04
Single Score Environmental impacts at different rewash rate	1.13E-04 (3% rewash rate)	9.75E-05 (0.93% rewash rate)	1.96E-04 (3% rewash rate)

When rewash rate is considered, the overall environmental impacts of Tiny Air pre-wash (0.93% rewash) are86% of manual wash (3% rewash) and 50% of the Medisafe SI PCF Ultrasonic machine pre-wash (3% rewash) which is very similar to that with 0% rewash rate.

2. Energy compositions

The provider used in Ecoinvent for the electricity input is 'market for electricity, low voltage | electricity, low voltage | APOS, S – GB', which represents the consumption mix of electricity in Great Britain. In other words, this provider takes into account the various methods by which electricity is produced in the U.K. as well as how much each method contributes to the overall production. However, the composition of this mix is not uniform throughout the U.K. with different regions contributing differently. For example, Scotland produces 97% renewable resources among which 78% is from wind energy[13]. As this particular study is focussed on the Central Decontamination Centre, NHS Greater Glasgow and Clyde at Cowlairs, the single score is re-calculated using electricity produced solely by an onshore wind turbine (GB) as the optimal scenario and compared directly to the market mix (Figure 9).

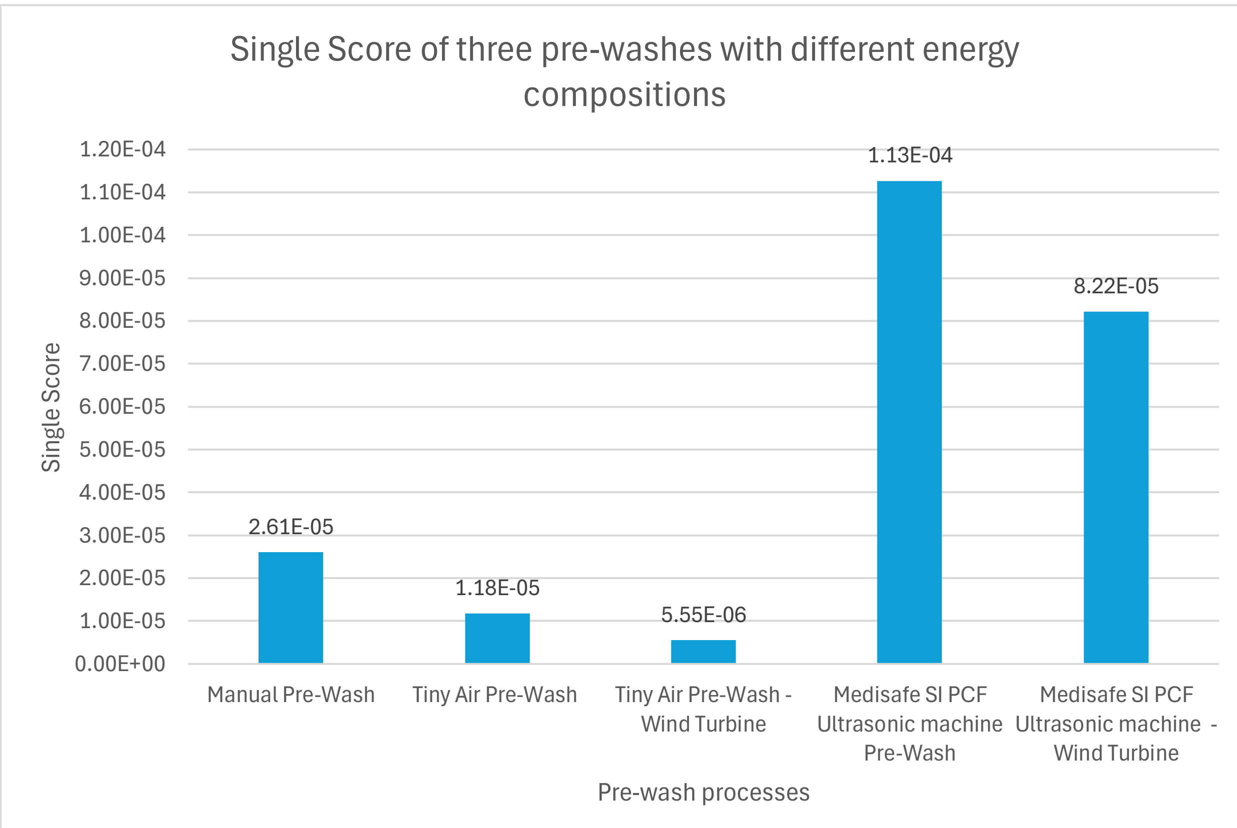

Figure 8 Single score of three pre-washes with different energy composition

Figure 8 highlights the potential for green energy to further decrease the environmental impact of the decontamination process. Since manual pre-wash does not consume any

Since manual pre-wash does not consume electricity energy, there is no change to this. However, compared with the UK market mix, Tiny Air further reduces the environmental footprint. Figure 8 showed the environmental impacts of Tiny Air pre-wash is reduced from 45% to 21% compared to the manual pre-wash and 10% to 7% compared to the Medisafe SI PCF Ultrasonic machine pre-wash.

5. Conclusion

A comparative Lifecycle analyses are undertaken in this study to evaluate the environmental impacts of three different pre-wash. The results have shown that different type of decontamination methods for reusable surgical medical devices could have significant impacts on environmental footprint. Tiny Air pre-wash has significantly less environmental impacts compared to the manual and Medisafe SI PCF Ultrasonic machine.

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