LCA OF ARC 30HT DYEING MACHINE

FLAINOX

In collaboration with

RINA

the innovation consulting partner

Goal of the study

The aim of the study is to **assess the energetic and environmental impacts of the ARC 30HT machine** along the entire life cycle, considering a process treating a conventional Polyester. Goal of this study is to assess the environmental impact of the chosen product, considering the CO_2, the embodied energy and other impacts as described in LCIA scope settings.

Boundary limits, functional units, and any other point useful for contextualize the report will be properly defined in following chapters.

WHAT IS AN LCA?

Life Cycle Assessment (LCA) is a compilation and evaluation of the inputs, outputs, and the potential environmental impacts of a product system throughout its life cycle.

Life Cycle Assessment is a structured, comprehensive, and internationally standardized methodology, used to quantify all relevant emissions and resources consumed by a good or service and their related impact on environment, human health and resources depletion.

The LCA study is performed in accordance with internationally recognized guidelines (ILCD Handbook: General guide for Life Cycle Assessment - Detailed guidance") and standards (ISO 14044:2021 and ISO 14040:2021) main requirements that identifies a series of steps, i.e.:

1. Goal & scope definition
2. Life Inventory Analysis (LCI)
3. Life Impact Assessment (LCIA)
4. Results Interpretation

Scope of the study

Several considerations and assumptions were made to define the details of the LCA model to be developed in the GaBi LCA-dedicated software. The scope of this study is to evaluate the **environmental impacts** of the Flainox ARC 30HT, considering a process treating a conventional PES.

A **"cradle to grave" LCA analysis** is performed, including the raw materials extraction, materials and components production, components processing and assembly in FLAINOX facilities in Quaregna (BI), the machine transport to a client facility, the use phase and, finally, the end-of-life steps.

Function, functional unit, and reference flow

The functional unit of the analysis is the ARC 30HT machine, having a **mass of 1800 kg** and a **life span of 30 years**, performing 46673 cycles per life span.
The amount of textile treated during these cycles are 1166817.
In the use phase a defined and repeatable dyeing process is assessed, according to specific customer information provided to Flainox.

Moreover, also the **ARC 10HT** is assessed, through a conversion table created from ARC 30HT results.

The ARC 30HT is an open pocket rotary machine for dyeing, washing, and centrifuging of garments, hosiery and seamless, which is available in several configurations according to the specific customer requests. The ARC 30HT is manufactured in Quaregna (Biella, Italy) and exported as final product all over the world. In this analysis a customer is considered, located in Bangladesh. Flainox in fact has a wide customer network in Asia, Africa, and America.

Modelling framework

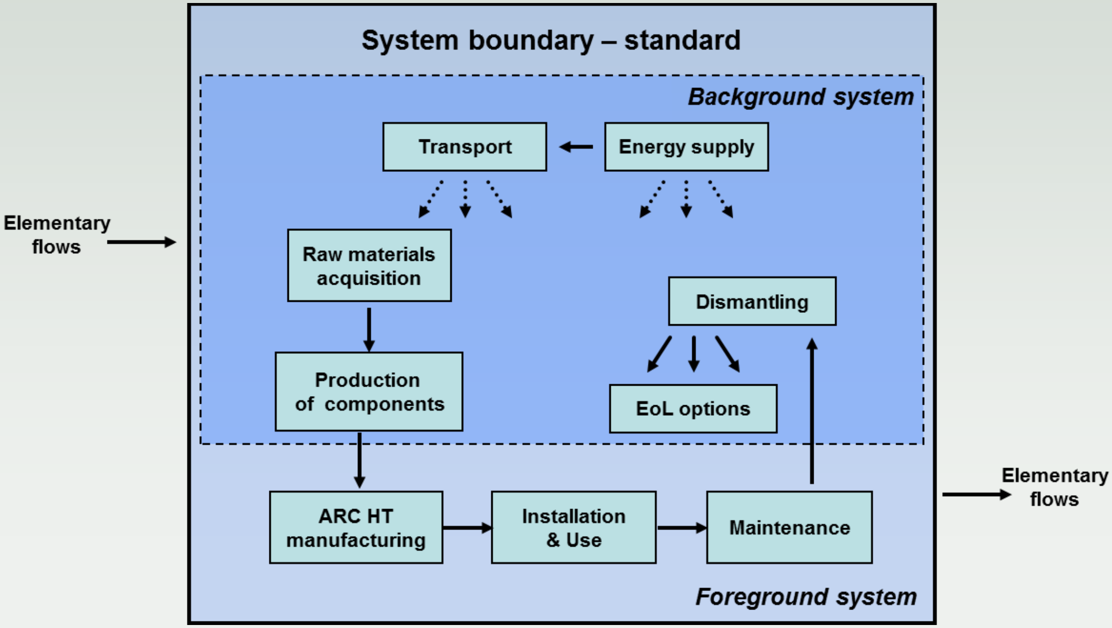
Processes in the **background** system have not been inventoried with currently available data from suppliers but included and evaluated based on data taken from dedicated databases. Waste flows belonging to such processes have been connected to disposal management processes according to the cut-off rule. Processes in the **foreground** system have been instead inventoried based on data from the owner of the technology, i.e., FLAINOX, its suppliers and the users of their machines. All the manufacturing processes which take place inside FLAINOX, the definition of standard dyeing process (according to specifications of a defined customer) and one of the three dismantling options consumptions belong to foreground system.

System boundaries

A "cradle to grave" LCA analysis is performed, including the manufacturing, transport, use, and end-of-life phases of the machine.

Regarding the **geographical boundaries**, the datasets used for the manufacturing process and end-of-life process LCA models are mainly referred to European averages. The transport operations have been modelled considering Bangladesh as installation country. Regarding the **time boundaries**, the expected lifetime of the machine is 30 years. All the phases last different time periods: the entire cycle until the installation could be assumed to be 1 year. These estimations are surely generic because they do not consider the specific production process of a company and its real timing of activities, but they could be considered quite factual. Besides, this choice warrants to the analysis a solid background bypassing any type of problem linked to the collection of data.

Figure below schematically depicts the steps considered in the analysis. Raw materials are extracted and processed before reaching the factories of different suppliers, where the single components are produced. Then they are assembled and require further manufacturing operations by Flainox and finally installed in the chosen dyeing industry. The product is then used by consumers throughout its life and finally dismantled. Transport and energy supply support all the processes in the system boundary.



ARC 30HT LCA System Boundaries

Life Cycle Inventory analysis

The Inventory analysis is the LCA phase that involves the compilation and qualitative/quantitative identification of inputs and outputs for a given product system throughout its life cycle or for a single process. The inventory analysis includes iterative data collection and the compilation of the data in a Life Cycle Inventory (LCI) table.

The Life Cycle Inventory model has been implemented through dedicated software, namely GaBi.

The main phases of NRG HT machine life cycle are:

- raw materials extraction and processing
- assembly and manufacturing operations
- transport to the customer
- use phase
- end-of-life

LCA models on GaBi have been created for the life cycle steps of the product.

The ARC 30HT is an open pocket rotary machine for dyeing, washing and centrifuging of garments, hosiery and seamless, which is available in several configurations according to the specific customer requests.

ARC 30HT

ARC 30HT – Technical Data

Nominal Load	kg	30
Number of compartments	n.	1
Usable drum volume	L	650
Drum diameter	Mm	1050
Minimum dyeing speed	Rpm	5
Maximum drum speed	Rpm	550
Number of tanks for additions (standard)	n.	2
Average power adsorbed	kW	4
Machine width and depth	mm	2000
		1670
Machine height	mm	2200
Machine weight	kg	1800
Max working temperature at sea-level	°C	135

The machines can be tuned by customers according to their experience, required product quality parameters, textile substrates and needed chemicals.

Therefore, a standard reference cycle does not exist so, in the following LCA analysis the practitioners have performed the assessment based on a specific process defined by Flainox to investigate the environmental impact. The process of the ARC 30HT machine is intended to be used for dyeing 25 kg of PES stockings in blue/black. A lifetime of the machine equal to 30 years is considered.

Through normalization factors, the results have been extended to ARC 10HT.

For this machine, the goal of the system is the same (dyeing conventional polyester, stocking in blue/black) but the loads differ:

- 7 kg for ARC 10 (factor: 0,28)

Life cycle Impact Assessment

The Life Cycle Impact Assessment (LCIA) identifies and evaluates the amount and significance of the potential environmental impacts arising from the LCI. Inputs and outputs are assigned to impact categories and their potential impacts quantified according to characterization factors.

Impact category (EF3.0)	*Units*
EF 3.0 Acidification	[Mole of H+ eq.]
EF 3.0 Climate Change - total	[kg CO2 eq.]
EF 3.0 Climate Change, biogenic	[kg CO2 eq.]
EF 3.0 Climate Change, fossil	[kg CO2 eq.]
EF 3.0 Climate Change, land use and land use change	[kg CO2 eq.]
EF 3.0 Ecotoxicity, freshwater - total	[CTUe]
EF 3.0 Ecotoxicity, freshwater inorganics	[CTUe]
EF 3.0 Ecotoxicity, freshwater metals	[CTUe]
EF 3.0 Ecotoxicity, freshwater organics	[CTUe]
EF 3.0 Eutrophication, freshwater	[kg P eq.]
EF 3.0 Eutrophication, marine	[kg N eq.]
EF 3.0 Eutrophication, terrestrial	[Mole of N eq.]
EF 3.0 Human toxicity, cancer - total	[CTUh]
EF 3.0 Human toxicity, cancer inorganics	[CTUh]
EF 3.0 Human toxicity, non-cancer metals	[CTUh]
EF 3.0 Human toxicity, non-cancer organics	[CTUh]
EF 3.0 Ionising radiation, human health	[kBq U235 eq.]
EF 3.0 Land Use	[Pt]
EF 3.0 Ozone depletion	[kg CFC-11 eq.]
EF 3.0 Particulate matter	[Disease incidences]
EF 3.0 Photochemical ozone formation, human health	[kg NMVOC eq.]
EF 3.0 Resource use, fossils	[MJ]
EF 3.0 Resource use, mineral and metals	[kg Sb eq.]
EF 3.0 Water use	[m^3 world equiv.]

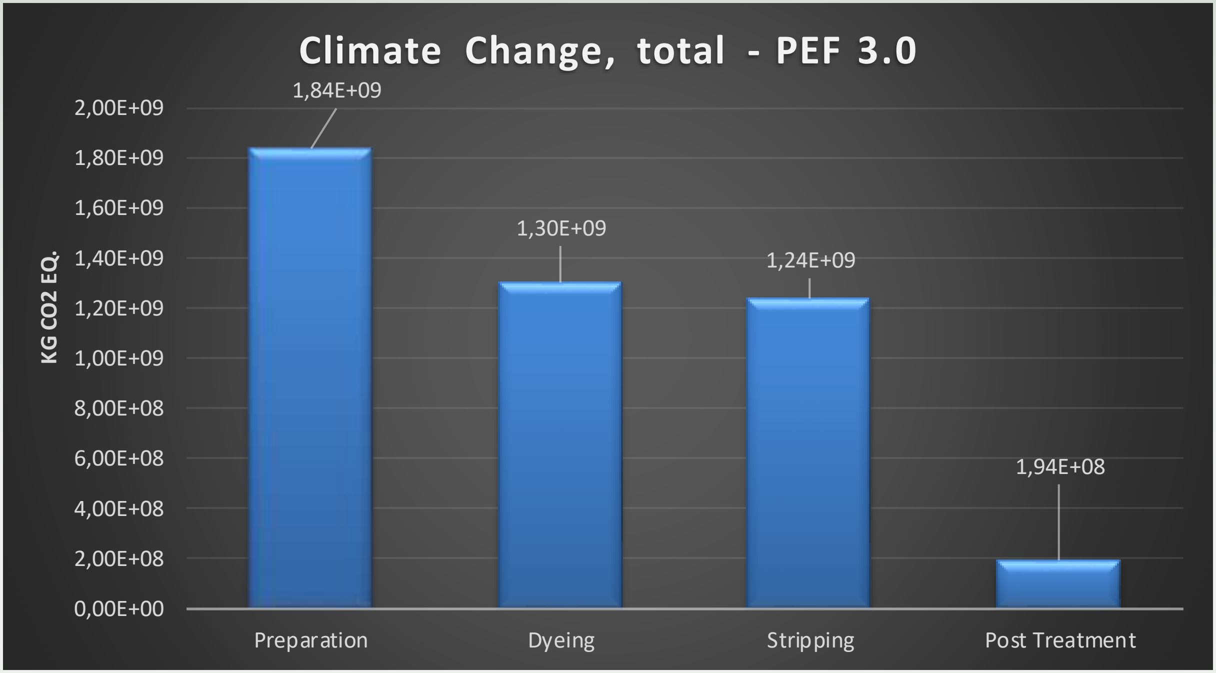
LCA Results

In order to have a more detailed view of the results, bar charts related to the **use phase** have been drawn starting from LCA results, since the contribution of **use phase**, compared to other ones is evident and it overcomes the 99% in all the indicators

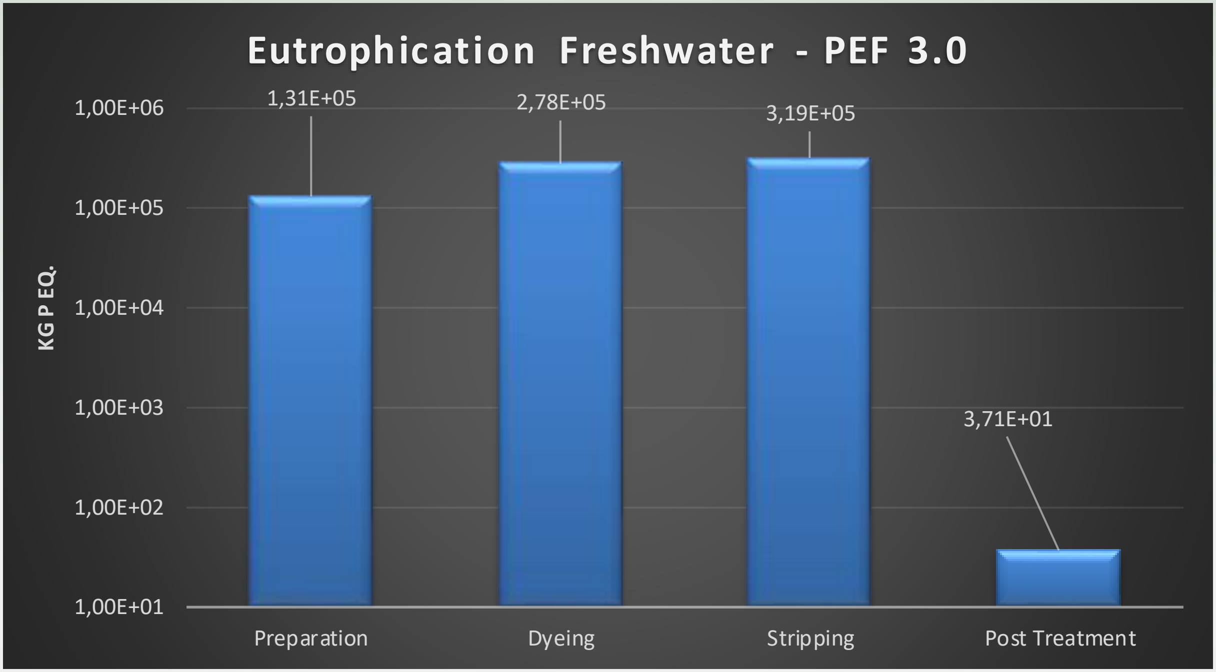
In particular, this analysis is focused on six most representative indicators (according to PEF 3.0 Impact assessment methodology):

- **Climate Change, total**, which is usually one of the most understandable and well-known impact indicators, evaluating the emission of greenhouses gases (GHG);
- **Eutrophication Freshwater**, due to the high amount of water used, it evaluates the benefit from the reduction of this source in new processes, especially focusing on the effects of wastewater into environment;
- **Ozone Depletion**, which evaluates the burdens on ozone-hole effect
- **Resource Use, fossils**, which is one of the two indicators where raw materials have a noticeable impact;
- **Resource Use, mineral and metals**, which focuses on the consumption of specific raw materials from mineral and metal source;
- **Water Use**, which evaluates the depletion of water along the considered life cycles

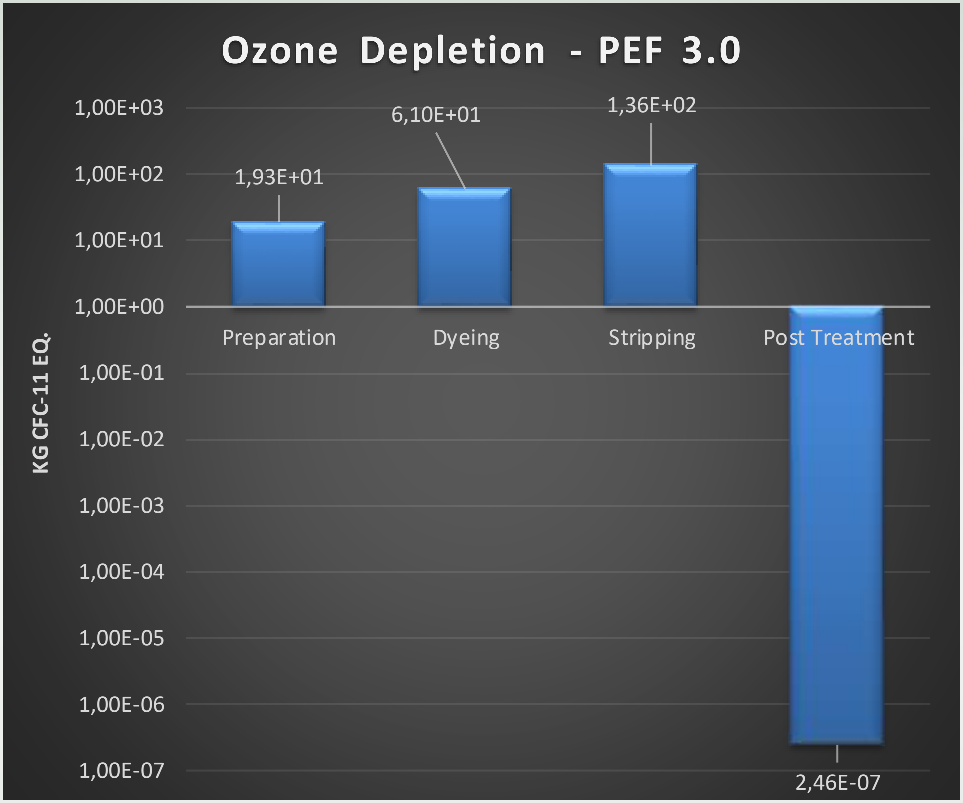
The following graphs will detail the impact assessment on the **4 steps of use phase**, which has the highest impact (>90% of the overall LCA impacts).



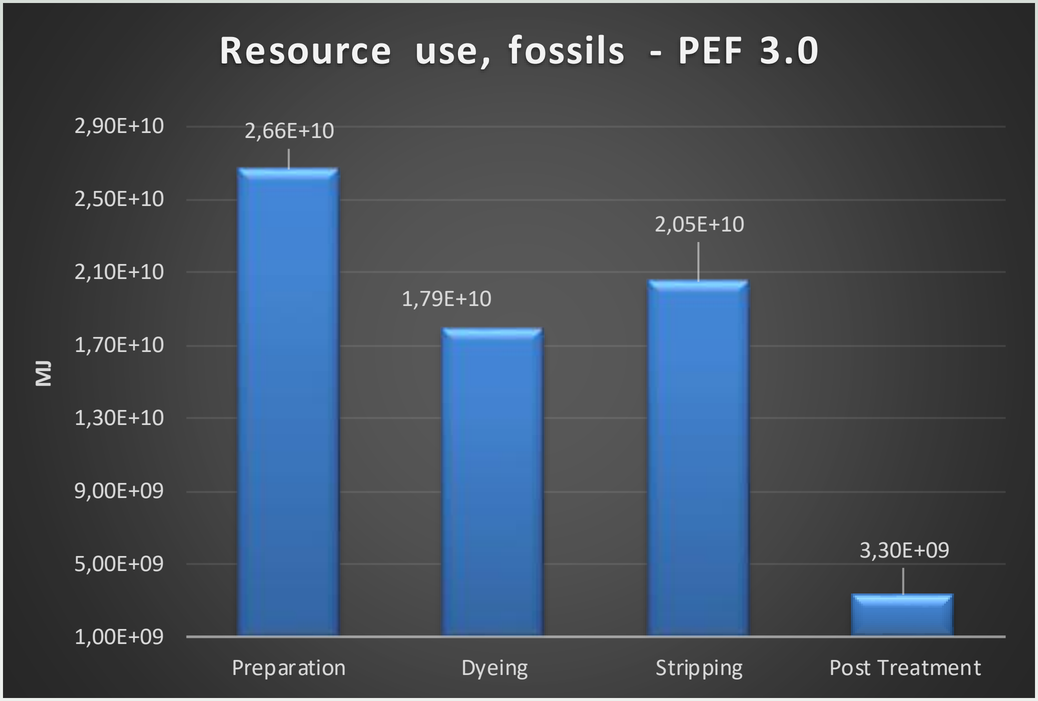
For this important indicator, the step which has the highest impact is the **preparation**, including several chemical products (40%). Furthermore, **dyeing** and **stripping** steps are quite equivalent (28% and 27%, respectively), while the lowest impact is associated to the **post-treatment** stage (which principally involves energy inputs).



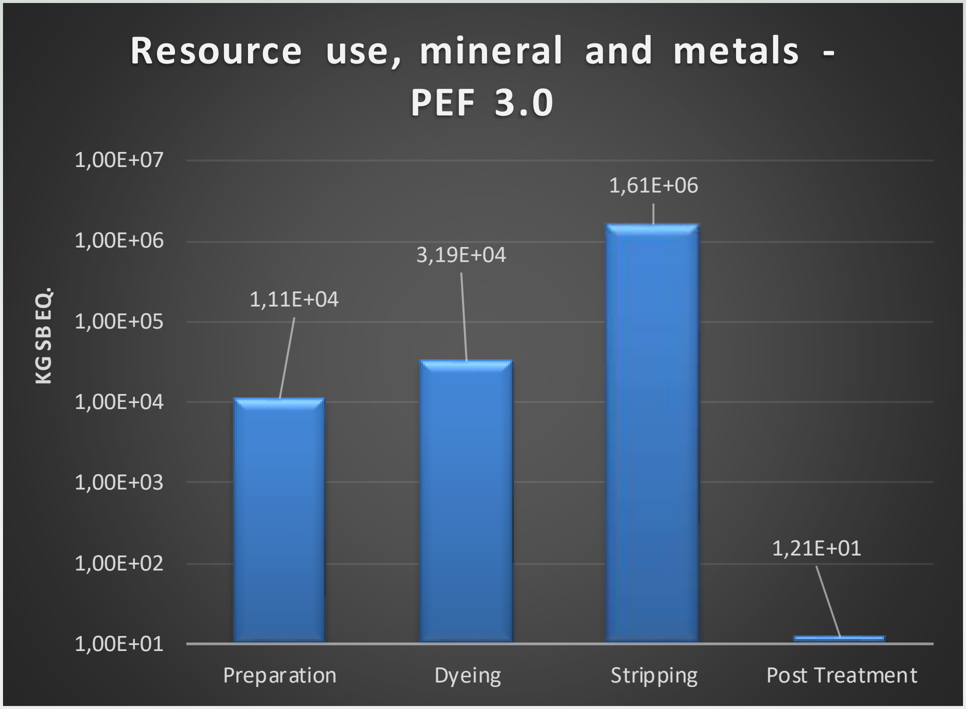
The analysis for the indicator "**Eutrophication freshwater**" outlines that the higher contributions are due to **stripping (44%),** and **dying (38%)** steps with a very high impact (where chemicals are highly employed. Also the **preparation** step has a remarkable impact (18%). Instead, the impact in the post-treatment stage is negligible.



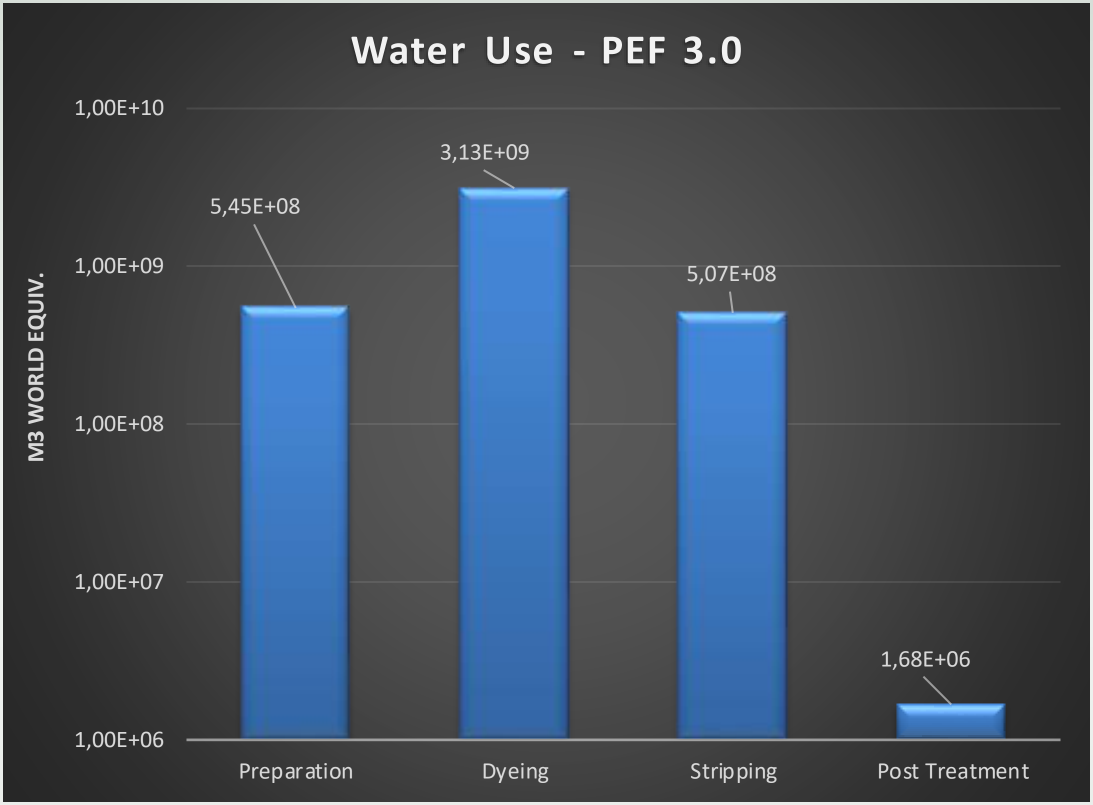
The **Ozone Depletion** highest value is associated to the **stripping** step of the use phase (63%), probably due to the high consumption of chemicals. A remarkable (28%) of Ozone Depletion value is also observed in the **dying** step; the **preparation** impact is of 9% on the total impact, and the **post treatment** one substantially insignificant.



Considering this indicator, **preparation**, **stripping**, and **dyeing** present an environmental impact that is quite similar each other, with a contribution of 39%, 30%, and 26%, respectively. The **post treatment** impact is almost negligible (5%).



Concerning the indicator "**Resource use, mineral and metals**", the analysis points out that the **stripping** step of the use phase has the highest impact (97%), while the other steps show insignificant contributions.



Finally, the depletion of water in the use phase of ARC 30HT is highest during the **dyeing** step (75% of the impact). **Preparation** and **stripping** steps present a contribution equal to the 13% and 12%, respectively, while the **post treatment** impact is practically negligible.

CONCLUSIONS

The LCA study described in this document has been performed by RINA Consulting in accordance with main requirements of international standards (ISO 14040:2021 and 14044:2021) and internationally recognized guidelines (i.e., ILCD Handbook: General guide for Life Cycle Assessment - Detailed guidance).

The report provides information on the environmental footprint of one of the main products of Flainox catalogue, the ARC 30HT machine. The main outcome of the study is that contribution of **use phase**, compared to other ones is evident and it overcomes the 99% in all the indicators.

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Results for ARC 10HT

Starting from impacts obtained for ARC 30HT, a conversion has been conducted to evaluate the impacts only of the Use Phase of a different model of the same series ARC HT, i.e. ARC 10HT.

The Use Phase is the main impacting one and the results for ARC 30HT processes have been converted for ARC 10HT, through a factor, i.e., 0,28.

The results, including the **Use Phase** only, are presented in the following tables.

INDICATOR	**Value**	**Reference unit**
EF 3.0 Acidification	7.17E+06	[Moles of H+-Equiv.]
EF 3.0 Climate Change - total	1.28E+09	[kg CO2 eq.]
EF 3.0 Climate Change, biogenic	3.15E+06	[kg CO2 eq.]
EF 3.0 Climate Change, fossil	1.09E+09	[kg CO2 eq.]
EF 3.0 Climate Change, land use and land use change	1.91E+08	[kg CO2 eq.]
EF 3.0 Ecotoxicity, freshwater - total [CTUe]	2.82E+10	[CTUe]
EF 3.0 Ecotoxicity, freshwater inorganics [CTUe]	8.82E+09	[CTUe]
EF 3.0 Ecotoxicity, freshwater metals	1.57E+10	[CTUe]
EF 3.0 Ecotoxicity, freshwater organics	3.66E+09	[CTUe]
EF 3.0 Eutrophication, freshwater	2.04E+05	[kg P eq.]
EF 3.0 Eutrophication, marine	1.96E+06	[kg N eq.]
EF 3.0 Eutrophication, terrestrial	9.45E+06	[Mole of N eq.]
EF 3.0 Human toxicity, cancer - total	8.43E+00	[CTUh]

INDICATOR	Value	Reference unit
EF 3.0 Human toxicity, cancer inorganics	4.06E-11	[CTUh]
EF 3.0 Human toxicity, cancer metals	7.85E+00	[CTUh]
EF 3.0 Human toxicity, cancer organics	5.84E-01	[CTUh]
EF 3.0 Human toxicity, non-cancer - total	1.59E+01	[CTUh]
EF 3.0 Human toxicity, non-cancer inorganics	2.11E+00	[CTUh]
EF 3.0 Human toxicity, non-cancer metals	1.28E+01	[CTUh]
EF 3.0 Human toxicity, non-cancer organics	1.10E+00	[CTUh]
EF 3.0 Ionising radiation, human health	7.66E+07	[kBq U235 eq.]
EF 3.0 Land Use	1.33E+10	[Pt]
EF 3.0 Ozone depletion	6.07E+01	[kg CFC-11 eq.]
EF 3.0 Particulate matter	5.68E+01	[Disease incidences]
EF 3.0 Photochemical ozone formation, human health	2.65E+06	[kg NMVOC eq.]
EF 3.0 Resource use, fossils	1.91E+10	[MJ]
EF 3.0 Resource use, mineral and metals	4.62E+05	[kg Sb eq.]
EF 3.0 Water use	1.17E+09	[m^3 world equiv.]

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