

**ADVANCES IN THE JEANS FINISHING INDUSTRY
TOWARDS A MORE SUSTAINABLE PRODUCTION MODEL**

Jeanologia[®]
THE SCIENCE OF FINISHING

ABSTRACT

The jeans industry is one of the most iconic within the textile sector but also one with a significant environmental impact. From cotton production to the processing and finishing of the final product, the manufacturing process of jeans can be highly polluting. The complexity of the manufacturing chain and the high number of stages, often carried out by different companies, make it difficult to objectively analyze the impact at each stage of the production. However, one of the areas recognized as having the greatest impact is garment finishing, where complex processes combining dry and wet treatment techniques are applied to achieve a specific appearance and garment performance.

The jeans finishing industry has been and continues to be a primary focus for reducing environmental impact in jeans manufacturing. Currently, various technological alternatives exist that significantly reduce environmental and human impact compared to traditional techniques by reducing water and energy use, implementing safer chemicals, and replacing manual techniques that negatively affect workers' health.

This work aims, through the EIM environmental impact measurement software, to analyze data from more than 19,000 measured jean styles to offer a clear view of the current industry. The impact categories collected by EIM (water and energy use, characteristics of the chemicals used, and the impact on workers from manual garment treatments) will be analyzed, as well as the available alternatives to reduce this impact. Furthermore, the analysis will help identify the main challenges of this industry to advance towards a sustainable transformation. This work also aims to lay the foundations for monitoring progress in this field.

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Companies named in the report

- (1) Go Blu (Germany) : <https://www.goblu.net/>
- (2) Artistic Milliners (Pakistan): <https://artisticmilliners.com/>
- (3) Cone Denim (North America) - <https://conedenim.com/>
- (4) Navina(4) Pakistan) - <https://naveena.net/>
- (5) DyStar / Kaiser : <https://www.dystar.com/denim-solutions/> <https://kaisertekstil.com/>
- (6) Kemin (Italy) <https://www.kemin.com/sa/es/markets/textiles/garmon-brand>
- (7) CHT (Germany): https://solutions.cht.com/cht/web.nsf/id/pa_jeans_y_prendas_es.html
- (8) Saitex (Vietnam) <https://sai-tex.com/>
- (9) Mactec (Italy): <https://www.mactec.it/>
- (10) HMS handmade stones (Turkey): <https://www.hmswashing.com/>

1 - INTRODUCTION

The textile industry is one of the oldest and most fundamental sectors in the global economy, providing employment to millions of people and essential products for daily life. However, its environmental impact is significant. According to the European Union, the textile sector is the third largest source of water degradation and land use, responsible for about 20% of clean water pollution and 8 to 10% of total carbon emissions, making textiles the second most polluting industry in the world.

The environmental issues associated with the textile industry encompass its entire life cycle. To effectively address these issues and promote cleaner textiles, it is necessary to consider each area of the value chain. The textile value chain is extensive and complex, involving fiber growing and production, textile manufacturing and distribution, consumer use, and disposal. Major issues in production are related to the over-production of goods that are wasted before even being used, the use of resources, and the waste generated.

Addressing textile manufacturing is already a challenge, as it involves different areas of expertise such as spinning, weaving, wet processing, or sewing. Additionally, technologies, equipment, processes, and consequently, environmental impacts vary for different materials (fiber types), fashion segments, or types of clothing. Analyzing each individual textile product in depth, tracing its production, and gathering data directly from the supply chain is probably the most effective way to visualize where the impacts are highest and implement measures to address environmental problems. This approach will also help raise awareness at both the manufacturing and consumer levels, allowing both to make decisions considering environmental impacts.

Following the product category approach, focusing on apparel, and more specifically on casual wear and denim, the environmental impacts associated with the production chain are related to the use of resources and chemicals. Among the most impactful areas is garment finishing, where dry and wet processing steps are combined to achieve a specific.

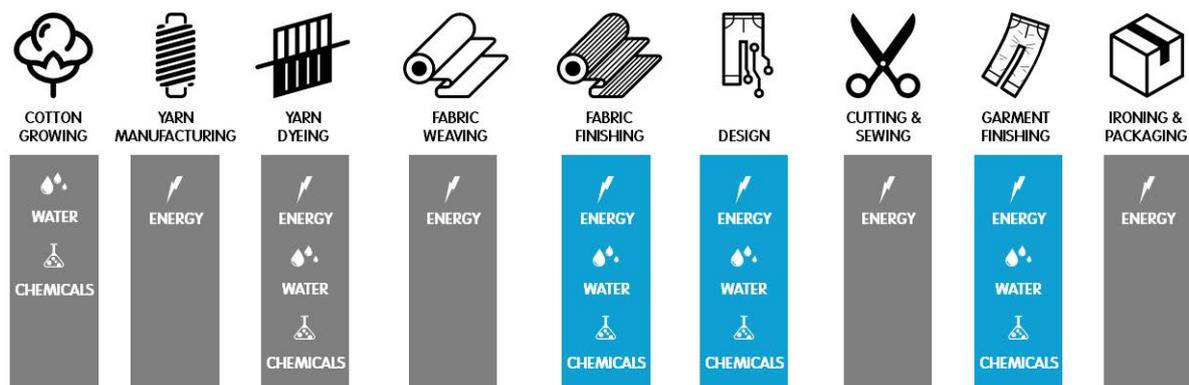


Fig.1 Denim value chain and main environmental impacts

The optimization of processes, implementation of technologies or new production models are necessary to build a more sustainable textile industry. To identify where the impacts are bigger and monitor that decision taken leads to the right direction, the use of specifically developed measuring tools are absolutely necessary. One of these tools is de EIM (Environmental impact measuring software) that was launched in 2011 by Jeanologia and open to all garment finishers. The analysis of the data collected from milliards of processes measured through EIM also allows to have a great picture of the status of a complex manufacturing process supporting the definition of challenges and opportunities to move towards an eco-efficient production.

2 - SCOPE OF THE REPORT

As previously introduced, garment finishing is one of the casual wear and denim manufacturing stages with higher use of resources and chemicals and therefore one of the higher impacts to the environment. The EIM software measures, based on the manufacturing process followed, the environmental impact of this specific production stage. The data introduced directly from the manufacturing of hundreds of EIM users, allows a deep analysis of the situation of the industry with regards to sustainability. The present report analysis denim garment finishing industry situation focusing the analysis on data collected for one year, from July 2023 to July 2024. EIM reports of the period under analysis uses the EIM V2.0, an upgrade version that Introduced important changes on the measuring criteria for a more robust and scientific measuring and benchmarking approach. The purpose of this data analysis is to identify major challenges to address to reduce the environmental impact of denim garment finishing processes as well, as based on the EIM benchmark monitor the achievements over the last year. The report aims as well to collect best industry practices that are leading to this industry transformation pointing at the different opportunities for further improvement. Last but not least, the current report will also permit to define updated industry references to track progress as well as motivate the collaborative work between stakeholders to find and implement solutions to hurry up the transformation.

Sample size consider in the report account with more than 90 thousand processes introduced by 358 garment finishers.

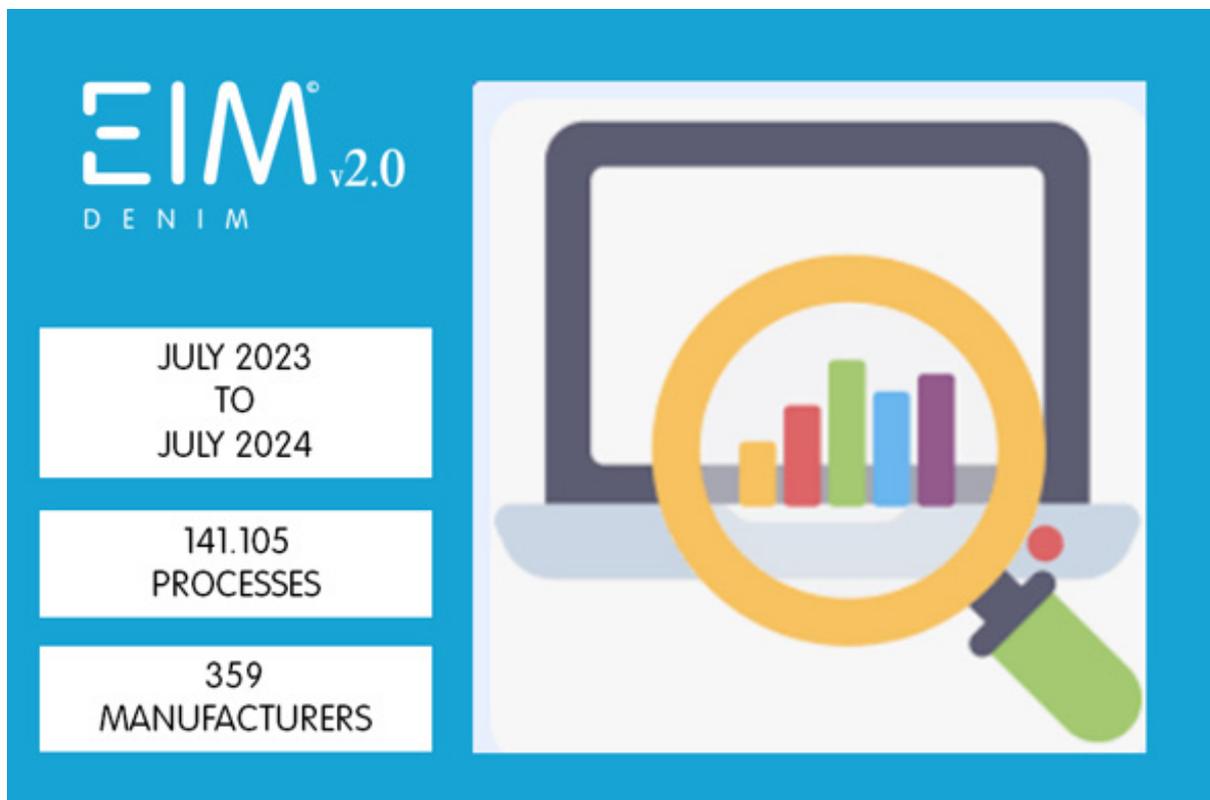


Fig.2 Data source & sample size

3 - ABOUT EIM

EIM stands for “Environmental Impact Measuring”. It is a software specifically developed to measure impact of garment finishing processes. It is a powerful self-accreditation tool aimed to improve environmental performance of garment finishing (jeans, garment dye and garment wash) at the manufacturing stage.

EIM software was developed by Jeanologia in 2009 as an internal tool to be used by Jeanologia engineers and designers to drive the company R&D. It proved to be a great tool to direct development teams not to only develop nice garments but also to focus on the “how” those final products were manufactured, motivating the teams to study ways to reach same equal or equivalent result but lowering the environmental impact of the garments. This also helps Jeanologia experts to connect dots and move from individual solutions to address specific issues, to integrated solutions overcoming multiple challenges, that in some cases lead to the definition of new production models. Jeanologia as part of its mission of transforming textile industry into a more eco-efficient one, decided to support all garment manufactures giving them the possibility of using EIM as a continuous improvement tool creating a user-friendly software, open to all finishing industry, whether Jeanologia technologies are used or not. EIM is open to all finishing equipment including those manufactured by direct Jeanologia’s competitors, facilitating, and making possible the standardization of its use with clear and transparent measurement rules and criteria as well as facilitating access to all kind of producers.

EIM is a tool developed for garment manufactures but it is also used by brands and retailers since it has been proven to be a great tool to better understand, without being a finish expert, manufacturing process giving them the opportunity to introduce a unique, standard, easy and economically viable way to know about the environmental impact in the garments they produce. Among the different possibilities of EIM we can underline:

- A.** Assess where the impact is higher and take the necessary actions to reduce the environmental footprint.
- B.** Compare different processes to take informed decisions.
- C.** Monitor if decisions taken are leading to the right direction.
- D.** Motivate and accelerate the introduction of new finishing techniques that can lead to different levels of reduction of the environmental impact.
- E.** Have a standard to measure the environmental footprint of the garment finishing stage no matter where it is produced.
- F.** Add a new decision element for buyers at business to business but also at business to consumer level.

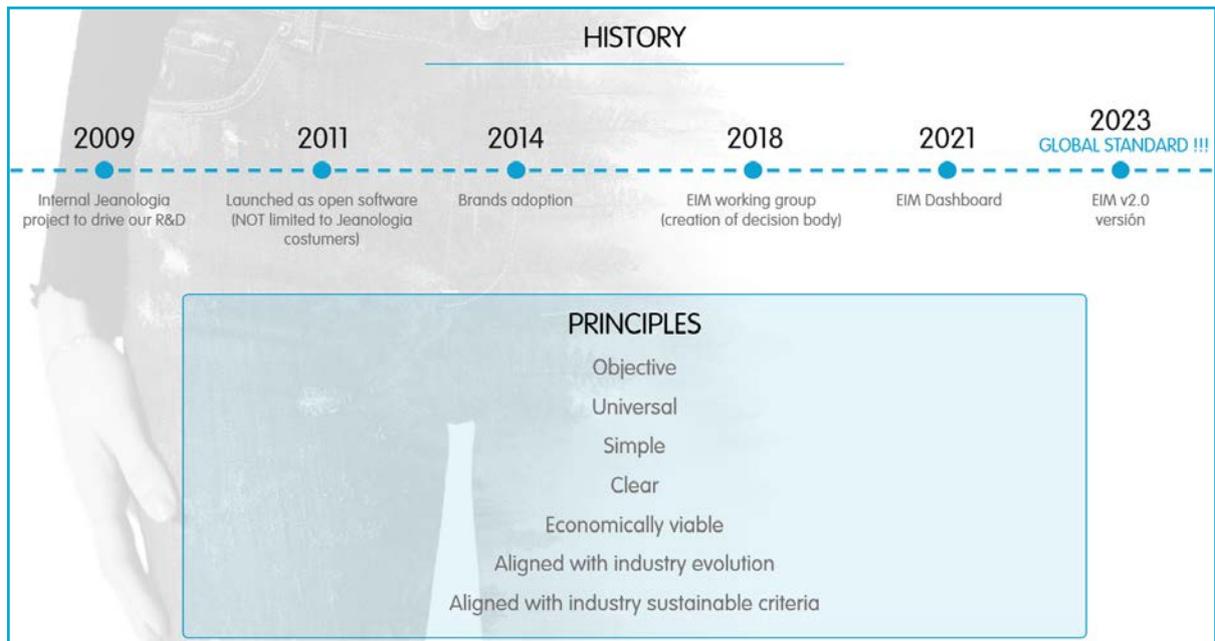


Fig.3: EIM History & principles

3.1.- EIM SCOPE:

EIM measures environmental impact of the process done to produce a garment and benchmark the results to give a final EIM score. The score allows the classification of the production process into a process of low, medium or impact.

EIM understand the impact considering four different categories: Water and energy needs, chemical impact and worker impact.

Based on a process (recipe) description, the software works in 3 steps:

- 1.** Quantification: Each of the categories are quantify following a defined criteria an calculation methodology.
- 2.** Benchmark against an environmental threshold defined for each of the categories.
- 3.** EIM score calculation and process classification as average of the 4 categories, with equal weight on the final score.

3.2.- EIM SCORES CALCULATION STEPS

3.2.1- QUANTIFICATION

EIM understand a finishing process as the combinations of multiple processing steps. Steps are as well divided into wet or dry step. Wet steps are the steps that are done in a batch of garments while dry steps are those made garment by garment.

EIM		17/06/2024 User: Center: Jeanologia BB	
Report process: STONE WASH WITH WHISKERS AND USED (EIM V2.0)			
More Info:			
STEPS			
1 - Stdad - Manual Scraping D Pneumatic Manequin Time: 4 min	2 - Drain and rinse W Washing machine (Front loading) Time: 3 min Temperature: 25°C LR 1:10 Gradient 4 °C/min Recycled water? No	3 - Rinse and drain W Washing machine (Front loading) Time: 3 min Temperature: 25°C LR 1:10 Gradient 4 °C/min Recycled water? No	4 - Drain and rinse W Washing machine (Front loading) Time: 3 min Temperature: 25°C LR 1:10 Gradient 4 °C/min Recycled water? No
5 - Drain and rinse W Washing machine (Front loading) Time: 3 min Temperature: 25°C LR 1:10 Gradient 4 °C/min Recycled water? No	6 - Drain and rinse W Washing machine (Front loading) Time: 3 min Temperature: 25°C LR 1:10 Gradient 4 °C/min Recycled water? No	7 - Stda - Hydroextraction W Hydro Extractor Time: 5 min	8 - Stdad - Tumbler Drying W Tumbler dryer Time: 30 min Temperature: 80°C
9 - Soaping (60°C) W Washing machine Time: 10 min Temperature: 60°C LR 1:10 Gradient 4 °C/min Recycled water? No Chemicals Detergent (APEO free) 1 g / L	10 - Stdad - Stone Wash W Washing machine (Front loading) Time: 60 min Temperature: 40°C LR 1:10 Gradient 4 °C/min Recycled water? No Chemicals Dispersing agent (APEO free) 1 g / L Stones (Pumice) 1 kg / kg	11 - Softening W Washing machine Time: 10 min Temperature: 30°C LR 1:10 Gradient 4 °C/min Recycled water? No Chemicals Silicone Softener 3 g / L Cationic Softener 1.5 g / L	12 - Desize W Washing machine Time: 10 min Temperature: 50°C LR 1:10 Gradient 4 °C/min Recycled water? No Chemicals Enzyme (Alpha amylase) 2 % owg Defoaming (Based on silicone) 0.3 g / L Dispersing agent (APEO free) 0.5 g / L Wetting agent (APEO free) 1 g / L Detergent (APEO free) 2 g / L

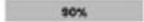
PROCESS SUMMARY (per garment)				
 Threshold: EIM V2.0 - DENIM	Water (l/garment)	Energy (kWh/garment)	Chemical's Breakdown	Worker Impact
	Calculated Effective 90 90	Calculated Effective 1.94 1.94	ZDHC Conformance 	7
Renewable Water 0%	Renewable Energy capacity 0%	With SC Score 		
Garment weight (kg): 1 Process time: 2h 57' 45s		Carbon footprint (kgCO2/garment) 0.72		
EIM ENVIRONMENTAL IMPACT				
EIM SCORE 52 Threshold: EIM V2.0 - DENIM Medium Impact	Water Impact (l/kg of garment) 90	Energy Impact (kwh/kg of garment) 1.94	Chemical Impact (garment) 100	Worker Impact (garment) 7
	0-45 45-90 +90 l/kg	0-2.5 2.5-3.6 +3.6 Kwh/kg	0-33 33-66 +66 garment	0-13 13-29 +29 garment

Fig.4: Example of EIM process report detailing the combination of wet and dry steps.

The element that defines the step, is the type of machine or tool used for the operation. According to this selection, when creating the step, the system will guide the user to introduce the information related to the processes variables that will impact the environment, information required for the system to calculate the impact according to the set criteria.

1 - Stdad - Manual Scraping	2 - Drain and rinse	8 - Stdad - Tumbler Drying
1 D 2 Pneumatic Manequin	1 W 2 Washing machine (Front loading)	W Tumbler dryer
3 Time: 4 4 min	3 Time: 3 min Temperature: 25°C LR 1:10 Gradient 4 °C/min Recycled water? No	Time: 30 min Temperature: 80°C

Fig. 5: Processes steps description

Based on the described recipe, every step accounts for the calculation. Criteria to calculate each of the categories are:

1. Steps class (D for Dry step, W for Wet step)
2. Machine / tool type (There is a different selection of machines /tools as per the wash type)
3. Step variables that affect environmental impact
4. Process variable set values (to be filled by the user)

3.2.1.1.- CALCULATING WATER CONSUMPTION:

The quantity of water consumed in every single step of the process, will vary depending on the liquor ratio (liters of water per kg of garments) defined for every step of the washing / dyeing process. The total quantity consumed in a complete wet garment process is the sum of the liters required for each of the steps that involved water.

When using recycled water for one step, a correction factor will be applied to the calculated water. The factor applied is calculated based on the capabilities of the production site to clean and re-use water and express in the EIM report as effective water used.

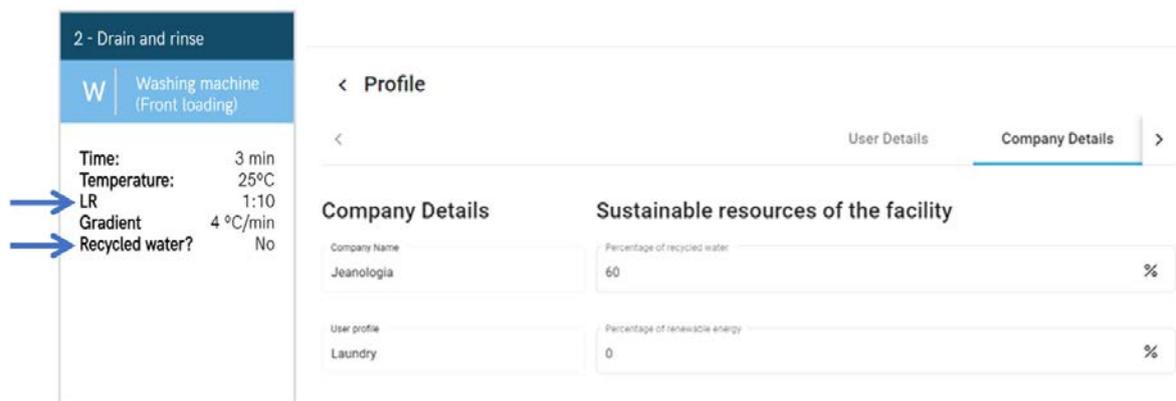


Fig 6. Variables consider calculating water requirements.

Water consumption is related to the kilos of garments produced but since the weight of the garment is a required value, the report gives also the liters required per garment produced. EIM score calculation is based on the effective calculate per kg of garments produced.

PROCESS SUMMARY (per garment)	Water (l/garment)		Energy (kWh/garment)		Chemical's Breakdown	Worker Impact
	Calculated	Effective	Calculated	Effective		
Garment weight (kg): 0.5 Process time: 2h 47' 0s	15	9.3	0.7	0.7	ZDHC Conformance: 75% / 25% With SC Score: 60% / 20%	0
	Renewable Water 38%		Renewable Energy capacity 0%			
	Carbon footprint (kgCO2/garment) 0.29					
EIM ENVIRONMENTAL IMPACT						
Threshold: EIM V2.0-DENIM						
	Water Impact (l/kg of garment)	Energy Impact (kwh/kg of garment)	Chemical Impact (garment)	Worker Impact (garment)		
	18.6	1.4	48	0		
	0-45 45-90 +90 l/kg	0-2.5 2.5-3.6 +3.6 Kwh/kg	0-33 33-66 +66 garment	0-13 13-29 +29 garment		

Fig 7. EIM report. Water & energy consumption values

3.2.1.2.- CALCULATING ENERGY CONSUMPTION:

EIM aims to use an energy calculation methodology that allows the user to have an accurate estimation of the energy requirements with independence of the specific machines and installation. This methodology will allow comparison between processes made at different locations and / or following different finishing processes at a product level. The energy calculation result, need in consequence, be taken as a reference as well as good estimation on the process efficiency.

EIM measures the total energy required in kwh considering both the one required to run the machines (electrical energy) and the one required to heat the water and the air for drying processes. Electrical energy is variable as per the machine running time and the nominal power of the machine used. The heating energy will depend on the final temperature to reach, the quantity of water or air to heat to the set point. It also accounts for the heating energy the one required to maintain the set temperature through the step processing time. The capabilities of a production facilities to generate clean energy, is also considering in EIM. The calculated energy is corrected by calculating the correction factor according to the percentage of self-sufficiency in renewable energy of the facility. Equally to water, energy value consider for the calculations of the EIM score is the effective energy required per kg of garment produced but as in water, data per garment produce is given in the reports.

Based on the energy requirements, EIM can give as well a first estimation on the kg of CO₂ emitted by each garment produced. For this first estimation we are considering an average factor mix (current factor mix: 0.46) for the electrical energy. To calculate CO₂ emission due to the use of fossil fuels, the consideration taken is that most common heating sources are gasoil and gas. In consequence an emission factor of 0.29 is the one consider calculating emissions due to heating energy needs.

3.2.1.3.- CALCULATING CHEMICAL IMPACT:

One of the biggest challenges we faced when defining EIM measuring criteria was related to the chemical impact. Many chemical products are used in the garment finishing process. As a result of their use, chemicals can impact in different ways such as:

Waste water containing the products used and / or subproducts due to the reactions between the different chemicals used and between the chemicals and the textile goods, air quality emission, exposure of the workers due to the manipulation of the chemicals to be used and the subproducts due to interactions during processing.

At this stage, EIM chemical impact focus on the chemicals used and its individual characteristics.

The methodology adopted by EIM to quantify quantify and be able to calculate the chemical impact as a number, it is necessary first to score each chemical product or formulation used in the finishing process. Scivera, an Enhesa Group company brought his expertise and define the EIM chemical impact score (EIM CIS) as well as its calculation methodology. Scivera, is a leader in providing chemical suppliers, chemical formulators, manufacturers, and brands across all industries with intelligence about the chemicals they are using in their products. The EIM CIS, integrates, ZDHC MRSL conformance, and the hazard assessment of each individual ingredients of a chemical product or a formulation following the Screen chemistry Score methodology.

The need to have each chemical characterized and scored according to the defined criteria, makes also necessary to have a list of options the user can select those chemicals formulations or commodities they are using in their processes. The EIM chemical database is form by more than 3000 options among we find the following groups:

- Commercial formulations with at least ZDHC level 1 3rd party certificate. (That is the minimal requirement for a chemical to be in EIM)
- Commodities or basic chemicals.
- Generic chemicals based on functionalization such as enzyme, detergents, softeners, etc.
- Other special products such as pumice stones and its alternatives that are in fact not chemicals but can consider as such when describing a garment finishing process.

All chemicals in EIM have their EIM CIS represented by a color and by a number. The EIM CIS can go from 0 (most sustainable chemicals. Preferred chemicals to be used) to 100 (products of concern with environmental or human important hazards).

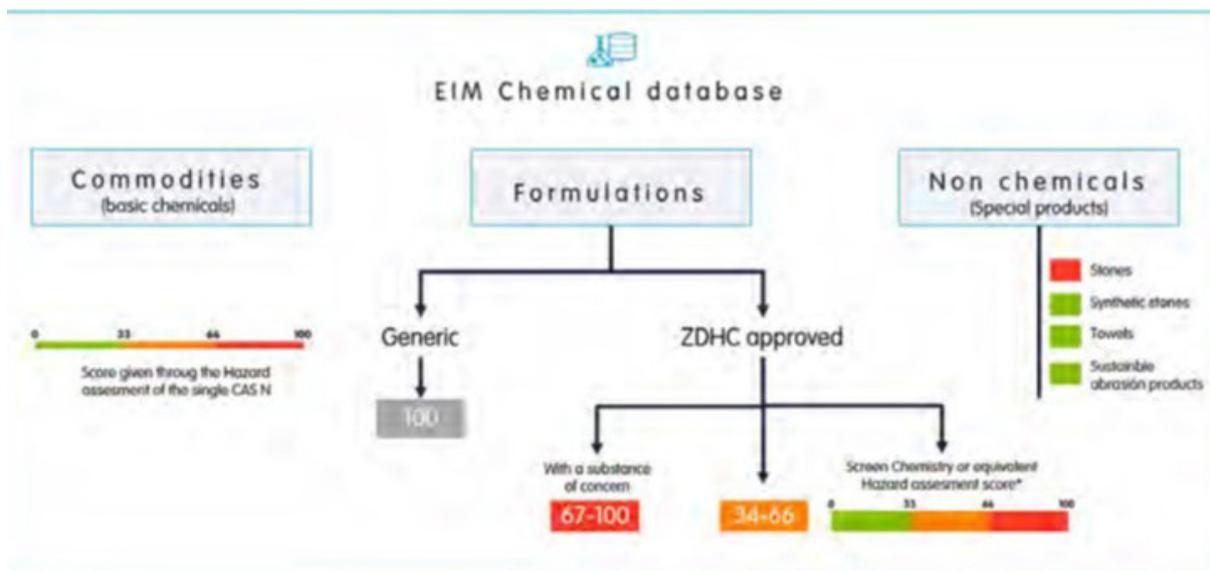


Fig. 8: EIM chemical data base scheme

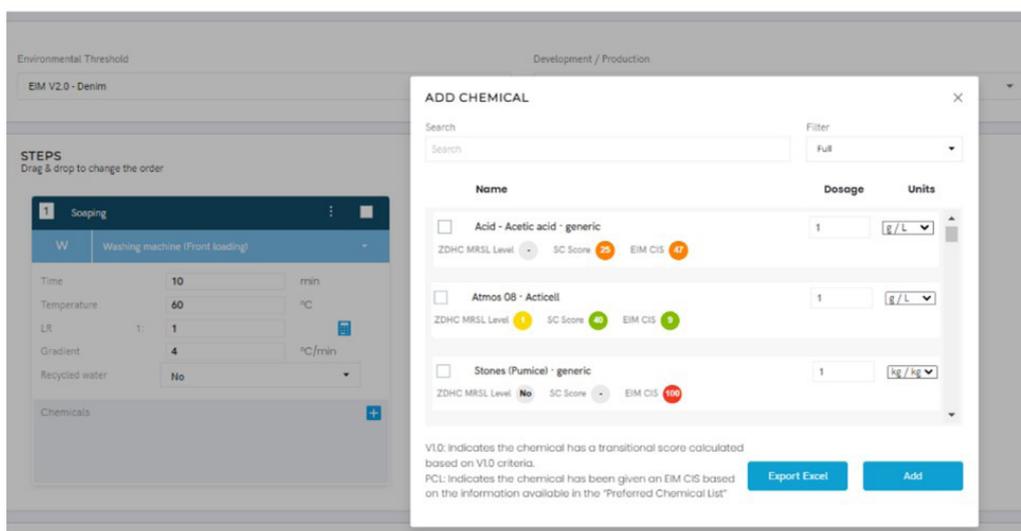


Fig 9: EIM, adding chemicals into a recipe:

The EIM chemical impact score, is calculate through a complex algorithm that considers both EIM CIS and the quantity of each of the chemicals used. The algorithm has been developed by Sumerra, an advisory company with expertise in sustainability rating systems including data modeling and calculation.

For the calculation of the chemical impact the following factor are being consider:

- A factor (W) that will consider the sustainability of the chemicals used in the recipe.
- A factor (Q) that will consider the total quantity of chemicals in a recipe.
- A factor (N) that will consider the number of unique chemicals in a recipe.

The score (S) will be the average of the three factor scores.

$$S = (W+Q+N)/3$$

The Sustainability factor will be a simple mean of the maximum EIM CIS score of the chemicals used in the recipe.

$$W = \text{Weight Score} = \{csi, \dots, csn\}$$

Where $csi = \text{EIM CIS Score for each chemical}$

For the quality factor (Q), each chemical in the recipe will be put in a cluster based on the EIM CIS score:

- Cluster 1 < 34
- Cluster 2 = 34 to 66
- Cluster 3 >66

Each cluster is weighted by a multiplier as follows.

- Cluster Multiplier 1 (CW1) = 0.5
- Cluster Multiplier 2 (CW2) = 1
- Cluster Multiplier 3 (CW3) = 3

The sum of the % of on weighted goods (o.w.g) in each cluster is multiplied by the number above and added together to generate a sum of weighted cluster scores (Wsum)

$$Wsum = (\sum\{owgi\dots owgn\}, cl=1)*CW1 + \sum\{owgi\dots owgn\}, cl=2)*CW2 + \sum\{owgi\dots owgn\}, cl=3)*CW3$$

Where $owgi = \text{o.w.g. for each chemical in the cluster (cl)}$
 $n = \text{number of chemicals in the cluster}$

Once the Wsum is generated we use the sigmoid function to create a sigmoid curve using a scaling factor (steepness of the curve) and a start value (point in curve where scale increases exponentially) for the designed curve and generate the Q factor.

$$Q = 100 / 1 + e^{-kq*(Wsum-sq)}$$

Where $Kq = \text{scaling factor} = 0.08$
 $Sq = \text{Start Scale} = 20$

For the number factor (N) the number of chemicals in each cluster (see above) are counted. Each cluster count is weighted by a multiplier as follows:

- Cluster Multiplier 1 (C1W) = 0
- Cluster Multiplier 2 (C2W) = 1
- Cluster Multiplier 3 (C3W) = 5

The count of each number in the cluster is then multiplied by the number above to generate a sum of weighted number scores (Nsum)

$$Nsum = ncl1*C1W + ncl2*C2W + ncl3*C2W$$

Where $ncl1 = \text{number of chemicals in cluster 1}$
 $ncl2 = \text{number of chemicals in cluster 2}$
 $ncl3 = \text{number of chemicals in cluster 3}$

Once the Nsum is generated we use the sigmoid function to create a sigmoid curve using a scaling factor (steepness of the curve) and a start value (point in curve where scale increases exponentially) for the designed curve and generate the N factor.

$$N = 100 / 1 + e^{-kn*(Wsum-sn)}$$

Where $Kn = \text{scaling factor} = 0.2$
 $Sn = \text{Start Scale} = 20$

Fig.10: Chemical impact calculation algorithm

Pumice stones belong to the group of special products that are used to achieve a specific look. The use of pumice stones during the garment finishing stages allows the recreation of natural jeans age-ing and true vintage looks. This very extended practice is associated with relevant negative impacts including habitat degradation occurring during the extraction of the pumices, intensive water use and Water Pollution, generation of solid waste and impact on Worker Health due to the exposure to pumice dust, that is why, chemical impact is scored as 100 (the worst possible rate) when pumice stones are used in the finishing process.

Environmental Problems Associated with the Use of Pumice Stone:

A. Pumice Stone Extraction:

a.1) Habitat Degradation: The extraction of pumice stone can lead to the destruction of natural habitats and loss of biodiversity in mining areas.

a.2) Soil Erosion: Open-pit mining for pumice stone can cause soil erosion, affecting terrain stability and leading to sedimentation problems in nearby water bodies.

B. Water Consumption:

b.1) Intensive Water Use: The stone washing process requires large amounts of water, contributing to water resource depletion, especially in water-scarce areas.

b.2) Water Pollution: The water used in washing can become contaminated with pumice particles and other chemical residues from the process, affecting local water quality and harming aquatic ecosystems.

C. Solid Waste: Fragments of pumice stone and dust generated during the process can become challenging waste to manage. Accumulation of these solid wastes in the environment can lead to waste management issues and soil contamination.

D. 3.2.1.4.- CALCULATING WORKER IMPACT: Impact on Worker Health: Prolonged exposure to pumice dust can cause respiratory problems in workers.

Fig. 11: Environmental issues related to the use of pumice stone. (source: copilot)

3.2.1.4.- CALCULATING WORKER IMPACT:

Imitating the natural aging of a garment requires many operations, most of them, manual. The industrialization of these techniques, often inspired by artisanal methods, can have a significant impact on the health of workers who perform them. In this new version of EIM, the worker impact category focuses on analyzing the health impact of each technique used, highlighting the need to eliminate operations with inherent health risks for workers, regardless of administrative measures that may be implemented at the production center.”



Fig. : Vintage details

A deep analysis has been developed by the group of experts of “Ergonautas”, a department of the Polytechnics University of Valencia (UPV) specialized on ergonomics is the base to score every individual operation according to its inherent ergonomic potential hazard risk. The EIM worker impact score is calculated as the sum of individual scores of each operation done in the finishing process according to its recipe description.

	Manual Scraping	Grinding With Manual Device	Grinding With Table Machine	Damages With Manual Device	Damages With Cutter	Automatic Damaging Machine	Spray	Sponging	3d Whiskers	Manual Tagging	Automatic Tagging	Laser Marking
Repetitive movements	2	0	1	0	2	0	2	1	1	1	1	0
Load handling	0	0	0	0	0	0	0	0	0	0	0	0
Force application	1	0	0	0	0	0	0	0	0	0	0	0
Force posture	2	2	2	2	2	0	2	2	2	2	1	0
Vibrations	0	2	2	2	0	1	0	0	0	0	0	0
Contact pressure	1	1	2	1	1	0	0	0	0	1	0	1
Thermal local environment	0	0	0	0	0	0	1	0	1	0	0	0
Noise local level	0	1	1	1	0	1	2	0	1	0	0	0
Attention and risk	0	1	1	1	1	0	0	0	1	0	1	0
Repetitivity and monotony	1	1	1	1	1	1	2	1	1	1	1	0
	7	8	10	8	7	3	9	4	7	5	4	1

Fig.13. Operations risk factor matrix

Low probability for the risk to happen = 0
 Medium probability for the risk to happen = 1
 High probability for the risk to happen = 2

3.2.2.- BENCHMARK

Once we have each category calculated, they are compared against a threshold. The EIM user can select among three different thresholds. Each threshold is suitable for a specific market segment and have been defined following specific methodologies taking into consideration most common industrial processes applied to garments of each of the garment segment.

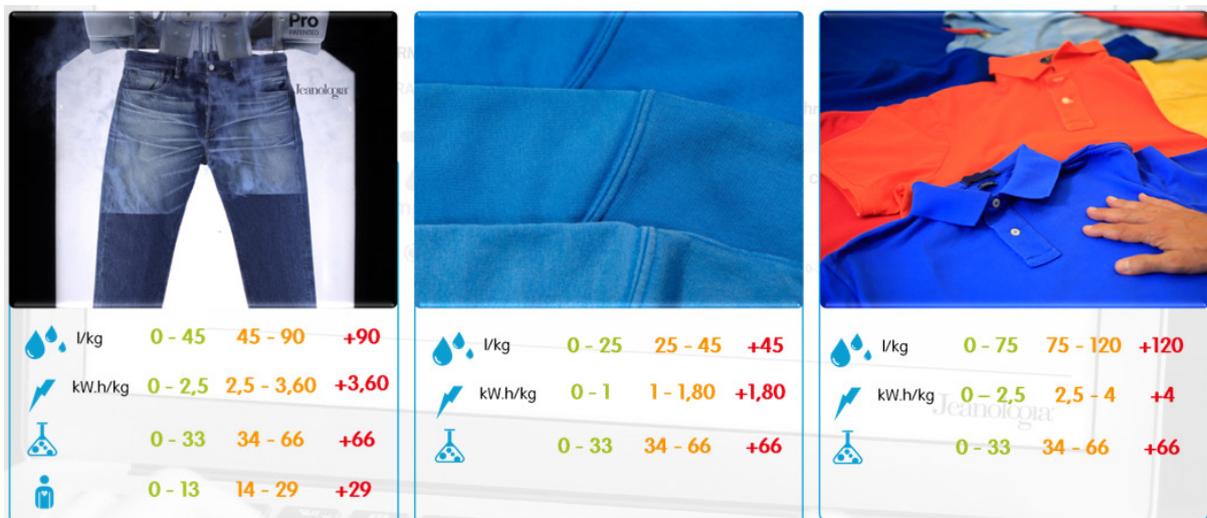


Fig. 7: EIM thresholds

3.2.2.1.- DEFINITION OF WATER & ENERGY THRESHOLDS

Basic industry processes have been identified for each of the garment segment consider in EIM. To set the upper and lower limits through average water consumption and energy slightly different methodologies have been followed for each group which are summarized in the below figures.

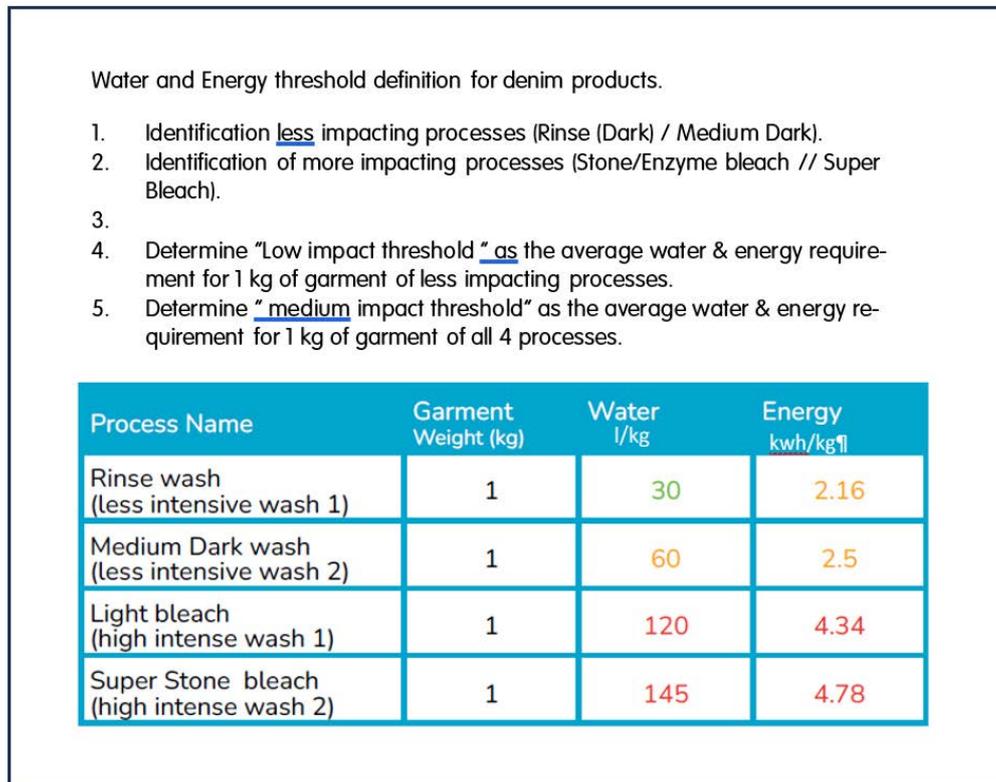


Fig. 14.- Water and energy threshold definition for denim finishing processes.

Water and energy threshold definition for garment wash and garment dyeing processes

Water and energy threshold definition for garment wash and garment dyeing processes

- 1.- Identification basic processes
- 2.- Calculate average water and energy requirements.
- 3.- Determine the "low impact thresholds" calculated as the 30% improvement from the average of the 2 processes.
- 4.- Determine high impact threshold as everything that goes above the 10% of the average.

Process Name	Garment Weight (kg)	Water (L/garment)	Energy (kWh/garment)
Enzyme Wash I	1	60	2
Basic Wash I	1	10	1.11

Process Name	Garment Weight (kg)	Water (L/garment)	Energy (kWh/garment)
Polyamide dyeing 1:10	1	90	3.85
Reactive dyeing 1:10	1	120	3.78
Wash-down cationisation & dyeing 1:10	1	110	3.18

Fig. 15.- Water and energy threshold definition for garment dyeing and garment washing.

3.2.2.2.- CHEMICAL IMPACT THRESHOLD DEFINITION

EIM chemical impact score is directly calculated as the EIM impact scale have been introduced in the EIM CIS calculation. If chemical impact scores between 0-33, the impact is consider low, if the resulting score is between 34 and 66 is medium impact while the high chemical impact is between 67 and 100.

3.2.2.3.- WORKER IMPACT THRESHOLD DEFINITION

The threshold methodology followed to benchmark the worker impact is taken as a base line for future data revision and analysis. The methodology to calculate the worker impact, considers:

1. Identification of most common effects that required manual operations:
 - Whiskers and used area
 - Damages
 - Grinding of waist band, waist band and bottom
 - Whiskers and used area enhancement
2. Identification of available methods for each of the effect
3. Calculation of EIM worker health category impact of the lowest, highest and average possible combina-tions.
4. Green upper limit range of the Worker impact threshold will be the score of the lowest impact combina-tion. Orange upper limit range, the score of the average impact combinations and the Red upper limit range, the score of the highest impact combination.

		EIM Operation Score	Low Risk	High	Med/ High	Med/ Low
Wiskers and Used Areas (1 operation)	Laser Marking	1	1			
	Manual Scrapping	7		7	7	7
Damages	Cutter	9		9		
	Pneumatic Griding device	8			8	
	Laser	1	1			
	Damage automatic machine	3				3
Grinding	Table griding machine	10	10	10	10	10
Effect	Sponging	4				4
	Spray	8		8	8	
	Laser marking	1	1			
			13	34	33	24
						29

Fig. 16: Worker impact threshold definition

The threshold for worker impact is therefore:

Low worker impact: 0-13

Medium impact worker: 14-29

High worker impact: +29

3.2.3.- EIM SCORE CALCULATION AND PROCESS CLASSIFICATION

According to threshold the category score is transformed through an algorithm into a common scale that goes from 0-100 being the first third (0 to 33) the low impact section, the second third (from 33.1 to 66) medium impact and the third one (66.1 to 100) the high impact one. The EIM score is the average of each 4-category score for denim finishing processes. Worker impact category does not account on the EIM score of garments dyeing or garment wash processes since dry steps are not relevant in most common processes of his two types of processes.

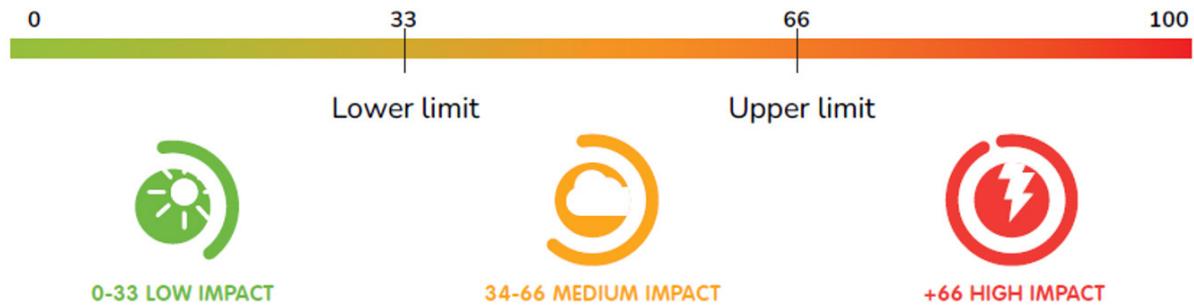
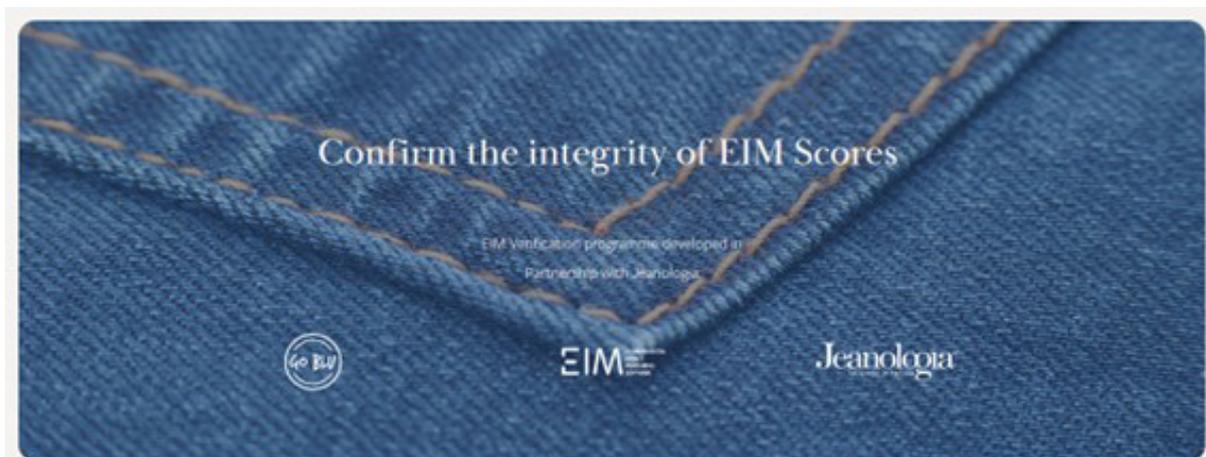


Fig.17 EIM score classification scale.

4 - EIM DATA ANALYSIS RESULTS

Since its launch in 2011 near 1 million processes from more than 500 users are included in the EIM global database. It is important to mention that a process in EIM refers to the process applied to a specific garment style therefor in the EIM language, process are the equivalent to garment styles. Over the years, EIM has included changes for more precise impact calculation, however the EIM V2.0 included as well relevant upgrades in the measuring criteria. In July 2023 the EIM V2.0 completely replaced the previous versions after one year of transition. The current report does consider data collected and processes through EIM V2.0. Still a good sample size to identify challenges and opportunities as well as defining a good data supported starting point to track yearly progress.

EIM is founded under self-evaluation tool principles, therefore we shall expect to manage trustful information. In addition to the foundation principles and to ensure the integrity of the data given to the system two complementary initiatives are under implementation. The first one is aimed to ensure that every EIM users understand the software in the same way. Users need to undergo through an accreditation program to validate user understanding and capabilities to deliver correct reports. The second one, goes one step further and includes a third-party validation define by Go Blue (1), an independent company specialized in accelerating sustainable change. The 3rd party validation approach involved and audit to the manufacturer ensuring they have the right measures in place to manage information and that possibilities for them to deliver incorrect reports are unlikely possible.

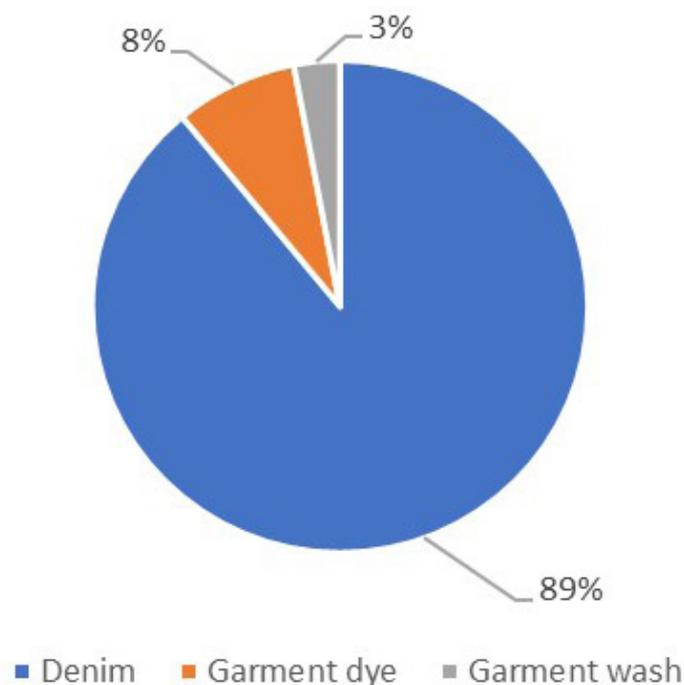


4.1.- GARMENT SEGMENT BREAKDOWN

EIM can measure any process made on any kind of garments. One of the specific upgrades of the EIM V2.0 is the introduction of specific threshold for each garment type or segment because each segment has his own characteristics and impacts might be different. 89 % of the processes measured in EIM are denim product while only, 8% are garment dyed and 3% are garment wash. We do, However, anticipate a considerable increase in processes to be compared against these new benchmarks for a broader understanding of these finishing industries to emerge, allowing us to identify trends, challenges, and opportunities for every kind of product more clearly.

Graphic 1 – Breakdown by product segment

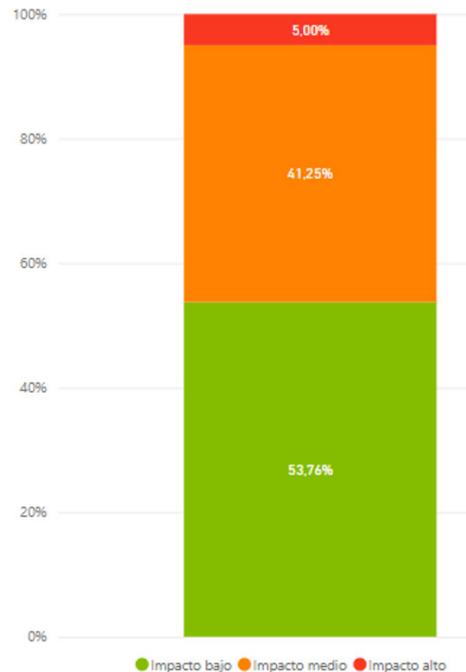
Breakdown by Product Segment



Based on the above facts, the present report will focus on EIM V2.0 Denim benchmarked processes, and so the data is bounded to processes introduced by 359 EIM users.

4.2.- DENIM PROCESSES BREAKDOWN

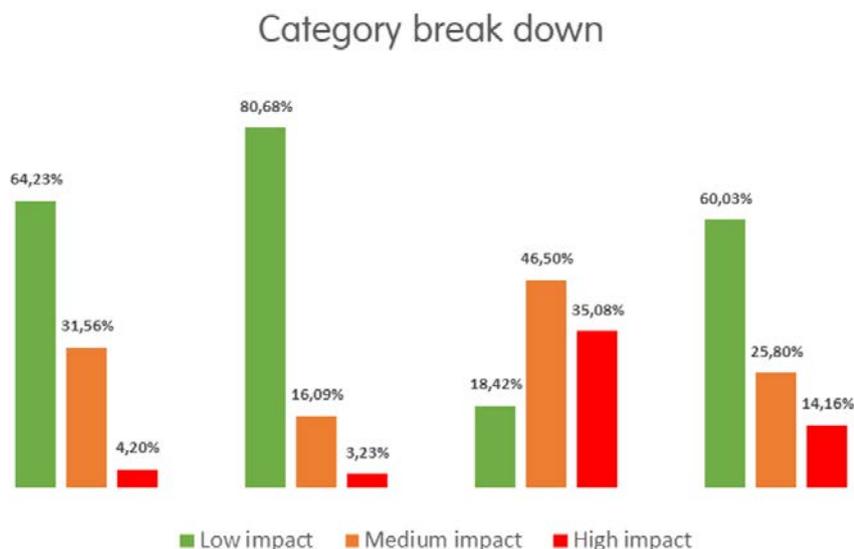
From the 82.189 denim processes measured 53,76 % are of low impact, 41.25 % of medium and only 5% of processes are consider of high impact. The data is encouraging and shows a good progress of the industry, but it also shows that there is still room for improvement. Special attention needs to be taken on the percentage of the high impact washes.



Graphic 2 – Denim processes. Breakdown by EIM score

4.3.- DENIM PROCESSES. BREAKDOWN BY CATEGORY

The individual analysis of the impact categories will help to identify those categories of impact that required more attention. This will help to address efforts and aligned industry stekholders bringing specific solutions to the major challenges.



Graphic 3 – Denim processes. Breakdown by category of impact

4.3.1- WATER & ENERGY IMPACT ANALYSIS

Water and energy industry results are pretty good showing a great breakdown in both categories. Even if we might expect an increase in energy requirements due to the consolidation and wide implementation of technologies to replace manual operations, the data evidence good progress on the implementation of measures to reduce the use of resources in denim manufacturing.

Although processes of low water and low energy impact are numerous, further optimization can be addressed through continuous improvement strategies to maximize cumulative benefits. Any of the two impact categories might not be a priority but should keep working specially to reduce the percentage of processes classified as process of high impact in water or in energy.

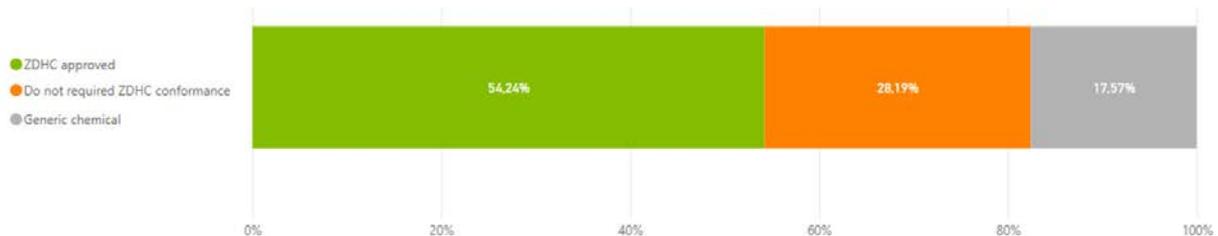
We should also expect a growth in the energy requirement due to the introduction of technologies to replace manual operation with high impact in worker health. It is important to underline that higher energy demand does not necessarily involve a growth in CO2 emission since technologies are from one side, developed to be highly efficient and from other side they can be feeded with clean energy.

4.3.2- CHEMICAL IMPACT ANALYSIS

The breakdown by category of impact, reveals that chemical and worker impact are the main cause for medium and high impact processes showing were major industry challenges are.

The chemical impact is calculated using the EIM Chemical Impact Score (CIS), which is based on the ZDHC conformance of formulations used in the finishing process and the Screen Chemistry Score. Besides the chemical impact value, the EIM report also provides information on the performance of the chemicals used, according to these two specific certifications. Chemicals are categorized into four groups: formulations with a ZDHC third-party conformance report, those with a third-party Screen Chemistry report, commodity chemicals (single CAS number), and generic chemicals that do not belong to any of the other three groups (generic chemicals). The breakdown of recipes according to ZDHC conformance or the Screen Chemistry Score offers valuable insights into the kind of chemicals being used and the progress on the implementation of these two initiatives.

Graphic 4 – Denim processes. Breakdown of chemicals according to ZDHC conformance



Graphic 5 – Denim processes. Breakdown of chemicals according to Screen Chemistry Score



Graphics 4 and 5 illustrate that nearly 30% of the chemicals used in denim finishing processes are commodity chemicals. EIM V2.0 highlights the need for increased transparency in jeans production by assigning the worst possible EIM Chemical Impact Score (CIS) of 100 to generic chemicals. The fact that 17% of the chemical formulations used are of unknown conformance presents significant opportunities for improvement. We encourage EIM users to utilize only formulations listed in EIM to enhance overall scores and improve the chemical category breakdown.

55% of the chemicals used comply with the ZDHC conformance program, indicating substantial progress in program implementation. However, the Screen Chemistry score program has a low implementation rate, with less than 25% of chemicals achieving the score. Next year's data analysis will provide insights into the implementation trends, allowing us to quantify the growth of the programs from one year to the next.

Referring to the EIM chemical database and its scoring criteria, EIM V2.0 penalizes the use of stones due to environmental concerns by assigning the worst possible chemical impact score to processes that utilize them. Notably, 21% of processes involve the use of stones. This highlights a significant challenge for the industry to address.

4.3.3- WORKER IMPACT ANALYSIS

The worker impact is related to manual operations. The industrialization of artisanal techniques leads to repetitive operations. The automation and digitalization of those operations will help to reduce impact on this indicating improving opportunities. Focusing on the 14% of processes of high impact and going further into the analysis reveals that potassium permanganate is still used in 12% of the processes. Data confirms the trend towards the replacement of this technique but also shows that there is still quite a lot to do and pointing at the second biggest challenges of the denim industry for the coming year.

Just as a curious data, 5% of the measures process mix both, the use of pumice stones and the pp blasting technique.

4.4.- DENIM PROCESSES. AVERAGE DATA

Having industry references would allow monitor yearly progress of an industry determine to lead an industrial transformation. Current averages clearly shows where denim industry is with regards to sus-tainability and where it is necessary to act.

Fig.18 EIM average scores



5 - DATA ANALYSIS CONCLUSIONS.

The Environmental Impact Measurement (EIM) tool is instrumental in tracking progress in the garment finishing manufacturing stage, a resource-intensive area. Since its launch, EIM has evolved, with the latest version, EIM V2.0, primarily focusing on denim finishing. However, there is an anticipated growth in measuring garment dyeing and washing processes due to the tool's versatility and the industry's drive for continuous improvement.

Denim finishing impact distribution shows that 53,76% of denim processes are low impact, 41,25% are medium impact, and 5% are high impact. This indicates significant progress but also highlights areas for further improvement, particularly in reducing medium and high-impact processes.

For a garment weighing 0.5 kg, the average water consumption is 24 liters, energy consumption is 1,08 kWh, the chemical impact score is 60, and the worker impact score is 21. These metrics provide a baseline for tracking yearly progress.

There has been notable progress in reducing water and energy use. However, continuous improvement is necessary to further lower high-impact processes.

Chemical and worker impact need special attention. Reasons for the poor performance in this impact categories are due to the use of stones and / or the use of potassium permanganate through manual spray systems. Replacement of both pumice stones and potassium permanganate will led to a EIM score improvement.

6 - MEASURES TO REDUCE EIM SCORE.

Improving EIM scores to reduce environmental impact can be approached from various angles, including fabric selection, process optimization, and chemical selection. The following chapters compile different measures aimed at this goal. For easier understanding, we have grouped the solutions according to the improvement of specific impact categories considered in EIM. However, as we will see, each measure can also affect multiple impact categories.

6.1- WATER IMPACT

One of the biggest environmental challenges in jeans manufacturing is the use of water. While there is no official data on the average water requirement to finish a pair of jeans, brand research estimates that it ranges between 45 and 70 liters per garment. Recent studies defining the EIM benchmark set this average at 45 liters per garment, based on an average garment weight of 0.5 kg. Growing awareness of water industry issues has motivated brands to set water consumption reduction targets. Denim stakeholders have developed and implemented solutions to achieve these targets. The industry's efforts have resulted in significant water reductions, establishing a new benchmark of only 28 liters of water per finished denim garment, according to EIM data considered in this report.

Various measures can significantly reduce water usage. Numerous initiatives have already been implemented to reduce water consumption in denim finishing processes. Some of these measures are detailed below. While implementing any of these measures individually is beneficial, the greatest reductions are achieved by combining several of them.

6.1.1.- PROCESS OPTIMIZATION:

In the garment finishing process, rinsing is one of the most frequently repeated steps. Rinsing is necessary to eliminate chemicals and other residues. Traditionally, rinsing has been done with increased liquor, based on the belief that more water is more effective and requires less time. However, it has been proven that more effective rinsing can be achieved with lower amounts of water, even though more rinsing steps may be required.

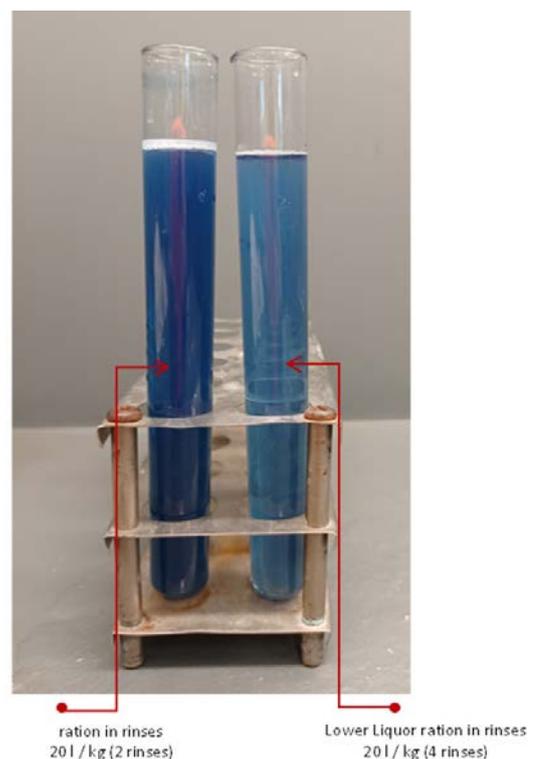


Figure 19. Rinsing effectiveness according to the LR.

6.1.2.- FABRIC SELECTION:

A good selection of fabrics, according to the final look required contribute to lower resources requirement by requiring less intense washing to reach the same appearance. For a garment finisher its raw material is a sewn garment, making the fabric an uncontrollable variable. Fabric reactions to different washing steps and processes can vary greatly based on fabric characteristics and previous manufacturing steps. Predicting fabric behavior in finishing processes without prior deep analysis is challenging, if not impossible. Despite these difficulties, fabric producers are striving to deliver fabrics that perform better and require fewer intensive processes to achieve the desired look and performance. Examples of commercial products that can lead to process optimization through fabric selection include “Crystal Clear” denim from Artistic Milliners (2) (Pakistan), “Flash Finishing Denim” from Cone Denim(3) (North America), and “Horizon” from Navina(4) (Pakistan). These fabrics combine the latest denim dyeing technologies with sustainable fabric finishing using Jeanologia G2 Dynamic. Better fabric preparation translates into a better EIM score during the garment finishing stage because less intense washing is required to achieve the same level of abrasion and wash down.

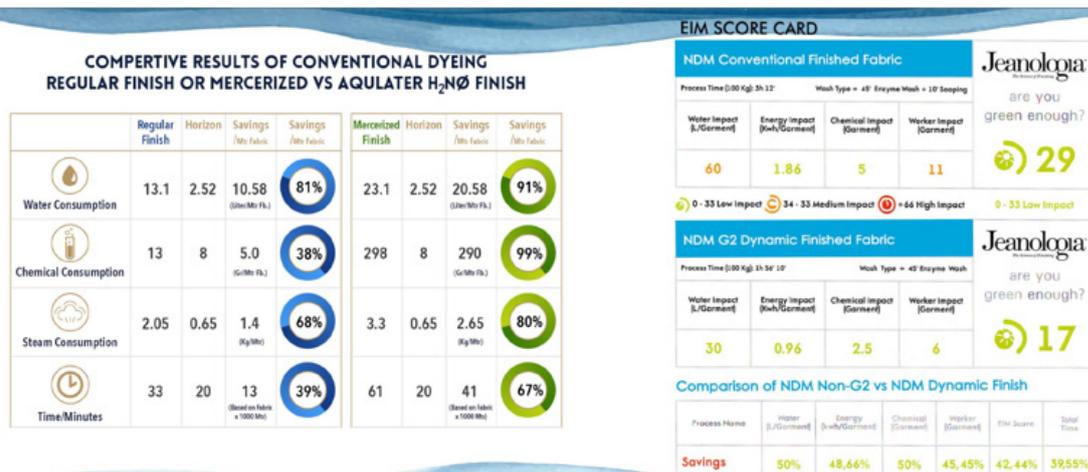


Fig.20. Example of effect on EIM score of the fabric selection

6.1.3.- CHEMICAL SELECTION

Chemical suppliers play a crucial role in designing formulations that combine multiple processes, thereby reducing the number of finishing steps and significantly lowering water requirements. Notable examples include Lava® Cell NEF from DyStar (5), Kemzyme Ultra from Kemin (6), or Geopower DS from CHT (7), which enable desizing and abrasion in a single step, saving up to 50% of water in the washing cycle

Recent advancements have resulted in the creation of enzyme treatments that can be applied without the need for water. Various commercial alternatives are available.

6.1.4.- UPDATE OF WASHING EQUIPMENT:

Different washing machines require specific washing conditions. Machine characteristics can limit the reduction of the liquor ratio (liters of water required per kilogram of garments washed). Horizontal loading machines are traditionally more water-demanding, requiring liquor ratios above 1:10 for a proper wash. In contrast, front-loading machines are usually more efficient, partly because they integrate more advanced software to manage the equipment. To optimize the process through liquor ratio in denim finishing, Jeanologia has developed Dancing Box technology, which allows the reduction of the liquor ratio down to 1:3. The characteristics of this technology and the kinetics of the garment movement inside the machine help generate higher mechanical action, also reducing processing times.

Liquor Ratio

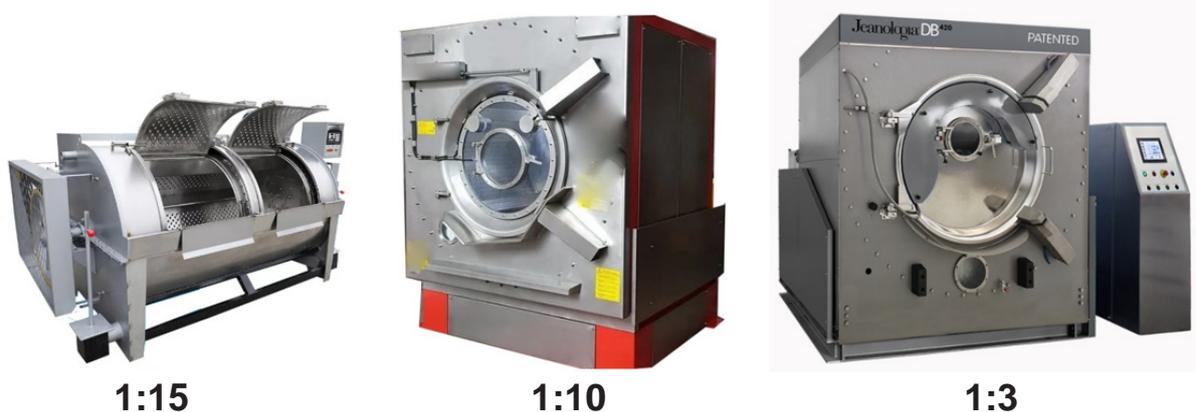


Fig.21. Washing machines and its working liquor ratio

6.1.5.- INTRODUCTION OF TECHNOLOGIES AND PROCESS RE-ENGINEERING.

Technologies like e-flow and ozone have significantly enhanced water reduction in laundry processes. For instance, preozonic treatments can substantially decrease water usage by replacing traditional desizing operations with advanced ozone treatments. This shift transforms a wet process into a dry one, where garments are processed in a Jeanologia G2 ozone smart box.



Fig.22
Jeanologia
Pre-Ozonic
process

The combination of micronization or nebulization techniques with specially developed chemicals can also result in significant water reductions. There are numerous alternatives available for various washing purposes.



To achieve the same goal of transferring chemicals to textiles using carriers other than water, Kemin has developed a smart foam system. Combined with specific chemicals, the company claims this system can reduce the liquor ratio to 1:1 or 1:2 in processes such as stone washing, bleaching, dyeing, and softening

6.2- REDUCING ENERGY IMPACT

Greenhouse gas emissions in denim garment finishing are a priority focus for reducing the environmental impact of textile production. The decarbonization of textile production aligns with industry sustainability goals and reflects a commitment to addressing environmental challenges. Energy requirements in the finishing process can come from various sources, such as the energy to run machines, heat water to optimal process temperatures, or dry garments. The EIM energy benchmark shows that 80% of washes are of low impact. However, these good results should not slow down the development of solutions to further reduce impact, using this year's average (2 kWh/garment) as a reference.

6.2.1.- WATER REDUCTION:

The highest energy demand in denim finishing processes is related to water and air heating. Therefore, measures to reduce water consumption will directly impact energy requirements. Consequently, all previous measures to reduce water will also positively impact energy use. For example, reducing the liquor ratio from 1:10 to 1:4 using the Jeanologia Dancing Box washing machine can reduce heating energy by 40%.

6.2.2.- CHEMICAL SELECTION

A significant contribution to the decarbonization of the garment finishing industry can occur through the reformulation of chemicals to be effective at lower temperatures. There are several good examples of this. Major chemical suppliers have developed versions of their enzymes for abrasion processes that are as effective at room temperature as they are at the typical enzyme working temperature of 60°C, reducing energy requirements by up to 20% in the enzyme bath.

6.2.3.- DRYING OPTIMIZATION

Tumbler dryers are the main equipment used for garment drying. Despite optimization and efficiency improvements, the drying process remains quite inefficient. Some garment producers, such as Saitex (confirmation needed from Saitex for inclusion in the report), have developed smart drying solutions that reduce drying energy requirements by almost 100%. By hanging the garments on a specially designed carousel, inspired by sewing goods transportation systems, garments are air-dried.



Fig.24: Carrusel for air drying ((<https://kingpinsshow.com/denim-talks-episode-3-time-for-a-reset-a-conversation-with-saitexs-sanjeev-bahl/>))

6.2.4.- DRYING TECHNOLOGIES

Research into technologies such as infrared, microwave, or ultrasound is ongoing; however, there are no commercially available alternatives using these heating sources yet. The Italian company Mactec has developed an automatic loading drying conveyor that, according to the company, can reduce steam requirements by one-third.



Fig.25: Mactec, Secomatic drying technology

6.3- REDUCING CHEMICAL IMPACT

According to EIM chemical classification and calculation criteria less than 30% of processes are of low chemical impact and about the same percentage shown processes of high impact. To understand the reason of the lower performance of the finishing processes, it is necessary to look at the chemical breakdown according to the ZDHC conformance, that as mentioned in previous sections of the report show clear directions to improve the chemical impact score and therefore reduce the EIM score.

6.3.1.- CHEMICAL SELECTION:

The 12% of generic chemicals shows great opportunity for improvement. The minimum requirement for a formulation to be listed in EIM is to have a valid 3rd party ZDHC conformance report. Selecting generic chemicals when generating an EIM means that the used chemical is not available in EIM, probably because it does not fulfill with minimum these requirements. Only replacing generic formulations for those listed in EIM chemical impact breakdown will improve showing higher percentage of medium and low chemical impact processes.

Chemicals with “red” EIM CIS is going to have a great impact in the chemical impact score and in consequence in the final EIM score. Find alternative to those chemical and only use preferred (green EIM CIS) or good to use (orange EIM CIS) chemicals will for sure have a positive impact reducing scores.

6.3.2.- REPLACING PUMICE STONES:

After the ethical band on sand blasting, replacement of pumice stones and potassium permanganate, are according the EIM measuring criteria, the two major areas for the denim finishing to address. There are multiple alternatives to replace stone wash among with we can find.

6.3.2.1.- SYNTHETIC STONES & OTHER ABRASIVES:

Synthetic stones are an alternative to traditional pumice stones. These stones are typically made from materials like silicate, plastic, rubber, or even recycled materials. Some key points about benefits of this alternative are related to and longer durability, no generation of sludge and allowing the reduction since less rinses are required. HMS (handmade stones) is of the available commercial alternatives.



Fig.26: HMS synthetic stones

Gruppo Itexa (xx) offer additional solutions aimed to generated mechanical abrasion during wet pro-cessing. Their JECOSTONE® system can cover the drum of any washing machine in-creasing the mechanical action produce by the impact of the garments again the drum during the washing processes.

6.3.2.2.- CHEMICAL ALTERNATIVES:

In addition to cellulase enzymes, chemical suppliers are offering specific chemical formulations that do not require the use of stones to achieve the stone wash effect. There are different product brands available for this purpose. Below

The Organ IQ Biopower (CHT) is a good example of that in combination with its application in spray or micronization systems such as e-Flow, does not only replace the stones, but also helps to reduce water and energy.

6.3.2.3.- OZONE TECHNOLOGIES:

Ozone has been proven a great technology to reduce water in denim finishing processes. Ozone can be used in its gas form or dissolved in water. Ozone gas is more effective and a better alternative to manage risk in production ensuring ozone concentration control and batch to batch reproducibility. Ozone gas can be applied on dry or wet garments having higher indigo oxidation power when the garments are wet. The use of ozone to clean backstaining of denim as replacement of bleach is well known and widely implemented, however to mimic the effect of stones it is necessary to combine ozone gas in dry garments in a humid atmosphere. The Atmos process, developed by Jeanologia is an air wash able to mimic ozone effects allowing replacement of stones impact considerably in water and energy reduction.



Fig.27: Atmos process as replacement of pumice stones

6.4.- REDUCING WORKER IMPACT:

According to the data, worker impact is another area that needs special attention. High worker impact processes are too high in comparison with the rest of the category mainly due to techniques such as potassium permanganate spray still too present. In addition to the complete elimination of PP blasting, the automatization of manual operation is necessary to reduce impact of this category of impact.

6.4.1- REPLACING POTASSIUM PERMANGANATE BLASTING

Potassium permanganate is a strong oxidizer classified as a hazardous substance by the European Chemicals Agency. Potassium permanganate (PP) is commonly used in the denim industry for local bleaching. However, its use poses significant health and environmental risks, making it essential to reconsider its application in denim production.

There are several reports highlighting the health risks associated with this product and the application technique which had help to rise awareness and bring viable alternatives to replace its use. Here below some of these alternatives:

6.4.1.1.- OZONE CLEANING

One reason for using potassium permanganate is to enhance and whiten areas that have been locally decolorized, allowing for further color reduction in specific parts of the garment. This need often arises because these areas become contaminated when indigo bleeds into the water during the washing process. Ozone is highly effective at removing backstained colors, and utilizing ozone technologies solely for cleaning can often eliminate the need for additional bleaching. Additionally, providing fabrics that bleed less during washing can reduce backstaining, ultimately leading to better results.

6.4.1.2- LASER TECHNOLOGY.

The use of laser for denim manufacture has been a great revolution. Specifically build solution such as the light PP from Jeanologia is a great replacement to enhance previously abraded area. PP blasting can be used in both pre-lasered garments or garments manually sand blasted. In both cases, it can be a great alternative to replace PP blasting and therefore reducing the EIM score considerably.

6.4.1.3.- ALTERNATIVE CHEMICALS.

Around 2015 some pioneer chemical suppliers such as Garmon – Kemin or CHT, launched alternative product to replace potassium permanganate. Today there are multiple available alternatives. Each of the alternative have their own characteristics and each of them are suitable to replace potassium permanganate.

6.4.2- DIGITALIZATION OF MANUAL TECHNIQUES

One of the more is the manual scraping. Industry digitalization has numerous environmental benefits. Replacing manual scraping, one of the more hazardous operations done in the garment finishing process is a great achievement. Replacing this operation by laser technology the worker impact is considerably reduced.



Fig.28: Manual local abrasion

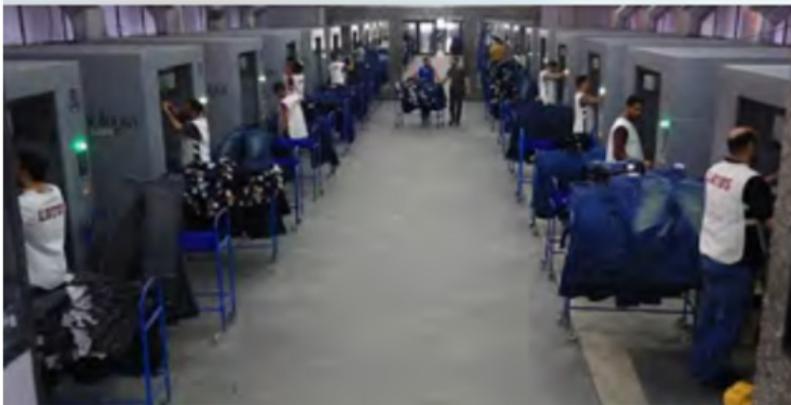


Fig 29: Digital local abrasion

6.4.3- AUTOMATIZATION OF MANUAL TECHNIQUES

The integration of automatic tools to replicate manual processes in the denim industry is crucial for several reasons, particularly in reducing worker health issues. The adoption of automatic tools fosters a safer working environment and helps to reduce impact according to EIM.

Each manual operation requires specific equipment. The Teca machine developed by Mactec that automatically crinkled pant top to imitate crinkles produced during the use of the garments is a good illustration of a machine with a purpose.



Fig.30: Teca (Mactec).

7. CONCLUSIONS

This document explores the challenges and opportunities within the denim industry, particularly focusing on the environmental impact of jeans production. It employs the Environmental Impact Measurement (EIM) tool to evaluate progress in reducing water, energy, and chemical impacts.

The EIM tool is essential for monitoring advancements in garment finishing, emphasizing the reduction of water and energy consumption, motivating for a chemical selection ensuring all chemicals used are in conformance with MRSL as well as motivating for minimizing worker risk in manual operations. Progress has been achieved, with more than 50% of denim processes now classified as low impact. However, there remains considerable scope for improvement, especially in minimizing medium and high-impact processes.

Notably, the average water usage per garment has been reduced to 24 liters, down from the previous 45-70 liters. This reduction has been accomplished through various measures, including waterless enzymatic treatments, technologies like e-flow and ozone, and chemical micronization or nebulization.

While 80% of washes now have a low energy impact, the high energy demand in denim finishing, primarily due to heating water and air, remains a challenge. Reducing water usage also positively affects energy consumption. Reformulating chemicals to be effective at lower temperatures can significantly aid in decarbonization. Additionally, new drying technologies present an opportunity to achieve EIM Denim V2.0 standards and further progress towards decarbonization.

The use of stones in finishing processes has a high chemical impact, which the industry must address. Data indicates a need for improved chemical management and adherence to ZDHC (Zero Discharge of Hazardous Chemicals) guidelines. The use of potassium permanganate is an urgent issue that the industry needs to resolve. With multiple alternatives available, actions must be taken to eliminate this technique entirely.

Continuous improvement and innovation are crucial to achieving sustainability goals and reducing the overall environmental footprint of denim manufacturing. These conclusions underscore the denim industry's ongoing efforts to tackle environmental challenges and highlight the importance of continuous innovation and improvement.

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