Cost-Benefit Analysis of Green Chemistry

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DEUTSCHE ZUSAMMENARBEIT

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On behalf of the
German Federal Ministry for Economic Cooperation and Development (BMZ)

Table of contents

Executive Summary

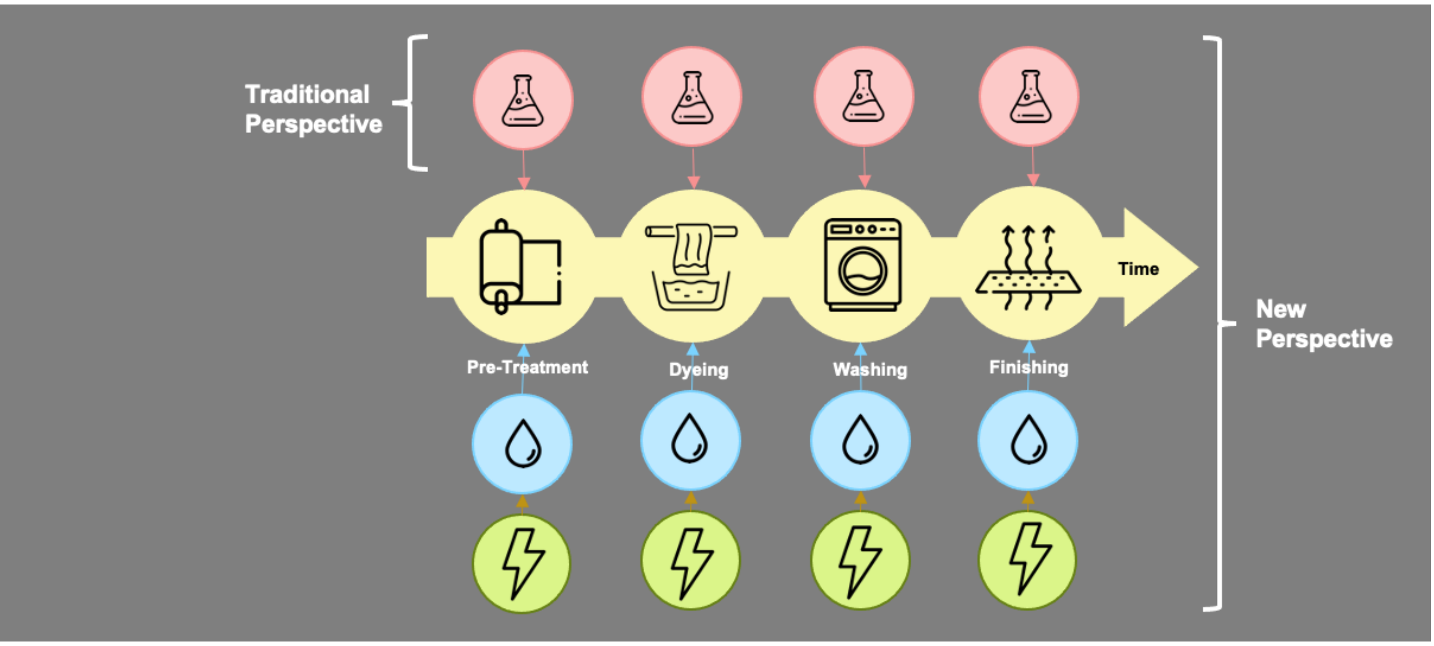
BACKGROUND:

There is a common perception that using greener chemistry is more costly than using conventional chemistry. The reason for this hurdle, could be because only the price of the chemicals are compared, kg vs. kg. This analysis study is to identify and develop clear guidance on how process costs are calculated, while revealing the advantages of considering sustainability as an integrated approach. This study was commissioned by GIZ and carried out by GoBlu International Limited and BluWin Limited.

- **GoBlu** is known for their acclaimed digital chemical management platform, The BHive.
- **BluWin** is a leading integrated service provider to the textile, leather, apparel and footwear industries.

TRADITIONAL VS. NEW PERSPECTIVE

Traditionally, when comparing the cost of greener chemistry, only the cost of chemicals per KG is considered. The new perspective takes into consideration; the amount of chemicals needed or reduced; the number of washers(water) needed or reduced; the amount of energy needed or reduced; and the overall amount of time needed or reduced (although time as a cost is not calculated in this study). The idea of this study is to provide a fuller picture of what the switch to using greener chemistry costs.



New perspective takes into consideration of all process costs, rather than just the cost of the chemistry kg vs. kg.

HYPOTHESIS

The hypothesis of this project is that the use of greener chemicals impacts the use of environmental resources such as water and energy and improves working conditions. Savings from resources used are expected to provide an **economical incentive** and improve uptake of greener chemistry.

METHODOLOGY

As the aim of the project is to serve as inspiration for higher adoption in greener chemistry, the project was designed to be relatable to a wider audience. The study took place in multiple countries/regions and covered different types of textiles, fibres, including cotton, polyester, or blends, and forms including yarn, knit, woven, and processes including washing/dyeing and printing stages.

At each facility, the research team conducted two consecutive trials: one using the 'original' conventional chemistry and another using an 'adapted' recipe employing greener chemistry. The research team measured every type of resource used during each trial and calculated the economic differences.

SCOPE

Facility Covered Per Country	Textile Covered	Fibre	Chemistry Covered
4 X Bangladesh 3 X India 2 X Pakistan 2 X Sri Lanka (1 offsite)	Knit Woven Garment/ Denim	Cotton Polyester Cotton/ Poly blend	Pre-Treatment Chemicals Dyeing Chemicals Finishing Chemicals

Countries Covered (Bangladesh, India, Pakistan, Sri Lanka)

CASE STUDIES

While 11 studies were carried out, the following section will highlight 3 specific case studies as a part of the executive summary. These highlighted facilities are primarily chosen based on the process focus and the textile type covered. For the full 11 reports, please refer to the next section.

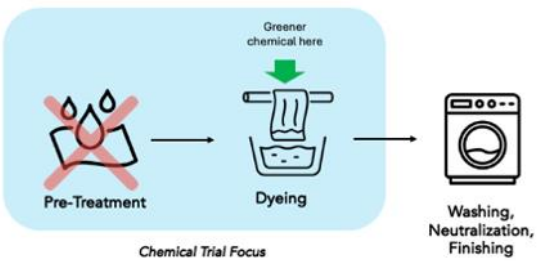
EX. SUMMARY CASE STUDY 1

(Case Study 1 is also Case Study F in the Full Case Study Section)

This case study was held at a Dyeing and Printing Mill, located in Bangladesh. The facility is a dyeing and printing mill. The textile that is focused in this study is polyester cotton, knit fabric. The wet process focus

Strategy: The strategy behind this study was to select a dye that eliminates the need for separate scouring and washing steps prior to dyeing—processes typically used to enhance fastness—while still achieving equal or better fastness results.

Greener Chemistry: In this study, the following greener auxiliaries were used; Seracon PNR (Mild oxidising agent), by DyStar and Sera con SFC (Anticreasing Agent), by DyStar. Greener dyes that were used were Dianix XF2 range of disperse dyes, DyStar.



The illustration above highlights how the chemical trial implemented greener chemistry in the dyeing process. By adopting this approach, it eliminates the need for traditional pre-treatments such as scouring and washing, which were previously required in the original recipe before dyeing.

Results: The following are process savings based on an average of 40,000kgs produced per year:

S#	Savings by optimising process modification	Standard process	Greener chemistry process	savings %	Annual Savings	Units
1	Water (In m^3)	4600	3200	30%	1400	m^3/40000 kgs
2	Steam (In Tons)	521	357	31%	164	Tons/40000 kgs
3	Power (electricity) (In MWh)	105	74	30%	31	MWh /40000 kgs
4	Time (in hours)	965	705	27%	260	Hours /40000 kgs
5	GHG (In tCO_{2e})	346	238	-31%	108	tCO_{2e}/40000 kgs
6	Total Chemicals cost	8580000	7920000	8%	660000	BDT/ 40000 kgs
					5593	Euro/40000 kgs
7	**Total Costs**	**14850000**	**12320000**	**17%**	**2,530,000**	**BDT/40000 kgs**
					21,441	**Euro/40000 kgs**

Summary: This study highlights the significant benefits of adopting a greener chemistry approach in an industrial process. By selecting greener dye and chemical products, specifically the Dianix XF2 range by DyStar, the study achieved a 17% total cost saving. This approach not only reduced environmental impact through lower greenhouse gas (GHG) emissions but also cut down on operational costs.

The Dianix XF2 dyes enabled the elimination of several process steps, such as scouring, hot washing, and acid washing, which were traditionally necessary at the beginning of the dyeing process. By addressing these needs in a single step, the dyeing and reduction clearing processes could be completed in one bath, streamlining the entire operation. This efficiency not only contributed to cost savings but also demonstrated the effectiveness of using environmentally friendly products in industrial settings.

EX. SUMMARY CASE STUDY 2

(Case Study 2 is also Case Study B in the Full Case Study Section)

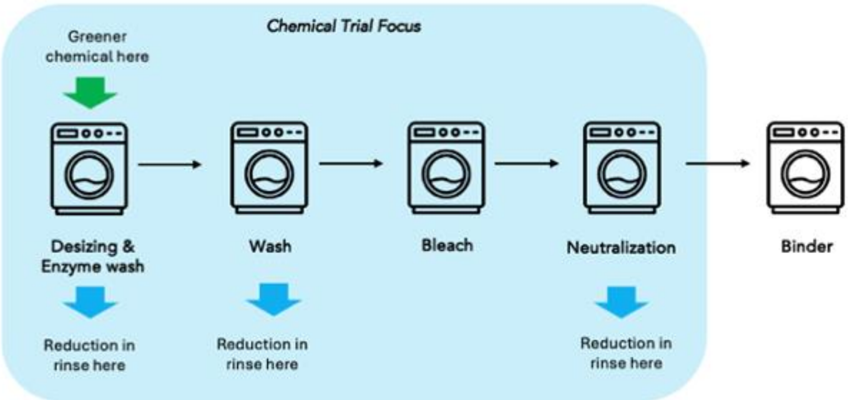
This case study was held at a Garment Washing Facility, located in Bangladesh. The facility is a garment washing and dyeing mill. The textile that is focused in this study is woven denim. The process focuses are in the pre-wash methods; desizing and enzyme washing.

Strategy: In this study, Altranol DSZL was chosen to modify the conventional process into a greener one due to its multifunctional properties. Altranol DSZL serves both as a wetting agent and a pH controller, allowing for the combination of traditionally separate steps into a single, streamlined process. Specifically, the desizing and enzyme application processes, which are typically carried out separately in conventional methods, can be merged into one step.

This integration not only simplifies the process but also reduces the need for rinsing during the cleaning stage after enzyme application and eliminates the rinsing stage after neutralization. By minimizing these steps, the use of water and other resources is significantly reduced, contributing to both environmental sustainability and operational efficiency.

Greener Chemistry: Altranol DSZL and Altranol-DSZ by LN chemicals were used as greener alternatives for this study.

Dyeing team



The illustration above demonstrates the impact of switching to greener chemicals during the desizing and enzyme wash stage. This change results in significant water reduction not only during the desizing and enzyme wash stage itself but also in the subsequent washing and neutralization stages.

Results: The following are process savings based on an average of 3000 kgs produced per year:

S#	Savings by optimising process modification	Standard process	Greener chemistry process	Savings (3000 kg)	savings %	Units
1	Water (In m^3)	264	204	60	23%	m^3/3000 kg
2	Steam (In Tons)	24.05	14.16	10	41%	Tons/3000 kg
3	Power (electricity) (In MWh)	3.55	3.37	0.2	5%	MWh /3000 kg
4	Time (in hours)	485	382.22	103	21%	Hours / 3000 kg
5	GHG (In tCO_{2e})	15.99	10.15	6	37%	tCO_{2e}/3000 kg
6	Total Chemicals cost	127600	116600	11000	9%	BDT/ 3000 kg
7	**Total Costs**	**401500**	**299200**	**102,300**	**25%**	**BDT/ 3000 kg**
				867		**Euro/3000 kg**

Summary: By using Altranol DSZL, the study achieved a total cost saving of 25% (excluding the cost of time). This significant saving was made possible by incorporating greener, bio-based multifunctional chemicals with desizing properties, which eliminated the need for a neutralization process. As a result, the Total Dissolved Solids (TDS) in the effluent were directly reduced, contributing to a more environmentally friendly process.

Additionally, the use of Altranol DSZL led to fewer wash-offs, reduced process time, and decreased the need for additional chemicals. The shortened process time not only improved efficiency but also directly reduced power consumption and greenhouse gas (GHG) emissions, further enhancing the environmental benefits of this greener chemistry approach.

EX. SUMMARY CASE STUDY 3

(Case Study 3 is also Case Study C in the Full Case Study Section)

This case study was held at a Garment Washing Facility, located in Pakistan. The facility is a knitted and woven fabric dyeing and garment manufacturing facility. The textile that is focused in this study is poly/cotton woven fabric. The process focus in this study is the fabric dyeing stage, specifically using the Pad-Dry-Pad-Steam Dyeing system (It is a continuous dyeing process, for cotton woven fabric, and generally suggested for dyeing long meters of fabric).

Strategy: The study focuses on replacing reactive dyestuffs with pigments, specifically using "Pigmentura" by CHT. This pigment was chosen for its unique binder that mimics the appearance and texture of reactive dyes.

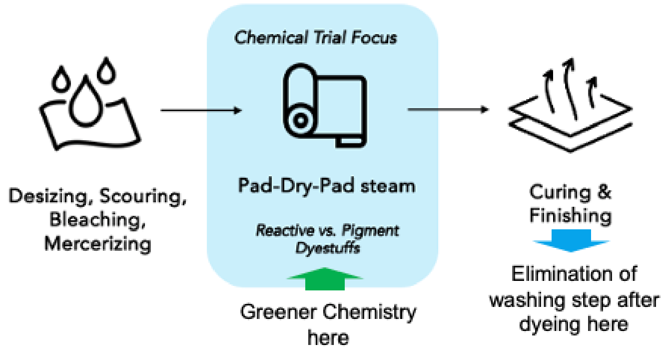
Comparison of Dyeing Methods:

- **Conventional:** Reactive Dyeing (Thermosol Method): This method typically requires significant water usage for washing and steaming to fix the dye, involving multiple wash-offs that extend processing time.
- **Greener Pigment Dyeing using 'Pigmentura':** In contrast, pigment dyeing using Pigmentura uses less water and requires fewer wash-offs, resulting in reduced water consumption and shorter processing time.

The strategy aims to enhance sustainability in textile dyeing by cutting down on water usage and processing time, while preserving the desired quality of the dyed fabric.

Greener Chemistry: The greener chemicals used in this study uses Pigmentura chemicals, by CHT and Bezaprint colours by CHT.

The illustration on the right shows the key difference in processing steps; eliminating the washing step after dyeing.



The illustration on the left shows the chemical trial focus. By switching out the dyes used in the Pad-Dry-Pad Steam process, the washing step after dyeing can be

Results: The following are process savings based on an average of 100,000 kgs produced per year:

S#	Savings by optimising process modification	Standard process	Greener chemistry process	savings %	Annual Savings	Units
1	Water (In m^3)	2844.22	1255.81	56%	1588.41	m^3/Year
2	Steam (In Tons)	855.31	481.32	44%	373.99	Tons/Year
3	Power (electricity) (In MWh)	23.68	22.62	4%	1.06	MWh /Year
4	Time (in hours)	115.75	104.58	10%	11.17	MWh /Year
5	GHG (In tCO_{2e})	577.7	353.84	39%	223.86	tCO2e/year
6	Total Chemicals cost	2,601,870	1,945,000	25%	656,870	PKR/ year
					2,212	Euro/year
7	**Total Costs**	**11,398,122**	**7,253,447**	**36%**	**4,144,675**	**PKR/year**
					13,690	**EUR/ year**

The Green chemistry approach has led to significant savings across all key performance indicators (KPIs), including water usage, electrical energy, greenhouse gas emissions (GHG), processing time, chemical costs, and overall costs.

Notably, there was a 36% reduction in total processing costs. These savings were achieved by replacing reactive dyestuffs with pigment dyestuffs, specifically from the Pigmentura (binder range) and Bezaprint range.

This switch allowed the Pad-dry-pad steam process to use less water and steam energy while maintaining the same fastness properties as the traditional reactive dyeing method.

Challenge: The only noted challenge from this study is the slight harsher hand feel. To solve this, softeners may be opted to overcome the comparative hand feel.

SUMMARY OF STUDY

In this project, wet processing trials were conducted at 11 different facilities, revealing a range of outcomes. The results varied, with savings ranging from 11% to 56%, while one case showed a negative result.

Specifically, in case 'H', savings were not realized due to the high up-front cost of chemicals.

The study, as outlined in the table, demonstrates that each case is unique and influenced by various factors. However, it also highlights numerous opportunities to adopt greener chemistry.

Country	Facility	Material	Knit/Wov/Gar	Pre-Treatment	Dyeing	Finishing	Summary on Alternative	Savings in total Process Cost
BD	A	Poly Cotton	Knit Fabric		x		Better Dyes = Less washoff required as result	17%
BD	B	Denim	Garment Woven	x			Better Desizing = Reduce rinse steps in several stages	25%
PK	C	Cotton	Woven		x		Replacement of Reactive Dyes with Pigment Dyes during Pad, Dry Steam, saving resources	36%
BD	D	Cotton	Knit Fabric	x			Enzyme based Pre-Treatment for Wetting, to increase productivity	56%
BD	E	Cotton	Knit Fabric	x	x		Multifunctional Chemical, less rinsing required	48%
SL	F	Denim	Garment Woven	x			Better wetting agent, multifunctional, low foaming, lower temperature, emulsifying properties.	14%
IN	G	Cotton	Knit Fabric			x	More effective Wash-off agents = reduce water fills & drains	35%
PK	H	Poly Cotton	Knit Fabric		x		Better Dyes= Less wash off as result	-27%
IN	I	Cotton	Yarn Dyeing	x			Better wetting agent, requires less steam & dye	27%
IN	J	Poly Cotton	Knit Fabric			x	More effective wash-off agents= reduce water fills & drains	11%
SL (Desktop)	K	Denim	Garment Woven			x	PP alternative, requiring less time, water fills & drains	37%

KEY LEARNINGS

This study illustrates the numerous ways that switching to greener chemicals can lead to savings. In some cases, like Case Study 3, the benefits are immediate and directly observed in the dyeing process. In other instances, such as Case Studies 1 and 2, the benefits are indirect, resulting from reduced wash-offs or the elimination of steps before or after due to the multifunctional properties of these smarter, greener chemicals. Beyond the cases highlighted, other factors that may influence the results include inlet water quality, whether wastewater is treated onsite or offsite, the ability to purchase chemicals at bulk prices, and various other "one-off" factors.

When transitioning to greener chemicals, it is advisable to collaborate with the chemical providers that the facility is already partnered with. Engaging these existing suppliers can help in sourcing products tailored to the specific processing setup of the facility, ensuring that the savings align with the facility's unique operational needs.

Overall, the integration of greener chemistry into operations is a promising component of a comprehensive sustainability strategy. It not only supports environmental goals but also offers the potential for significant economic gains.

DIRECT BENEFITS

There are sometimes Direct benefits in the processing step the chemicals are used in, where the savings were immediately seen in the dyeing process.

INDIRECT BENEFITS

There are sometimes in-direct benefits where lesser wash-offs, or where before, or after steps are reduced/ eliminated due to multifunctional properties of these smarter, greener chemicals.

Full Case Studies

The following section details case studies listed A – K.

CASE STUDY A

A.1 Profile

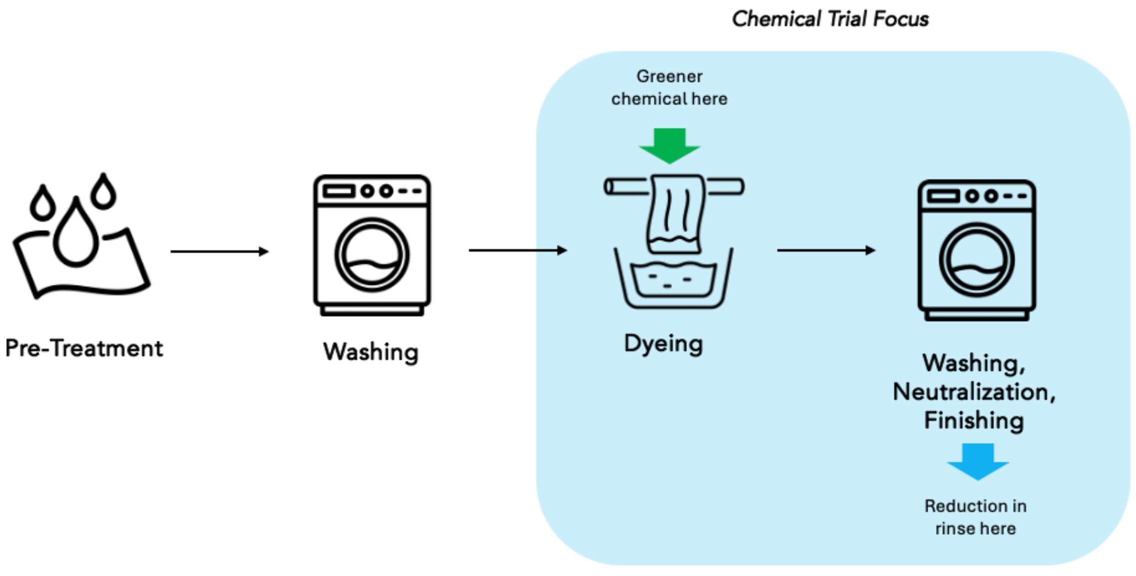
Case Study	A
Product Range	Knitted fabric dyeing & Garment manufacturing facility
Processes	Knitted dyeing, printing & Garments
Machinery	100% open width & Tubular Knitted fabric processing machines

A.2 Introduction

For the processing trial at this mill, the chemicals used for polyester-cotton knitted fabric dyeing were compared.

The idea is to use better dye selection that has the advantage in easier wash off properties while provide excellent fastness.

More information on how these advantages can potentially create savings in resources can be found in the hypothesis section.



	Conventional Process		Greener Alternative Process	
Process	Polyester- Cotton blend for knitted fabric		Polyester-Cotton blend for knitted fabric	
Auxiliaries	Chemical	Manufacturer	Chemical	Manufacturer
	Sera Gal PSDS (Polyester levelling)	DyStar	Sera Gal PSDS (Polyester levelling)	DyStar
	Laucol SRD	Croda	Seracon PNR (Mild oxidising agent)	DyStar
	Dekol ACA	Huntsman	SFC (Anticreasing agent)	Archoma
	Albatex AB-45 (Buffer)	Huntsman	Albatex AB-45 (Buffer)	Huntsman
	Samneu CAN (Acetic acid)	Samuda	Samneu CAN (Acetic acid)	Samuda
	Sera con SFC- Anticreasing	DyStar	Sera con SFC- Anticreasing	DyStar
Dyeing	Coralene range of dyes	Colourtex	Dianix XF2 range of disperse dyes	DyStar
Wash off	Sera fast CRD -wash off	DyStar	Sera fast CRD -wash off	DyStar

To carry out this assessment, the following processing steps will be evaluated these parameters: 1) Water, 2) Steam, 3) Power, 4) Time in hours, 5) GHG, 6)Costs.

A.3 Hypothesis

The conventional process for polyester/cotton blend fabric involves several steps. It begins with scouring and washing to improve absorbency, followed by disperse dyeing for the polyester part of the fabric. This is then followed by acid reduction clearing to remove unfixed dye and enhance fastness properties. The cotton part of the fabric undergoes enzymatic pretreatment before being dyed with reactive dyes. Finally, the process ends with washing and soaping.

In the greener process, pre-treatment, disperse dyeing, and reduction clearing are combined into one bath. This is followed by reactive dyeing, then washing and soaping.

The one bath pre-treatment, disperse dyeing and reduction clearing process is possible due to the selection of Dianix XF2 range of dyes. Due to the washing off properties of XF2 range, we can expect to achieve excellent fastness properties.

It is anticipated to see a reduction in a few hot washing baths while still achieving the same fastness properties using the greener process.

Note: The XF2 range of disperse dyes is a specific classification within the broader category of disperse dyes. It is known for its vibrant colours and stability under high temperatures (130°C to 140°C). The range offers excellent wet fastness to washing, light, and rubbing, ensuring long-lasting colour performance. It is highly suitable for dyeing synthetic fibres such as polyester and polyester/elastane blends and has good compatibility for Right-First-Time dyeing of ternary shades. Manufacturers include BASF, Dystar, and Huntsman.

A.4 Process Evaluation

For the conventional trial, the team followed conventional process of dyeing and measured the time and resources it took according to the current recipe. For the greener chemistry trial, the team modified the process by conducting one bath pre-treatment, disperse dyeing and reduction clearing by using Dianix XF2 range of dyes.

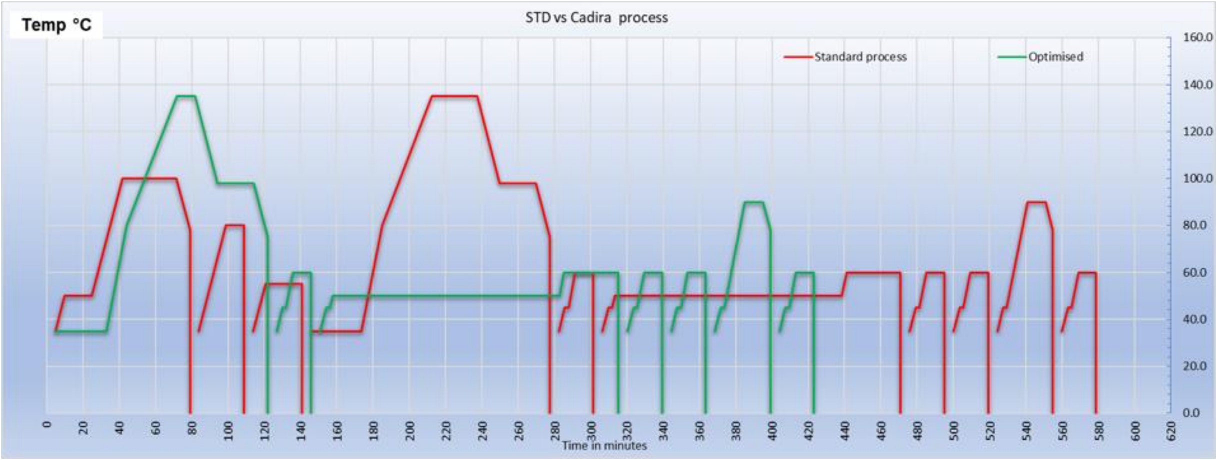
Conventional method: The process of polyester dyeing involves scouring for removal of the spin finishes and for cotton bleaching to get a brighter shade. The polyester part of fabric dyeing time during the conventional process was at 135°C,and ran for more than 30 minutes. This can be seen in the taller and wide red coloured peaked line (circled in purple) in the graph below.

Greener method: The Greener process uses the Dianix XF2 range dyes which enables the one bath pre-treatment, dyeing and acid reduction clearing process.

In the diagram below, the green curve shows the greener method, where there is no additional step of scouring and draining the bath followed by washing steps, because they all are combined in one bath. Another important point to note in greener process is less time of holding at high temperature for dyeing compared to the conventional process. This is possible through assessing the dyeability of the polyester fabric.

The whole process involves less water and steam energy use to achieve the desired fastness properties compared to conventional process.

Conventional Vs Green Alternative Processing flow for Polyester-Cotton dyeing:



The diagram shows the comparison between conventional process vs. the Greener Alternative for polyester-Cotton knit dyeing. The diagram is commonly known as a Time-Temperature diagram or a TT diagram where time is plotted on the X-axis and Temperature is plotted on the Y-axis.

The plot in red colour shows the conventional pre-treatment practice observed by the BluWin experts and the green colour lines show the recipe of the green alternative process.

As shown in the graph, the Green process takes less time, ending at 420 minutes, whereas the conventional process takes more time, ending at 580 minutes. Since the green process eliminates the additional hot washes after pre-treatments the amount of steam consumption is reduced, which required for these washes.

Dyeing machines

Instruments used for trial data collection

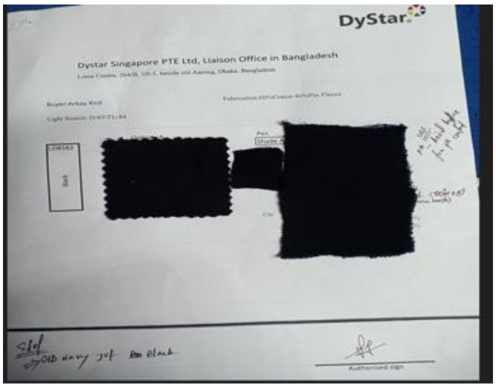
Collecting data from monitor

Thermometer use in machine to get accurate temperature during running of the machine.

Dyes use from DyStar.

Weighing of the chemicals

Measuring amphere of the dyeing machine.

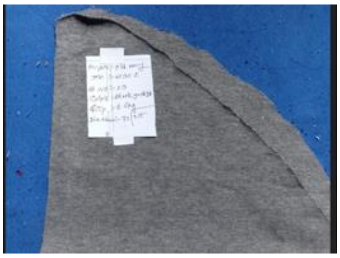


Original sample swatch card for shade match

pH paper use for measuring pH before dyeing of polyester part.

Discussion with team members during dyeing .

Checking soft water quality



Picture of fabric after polyester part dyeing

Final shade of the polyester/cotton fabric

A.5 Results

The greener process, where Sera Gal PSDS , Seracon PNR (mild oxidising agent), and DIANIX XF2 range of dyes were used, followed by the use of Sera fast CRD (for wash off); reduced the overall time and steam consumption of the production and achieved excellent fastness properties.

Additional note: The greener process is also called as Cadira® process ands as further support, mill can use the tools from DyStar to further optimise the dyeing process such as OPTIDYE® which is an Optimization program introduced by DyStar for dyeing recipes and processes to shorten dyeing cycle, reduce effluent load to improve right first time and to achieve improved quality of finished article.

The following are process savings based on an average of 40,000[1] kgs produced per year.

S #	Savings by optimising process modification	Standard process	Greener chemistry process	savings %	Annual Savings	Units
1	Water (In m^3)	4600	3200	30%	1400	m^3/40000 kgs

[1] This figure is considered keeping the average order size of this recipe which was taken only for one order in a year.
If we can increase the lots the volume of production will also increase but the % savings will remain constant.

2	Steam (In Tons)	521	357	31%	164	Tons/40000 kgs
3	Power (electricity) (In MWh)	105	74	30%	31	MWh /40000 kgs
4	Time (in hours)	965	705	27%	260	Hours /40000 kgs
5	GHG (In tCO_{2e})	346	238	31%	108	tCO_{2e}/40000 kgs
6	Total Chemicals cost	8580000	7920000	8%	660000	BDT/ 40000 kgs
					5593	Euro/40000 kgs
7	Total Costs	14850000	12320000	17%	2530000	BDT/40000 kgs
					21441	Euro/40000 kgs

A.6 Conclusion

The Green chemistry choice has shown the effective savings in all KPIs including Water consumption, electrical energy, reduction in GHG, processing time, chemical cost and total cost. The overall processing cost had savings up to 17% while comparing conventional process against greener dyeing method, when using greener chemistry.

Challenges and way forward.

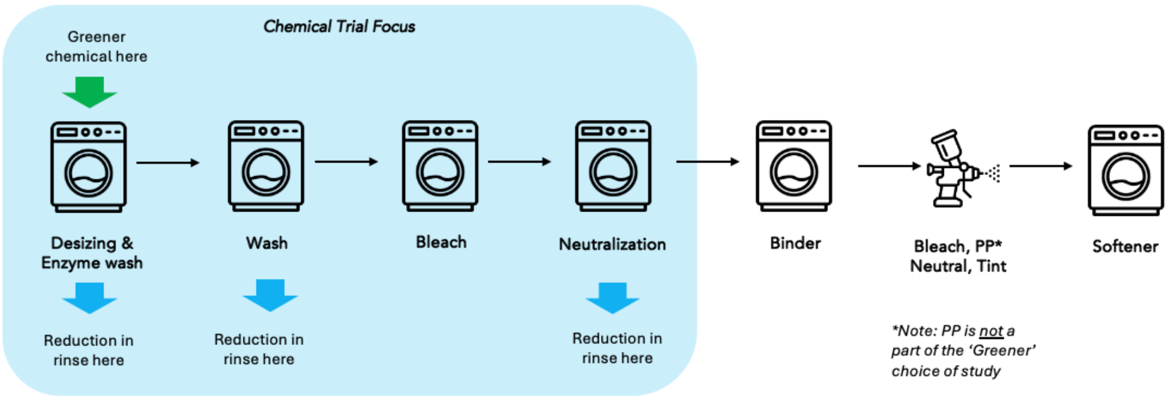
There were no challenges found while implementing this process, as the prices of the products are easily comparable. The mill can work with the lower liquor ratio machines, which can further reduce the manufacturing cost.

CASE STUDY B

B.1 Profile

Case Study	B
Product Range	Garment washing and dyeing
Processes	Garment washing
Machinery	Garment washing front loading machines and belly washers

B.2 Introduction



This processing trial takes place in a Garment Washing facility. The product being worked on are denim pants. The process that takes place here are the washing and finishing steps; they are done to achieve the desired design and look – in this case it is 'acid washing'.

Specifically, the comparison between two pre-wash methods are compared during the Desizing and cleaning stages.

> ***Technical Terms in this section***
>
> **What is Desizing?**
>
> Desizing is the process of removing the size material from warp yarns after a textile fabric is woven. Size coatings are typically applied to reduce fraction properties, decrease yarn breakage in loom and improve weaving productivity. However, sizing materials can prevent the efficacy of finishing and dyeing, therefore Desizing is needed to remove the size.

Important Note:
Please note, this trial will include the use of PP (Potassium Permanganate), as it is a part of the full list of processing steps. PP is harmful for worker's health (long term exposure can damage the liver and kidneys), but the substitution of PP is not a part of this study. This study focuses only on comparing the pre-wash chemicals, not the PP stage. No 'greener' alternative is suggested to replace PP here.

	Conventional		**Greener Alternative**	
Process	Desizing		Desizing	
	Chemical Name	***Manufacturer***	***Chemical Name***	***Manufacturer***
Chemicals	Anti slipping Agent AP New	S& D Chemical Associates	Altranol-DSZL	LN chemicals (sample)

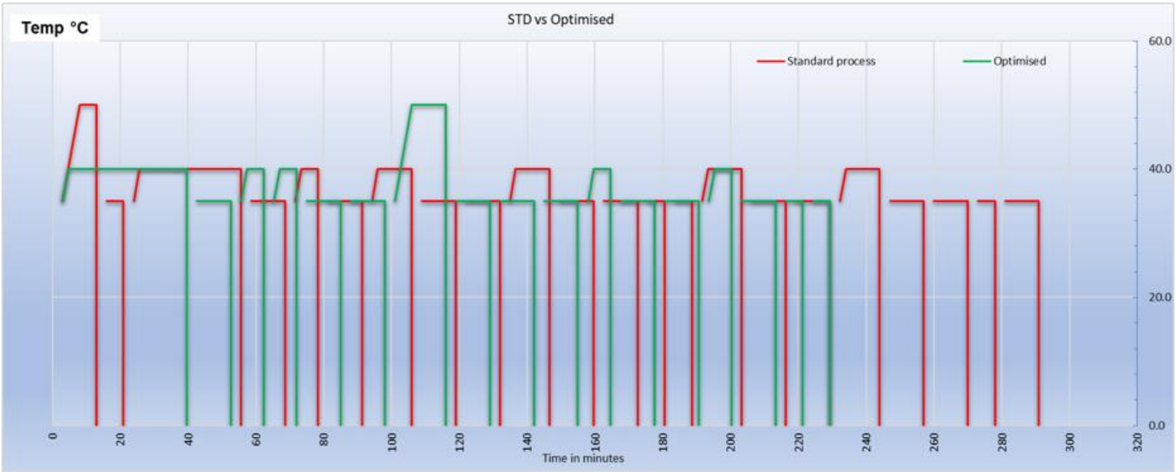
	ABS X-7	Garmon		
	Dyex DPH	Local Supplier		
	Setenzyme GAN	Garmon		
	ONURWET PWD 100	Local supplier	Altranol-DSZ	LN chemicals (sample)

To carry out this assessment, the following processing steps will be evaluated these parameters: 1) Water, 2) Steam, 3) Power, 4) Time in hours, 5) GHG, 6)Costs.

Processing Steps:

1. desizing washing	2. Bleaching
3. PP spray	4. neutralising

Process flow:
Comparative process for denim processing using pretreatment with caustic and wetting agent based de-sizing Vs Enzymes based de-sizing substitutes.



The diagram shows the comparison between the standard de-sizing and pre-treatment program for denim garments using enzyme washing in conventional process vs. the Greener Alternative for de-sizing and bleaching program. The diagram is commonly known as a Time-Temperature diagram or a TT diagram where time is plotted on the X-axis and Temperature is plotted on the Y-axis.

The plot in red colour shows the conventional de-sizing and pre-treatment program observed by the BluWin experts and the green colour lines show the recipe of the green alternative process using combined pre-treatment and de-sizing chemical.

B.3 Hypothesis

Altranol-DSZL is chosen to modify the conventional process into a more greener one for several reasons:

- Firstly, Altranol-DSZL is a multifunctional chemical, with combined functions of wetting, and pH controller.

- Secondly, by using Altranol-DSZL, the processes of Desizing and adding enzyme can be combined as one step, rather than having them separated (as the conventional method).
- Furthermore, the need for further rinsing during the cleaning stage after enzyme, and rinsing stage after neutralization can be reduced or eliminated.

Overall, this study expects a vast reduction in time, and reduction in number of fills and drains for rinses needed, therefore saving overall resources needed and costs.

Challenge: There were no challenges faced in this substitution.

B.4 Process Evaluation

Conventional washing process involving pre-treatment Process.

The conventional process used the wetting agent, lubrication agent for crease free garments and anti back staining agent as pre-treatment chemicals. The garments usually undergo multiple enzyme stone washes before taken for bleaching or fading processes.

> ***Technical Terms in this section***
>
> **Anti-Back Staining Agent:** This is a chemical used in the textile industry to prevent back staining during washing or dyeing. Back staining occurs when dye from a fabric transfers onto other parts of the same garment or onto other fabrics. Anti-back staining agents inhibit this dye transfer, keeping colours consistent.

Greener pre-treatment Process.

The greener chemical uses Altranol-DSZL which combine the pre-treatment and enzyme process. Due to this, the process has significantly reduced the water consumption as well as energy consumption.

This chemical is multifunctional in nature which combines functions of wetting agents, de-sizing agents and anti crease agents in garment processing.

Dyeing Team

Front loading garment Dyeing & washing machines

trial data collection

Measuring the data

Quality inspection after trial

Technical discussion

B.5 Results

As anticipated, when pre-treatment was carried out using Altranol-DSZL (greener alternative), a reduction in water consumption, and energy consumption were seen during the wash off cycles.

The Total Dissolved Solids (TDS) was also lower in the water discharge, since this chemical doesn’t require additional neutralisation step, which imparts the TDS in Effluent.

Overall, the alternative process saved significant amount of water, chemicals and GHG emissions.

The following are process savings based on an average of 3,000[2] kgs of similar style and process followed for the garments with similar process route.

S #	Savings by optimising process modification	Standard process	Greener chemistry process	Savings (3000 kg)	savings %	Units
1	Water (In m^3)	264	204	60	23%	m^3/3000 kg
2	Steam (In Tons)	24.05	14.16	10	41%	Tons/3000 kg
3	Power (electricity) (In MWh)	3.55	3.37	0.2	5%	MWh /3000 kg
4	Time (in hours)	485	382.22	103	21%	Hours / 3000 kg
5	GHG (In tCO_{2e})	15.99	10.15	6	37%	tCO_{2e}/3000 kg
6	Total Chemicals Cost	127600	116600	11000	9%	BDT/ 3000 kg
				93		Euro/3000 kg
7	**Total Costs**	**401500**	**299200**	**102300**	**25%**	**BDT/ 3000 kg**
				867		**Euro/3000 kg**

B.6 Conclusion

For this trail, savings were made in the areas of water, electrical energy, reduction in GHG, processing time and overall processing cost when comparing conventional vs. acid washing. This processing method is 25% cheaper when using greener chemistry.

Using greener multifunctional chemical with bio based de-sizing properties, removes the need of neutralisation process, which directly reduces TDS at the effluent. and also results in lesser wash-offs, reduced time and lesser additional chemical consumptions. The reduced time is a direct contributor to lesser power consumption and reduced GHG loads.

[2] This figure is considered keeping the average order size of similar recipe (for similar style) which was taken from one order, which normally represents the 30% of their process in a year, while the volume of processing may vary.
If we can increase the lots the volume of production will also increase but the % savings will remain constant.

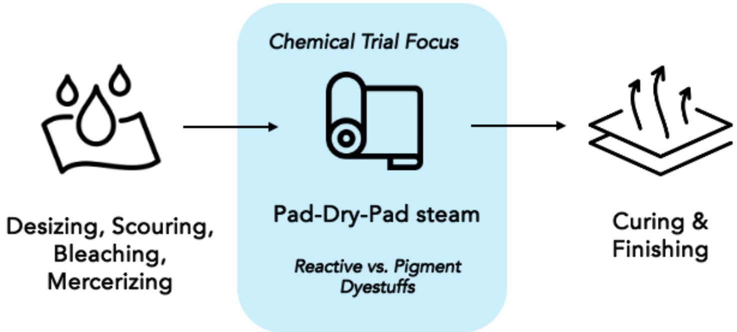
CASE STUDY C

C.1 Profile

Case Study	C
Product Range	Knitted & Woven fabric dyeing & Garment manufacturing facility
Processes	Knitted & Woven fabric dyeing, printing & Garments
Machinery	Knitted & Woven fabric processing machines,

C.2 Introduction

For the processing trial at this mill, the comparison conventional process for woven fabric, using Pad dry pad steam were compared. The conventional method uses **reactive dye stuffs**, and the greener alternative uses **pigment dyestuffs** offered by CHT, called PIGMENTURA.



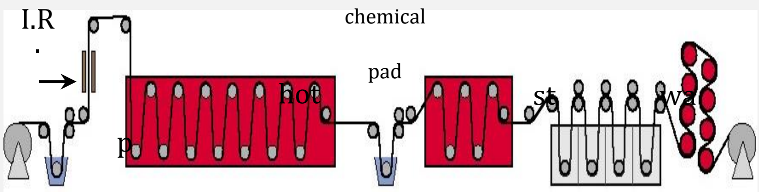
Technical terms in this section

What is Pad-Dry-Pad-Steam? The Pad-Dry-Pad-Steam process is the standard process in steam dyeing. It is a continuous dyeing process, for cotton woven fabric, and generally suggested for dyeing long meters of fabric.

In this process the dyes are padded first and intermittently dried by infrared dry section, followed by chemical padding , passed through steaming section where the dye stuff get fixed with the temperature as well with humidity with time.

Prior the Pad-Dry-Pad-Steam process, it is required for the fabric to be de-sized, scoured, bleached, and mercerized first. Then it is ready for padding the dyes and chemicals, to pass through this machine for the dyeing process.

Pad - Dry - Pad - Steam

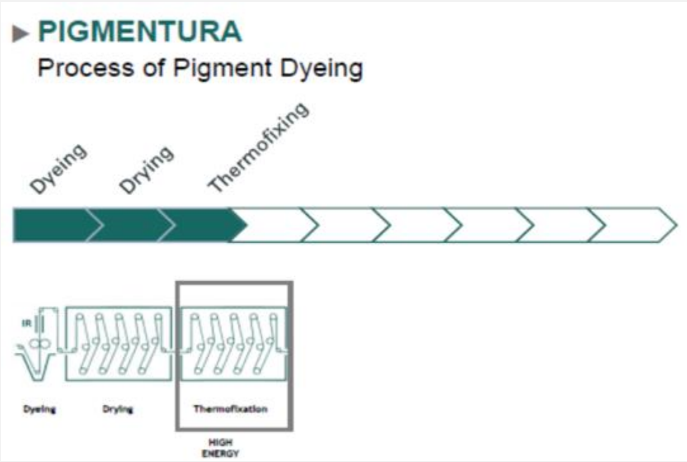


What are reactive dyes (conventional)?
Reactive dye is the dye class that can react with fibre like cotton or viscose (cellulosic) to form a covalent link, that is forming a permanent attachment in the fibre and be stable towards treatment with boiling water under neutral conditions.

What are pigment dyes?
Pigment dyes are insoluble, ground pigments that only coat the outside layer of fibres instead of absorbing into them. *Pigment dyes* require the use of a resin or a treatment such as emulsion or dispersion to properly adhere to fibres; however, once this is done, *pigment dyes* are able to attach to a wide variety of fabrics.

What is Pigmentura (greener alternative)?
PIGMENTURA by CHT is a novelty, pigment based dyeing approach. It claims to be a fast and easy to implement and requires no water for soaping and rinsing. It also claims to outperform older methods of pigment dyeing by achieving darker shades and increased colour fastness and smoother hand feel, therefore overcoming the traditional disadvantages of conventional pigment dyeing.

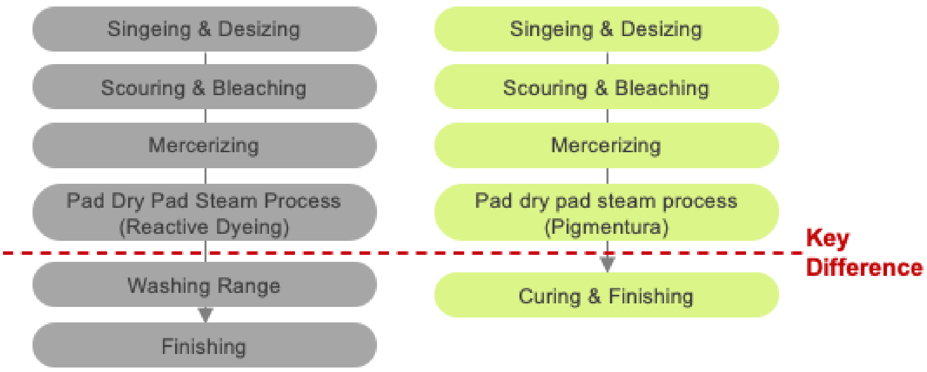
PIGMENTURA can be used on all substrates but is particularly suitable for cotton and cotton blends. Staple yarns are recommended to be used whenever possible for best possible results.



	Conventional		Greener Alternative	
Process				
	Chemical Name	Manufacturer	Chemical Name	Manufacturer
Chemicals	NOVACRON BROWN NC-	Huntsman	Pigmentura 1500 and 2000 systems	CHT
	NOVACRON OLIVE NC	Huntsman	BezaPrint Blue CCL	CHT
	PRODER M A.C. NUEVO	Bozzetto Group	BezaPrint Red CCG	CHT
	SYNOZOL GREY K-RF	Kisco	BezaPrint Yellow CCO	CHT

To carry out this assessment, the following processing steps will be evaluated these parameters: 1) Water, 2) Steam, 3) Power, 4) Time in hours, 5) GHG, 6) Costs.

Pad Dry Pad Steam using Reactive dyeing (Conventional) Vs Pigmentura (Greener Alternative) Processing Steps:



C.3 Hypothesis

The conventional method, which is reactive dyeing, uses the thermosol method; typically uses a lot of water to wash off and steam to fix. The method, utilizes pad dry pad steam for dyeing cotton and polyester-cotton blends. It involves padding the fabric with reactive dyes followed by drying with infra-red energy in a stenter. Subsequently, the fabric undergoes padding with alkali, steaming, and washing in washing ranges.

Alternatively, the greener method looks to the use of pigments dyeing, which requires less water to dye, and also less wash offs, therefore reducing the amount of water needed and time required. For this trial, the technology of 'Pigmentura' by CHT was selected since it has a unique characteristic binder, that replicates the look from reactive shades. The process is also expected to require the use of less water and steam energy, while achieving the same fastnesses properties as the conventional 'reactive dyeing' method.

Solution: The facility can apply silicone softeners in stenter to overcome the handle modifications, which can give better handle comparable to reactive dyeing.

C.4 Process Evaluation

During the trial, the team followed current dyeing process and measured the time and resources it took according to the current recipe and compared the values with Pigmentura process.

Bleaching range

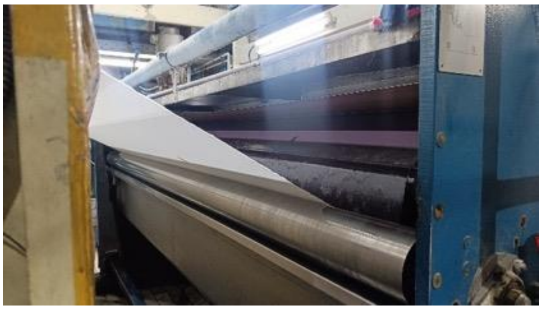
Mercerization

Pad Steam machine

Thermosol dyeing

Dyeing Team

Pigmentura parameter



Padding the dyes

Stenters

Power measurement

Stenter

C.5 Results

When comparing the conventional reactive dyeing process to the greener, pigment dye process using CHT's Pigmentura technology, the results show a reduction in water consumption, steam usage, energy usage and reduction in GHG emissions.

During finishing the mill has options to use softener, which can enhance the hand feel.

The following are process savings based on an average of 100000[3] meters produced per year.

S #	Savings by optimising process modification	Standard process	Greener chemistry process	savings %	Annual Savings	Units
1	Water (In m^3)	2844.22	1255.81	56%	1588.41	m^3/Year
2	Steam (In Tons)	855.31	481.32	44%	373.99	Tons/Year

[3] This figure is considered keeping the average order size of this recipe which was taken only for one order in a year.
If we can increase the lots the volume of production will also increase but the % savings will remain constant.

3	Power (electricity) (In MWh)	23.68	22.62	4%	1.06	MWh /Year
4	Time (in hours)	115.75	104.58	10%	11.17	MWh /Year
5	GHG (In tCO_{2e})	577.7	353.84	39%	223.86	tCO2e/year
6	Total Chemicals cost	2601870	1945000	25%	656870	PKR/ year
					2212	Euro/year
7	**Total Costs**	**11398122**	**7253447**	**36%**	**4144675**	**PKR/year**
					13870	**Euro/year**

- The costing is applicable only for the dyeing process / Pigmentura process, as mill has not shared the other costs.

** The cost includes the chemical cost for dyeing and total water for all the process.

C.6 Conclusion

The Green chemistry choice has shown the effective savings in all KPIs like, Water, electrical energy, reduction in GHG, processing time, chemical cost and total cost. The overall processing cost had savings 36% while comparing conventional process against greener dyeing method, when using greener chemistry.

Challenges and way forward

The hand feel of the greener dyed articles may be slightly harsher compared to conventionally dyed articles. To improve the hand feel, additional steps such as applying softeners during finishing might be required. Not all pigments are suitable for the Pigmentura process, so preliminary tests are required. CHT recommends suitable pigments that have been tested for suitability in advance. Other than the slightly harsher hand feel, no significant challenges were encountered with the implementation of this greener option. The prices of the products are comparable, and no other major issues were identified.

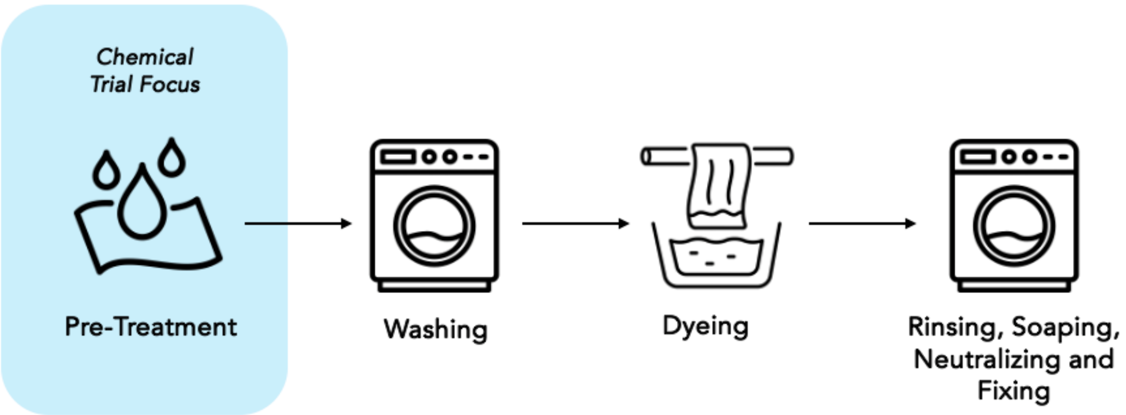
CASE STUDY D

D.1 Profile

Case Study	D
Product Range	Knitted fabric dyeing
Processes	Knitted dyeing
Machinery	100% open width & Tubular Knitted fabric processing machines.

D.2 Introduction

For the processing trial at this mill, both conventional and greener methods are compared at the ‘Pre-Treatment’ stage for cotton knit fabric. This pre-treatment stage is the step prior to reactive dyeing.



Conventional vs. Greener Process

	Conventional	Greener Alternative
Process	Pre-Treatment of Knitted fabric	Pre-Treatment of Knitted fabric
Specific Details	Wetting agent, sequestering agent, scouring and bleaching agent for Knit pre-treatment – Reactive Dyeing	Multi-functional agent (to replace conventional wetting, sequestering, and scouring agents.) for knit Pre-treatment-Reactive Dyeing
Name of Chemical	EXOVET HPJ, CEFAFLEX ENN and OPTAVON MEX – (This is a conventional wetting, scouring and sequestering agents used in pre treatment process)	Biotex NELA (This is an enzyme based pre-treatment agent for wetting)

		Biotex 50 T- peroxide killer to neutralise the residual peroxide
Chemical Company	INTEXSO BIOCHEM PVT LTD.	Biotex - Malaysia

Technical Terms from current section

- **Wetting Agent:** Wetting agents, or surfactants, reduce the surface tension of water, allowing it to spread and penetrate the fabric more easily. This ensures distribution of water and chemicals during pretreatment processes like scouring and dyeing.

- **Sequestering Agent:** Sequestering agents, or chelating agents, bind to metal ions present in water or on the fabric. These metal ions can affect processing. By binding these ions, sequestering agents prevent problems such as discolouration and fabric damage, ensuring effective treatment.

- **Scouring Agent:** Scouring agents are chemicals used to remove natural impurities, such as waxes, oils, and dirt, from the fabric. Common scouring agents include alkaline solutions (like sodium hydroxide) and surfactants. Effective scouring is crucial for achieving a clean fabric surface.

- **Bleaching Agent:** Bleaching agents, such as hydrogen peroxide or sodium hypochlorite, are used to lighten or remove the natural colour and stains from the fabric. This step helps in preparing the fabric for further dyeing processes and ensuring colour consistency.
  Each of these agents plays a role in preparing the fabric by increasing its absorption for subsequent processing stages

D.3 Hypothesis

Biotex NELA (greener multi-functional enzyme based pre-treatment chemical) and Biotex 50T (peroxide killer to eliminate the residual peroxide in the pre-treatment bath) were chosen to replace ‘conventional wetting, sequestering and scouring agents, and also to mainly facilitate the multi-functional properties such as improving fabric absorbency during pre-treatment process and enzyme based peroxide removal properties. When used together, the process typically removes the cotton impurities, requires less alkali and peroxide quantities compared to the conventional pre-treatment process.

This results in increased productivity and energy, water savings are expected.

The green chemistry process also eliminates the need for separate enzymatic biopolishing process.

Technical Terms from current section

Enzymatic biopolishing: It is a process used in textile finishing to improve the appearance and feel of fabric. During this process, cellulase enzymes are applied to the fabric to break down protruding fibres on its surface. This action removes loose fibres, reducing fuzziness and pilling, resulting in a smoother fabric. The biopolishing process improves the fabric's luster and softness and helps maintain its quality after multiple washes. It offers a sustainable alternative to traditional mechanical and chemical methods, utilizing biodegradable enzymes and milder conditions

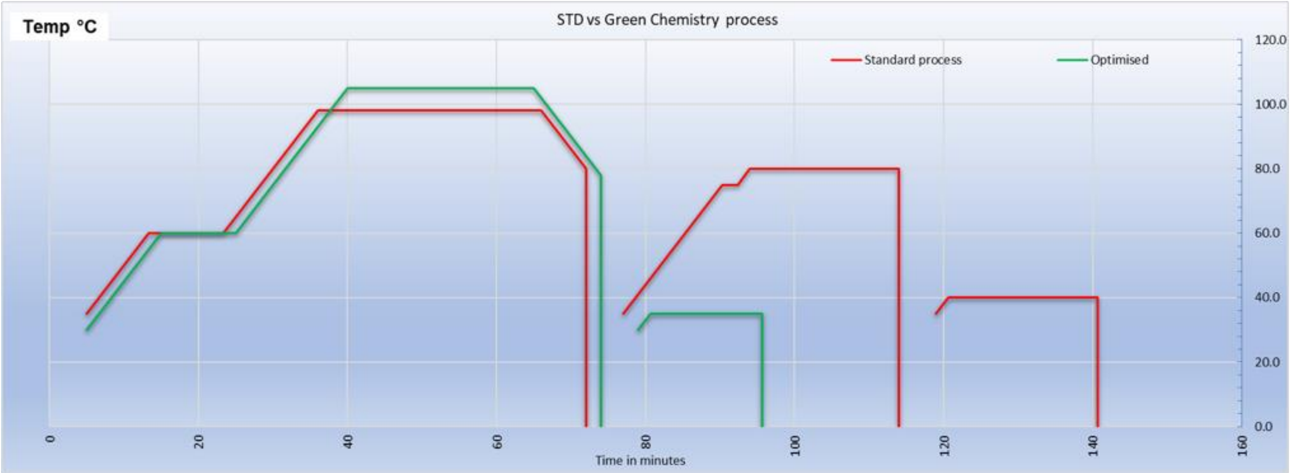
Whiteness index: In The CIE Whiteness Index, developed by the International Commission on Illumination (CIE), quantifies the perceived whiteness of a material by comparing its spectral reflectance curve to that of a perfect reflecting diffuser under standardized lighting (D65). This index, expressed in 1% -100% indicates how closely the material matches to perfect white. The higher values suggests greater whiteness. This is widely used in industries like textiles, paper and coatings industries and it guides colour quality assessment and control.

Whiteness measurement influences material perception, with lower levels appearing neutral and higher levels showing bluish tones. A perfect white sample scores 100 on this index, crucial for evaluating light reflection quality and guiding textile processing.

D.4 Process Evaluation

For both the conventional and greener processing trials, the team followed the processes of the knitted fabric, from the pre-treatment process, through the fabric dyeing stage, and the washing and finishing process. The team measured the time and resources it took according to the current recipe for the conventional trial, and the same for the adapted recipe for the green trial.

Conventional Vs Green Alternative Processing flow for pretreatment:



Name of the figure : Fig: Conventional vs. Green Alternative Processing Flow Cycle for Pretreatment

The diagram shows the comparison between conventional process vs. the Greener Alternative for pre-treatment of Knitted fabric dyeing in reactive dyeing. The diagram is commonly known as a Time-Temperature diagram or a TT diagram where time is plotted on the X-axis and Temperature is plotted on the Y-axis. The plot in red colour shows the conventional pre-treatment practice observed by the BluWin experts and the green colour lines show the recipe of the green alternative process.

As shown, the process using greener alternative uses far less time, stopping at 90 minutes, compared to the conventional process, stopping at 140 minutes. In the modified greener process. The temperature for the first part of the process is slightly higher, but the hot wash process was eliminated by a warm wash and third fill for the neutralization was eliminated by saving one fill and drain process.

D.5 Results:

When the modified pre-treatment was carried out using the greener chemical named Biotex NELA, the process reduced the water consumption along with saving in time by avoiding the heating and cooling cycle time & energy for hot wash.

The following are process savings based on an average of 40,000[4] kgs produced.

[4] This figure is considered keeping the average order size of shades requiring same type of pre-treatment with this recipe processed in a year.
If we can adopt this process in many similar shades and increase the processing lots, the volume of production will also increase but the % savings will remain constant.

S #	Savings by optimising process modification	Standard / Conventional process	Greener chemistry process	savings %	Savings (40000 kg)	Units
1	Water (In m^3)	720	480	33%	240	m^3/40000 Kgs
2	Steam (In Tons)	92	64	30%	28	Tons/40000 Kgs
3	Power (electricity) (In MWh)	21	14	33%	7	MWh /40000 Kgs
4	Time (In hours)	234	159	32%	75	Hours / 40000 Kgs
5	GHG (In tCO_{2e})	70	48	31%	22	tCO_{2e}/40000 Kgs
6	Total Chemicals cost	3300000	1210000	63%	2090000	BDT/40000 Kgs
					17712	Euro/40000 Kgs
7	**Total Costs**	**4510000**	**1980000**	**56%**	**2530000**	**BDT/40000 Kgs**
					21441	**Euro/40000 Kgs**

D.6 Conclusion

The trial was a success. When the greener chemistry, Biotex NELA was used, the pre-treatment process time and energy was reduced by eliminating one intermediate hot wash.

The resultant pH of the fabric after pre-treatment process, before intermediate hot wash, and before dyeing was close to neutral pH 7.0. The requirement of hot wash followed by peroxide killer treatment and neutralisation cycles were then combined with one anti-peroxide and neutralisation process, thus by eliminating two fill and drain cycles. This fill and drain and heating to hot water wash resulted in the reduction of production time as well as reduced steam consumption in the hot wash.

Savings were made in Water, Steam, Electrical energy, reduction in GHG, and reduction in time processing. The overall processing cost when comparing conventional vs. greener pre-treatment processing method is 56% cheaper when using greener chemistry.

Challenge:

1) **Whiteness Index Issue:** When using Biotex NELA in combination with Biotex 50-T, the whiteness index may be lower in the greener process compared to conventional methods.

2) **Technical Limitation:** Achieving the desired whiteness index is challenging with the greener product. While it is more environmentally friendly, it may not be suitable for producing pale or bright shades. It is recommended to use this pre-treatment process primarily for medium to darker shade dyeing.

CASE STUDY E

E.1 Profile

Case Study	E
Product Range	Knitted fabric dyeing
Processes	Knitted dyeing
Machinery	100% open width & Tubular Knitted fabric processing machines.

E.2 Introduction

For the processing trial at this mill, the study involves comparison of the chemicals used during the pre-treatment, dyeing and washing stages. Various chemicals such as wetting agents, enzyme, pH stabiliser, anti creasing agents, washing agents were used in the conventional method, whereas in the greener method, a multifunctional chemical is used instead of the four different chemicals.

Technical Terms from current section

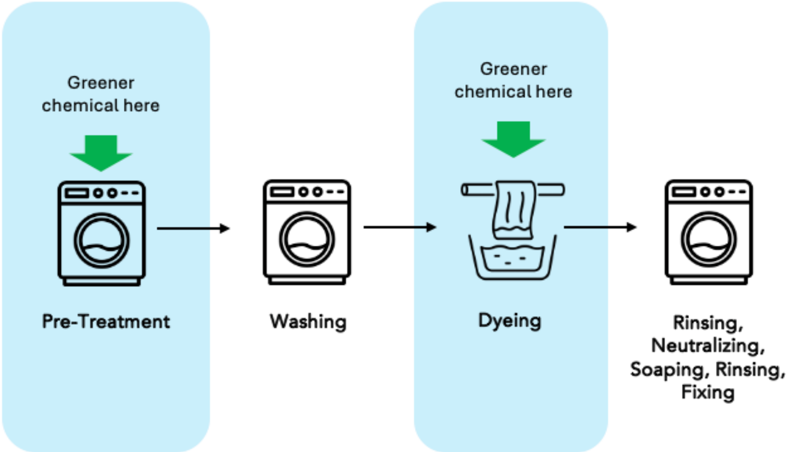
Wetting Agents: Enhance the penetration of water and chemicals into fibres, improving the efficiency of dyeing and finishing processes by reducing surface tension.

Enzymes: Facilitate the removal of impurities and improve fabric softness and appearance. They break down substances like pectin and starches, aiding in processes such as desizing and bio-polishing.

pH Stabilizers: Maintain the desired pH level during processing to ensure optimal performance of other chemicals and prevent damage to fibres and dyes.

Anti-Creasing Agents: Reduce the formation of creases and wrinkles in fabrics, improving the appearance and ease of handling during and after processing.

The reasoning is explained in the hypothesis below.



	Conventional	Greener Alternative
Process	Pre-Treatment, dyeing and washing process of knitted fabric	Pre-Treatment dyeing and washing process of Knitted fabric.
Specific Details	Various auxiliaries for Knit pre-treatment , dyeing and washing process in Reactive Dyeing	Multi-functional agent for knit Pre-treatment and washing process in Reactive Dyeing
Name of Chemical	Albaflow JET Ferol-ZUM Persoclan STN Scour-Zyme Enzyme Biozep 8000L	Ferol-ZUM Persoclan STN Black diamond
Chemical Company	BEN TECH CHEMICAL.	NC İSTANBUL KİMYEVİ ÜRÜNLER SAN. TİC. LTD.ŞTİ

E.3 Hypothesis

The reason why the greener process 'Black Diamond' was selected for this case, is because of its multifunctional properties. Black Diamond offers anti-creasing, levelling, antistatic, antipilling properties along with enzyme formulation which is effective at wide pH range that does not require additional pH adjustment and it is applicable for cotton, polyester, cotton spandex, nylon and all types of blended fabrics. Black Diamond also avoids additional enzymatic biopolishing process. Black Diamond also can save resource during dyeing and washing steps as well.

In comparison, the conventional pre-treatment, dyeing and washing process uses multiple chemicals, and is anticipated to require more time, water, produce effluent with higher TDS due to neutralisation with pH adjustment steps and steam to achieve the desired result.

Challenge: No particular challenges are faced during the performance of this trial.

> ***Technical Terms from current section***
>
> **What is Enzymatic biopolishing ?**
> It is a process used in textile finishing to improve the appearance and feel of fabric. During this process, cellulase enzymes are applied to the fabric to break down protruding fibres on its surface. This action removes loose fibres, reducing fuzziness and pilling, resulting in a smoother fabric. The biopolishing process improves the fabric's luster and softness and helps maintain its quality after multiple washes. It offers a sustainable alternative to traditional mechanical and chemical methods, utilizing biodegradable enzymes and milder conditions.

E.4 Process Evaluation

For both the conventional and greener processing trials, the team followed the pre-treatment, dyeing and washing processes from start to finish of the knitted fabric. The trial team measured the time and resources used such as water, steam, electricity for conventional and greener process recipes.

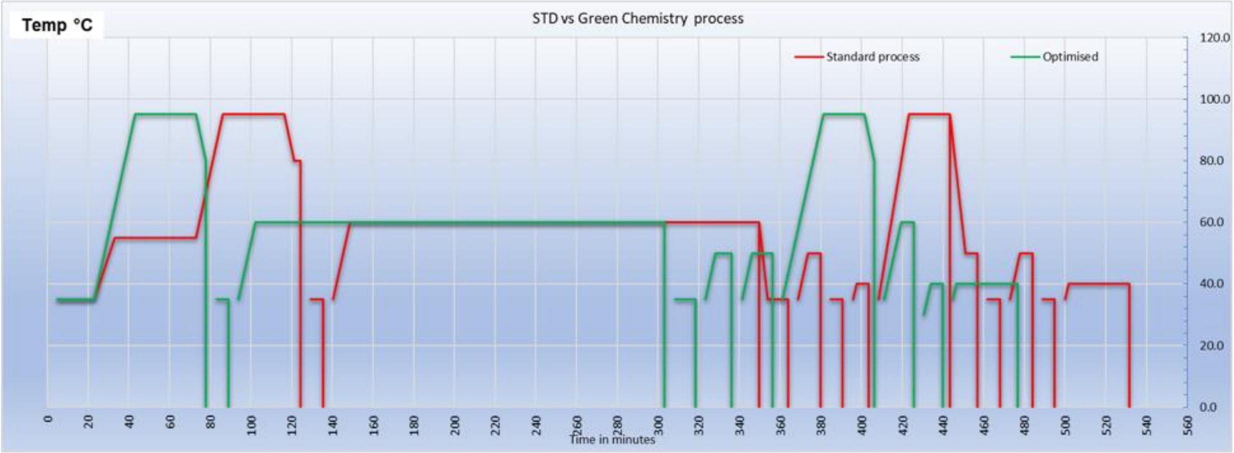
In case of the greener processing step for pretreatment was carried at a lower liquor ratio.

Fabric Dyeing

Pre-treatment controls

The following Key performance indicators for processing steps are evaluated : 1) Water, 2) Steam, 3) Power, 4)Time in hours, 5) GHG, 6) Costs.

Conventional Vs Green Alternative Processing flow for Pretreatment, Dyeing and Washing steps:



The diagram shows the comparison between conventional process vs. the Greener Alternative for pre-treatment, dyeing and washing processes of knitted fabric using reactive dyes. The diagram is commonly known as a Time-Temperature diagram or a TT diagram where time is plotted on the X-axis and Temperature is plotted on the Y-axis.

The plot in red colour shows the conventional pre-treatment, dyeing and finishing process and the green colour lines show the recipe of the green alternative process as followed and recorded by BluWin experts.

E.5 Results

When the modified pre-treatment, dyeing and washing process was carried out using the greener chemical, 'Black Diamond', the time for the total process cycle starting from the pre-treatment, dyeing and washing steps to unloading of the batch which includes the dyeing and after treatment was overall reduced.

The system reduced the water consumption and time by eliminating the requirement of heating and cooling cycle time & energy for hot washing process.

The following are process savings based on an average of 40,000[5] kgs produced.

S #	Savings by optimising process modification	Standard process	Greener chemistry process	Savings %	Savings (40000 kg)	Units
1	Water (in m^3)	3120	2400	23%	720	m^3/ 40000 kg

[5] This figure is considered keeping the average order size of similar recipes with similar processes for same range of shades, which was taken as sample from one shade.
If we can increase the dyeing lots (batches) the volume of production will also increase but the % savings will remain constant.

2	Steam (in Tons)	230	195	15%	35	Tons/40000 kg
3	Power (electricity) (in MWh)	80	69	14%	11	MWh /40000 kg
4	Time (in hours)	886	794	10%	92	Hours / 40000 kg
5	GHG (tCO_{2e})	200	171	15%	29	tCO_{2e}/40000 kg
6	Total Chemicals cost	12540000	5500000	56%	7040000	BDT/40000 kg
					59661	Euro/40000 kg
7	**Total Costs**	**15950000**	**8360000**	**48%**	**7590000**	**BDT/40000 kg**
					64322	**Euro/40000 kg**

E.6 Conclusion

The trial was a success using this greener chemical ; 'Black Diamond'. Because Black Diamond is a multifunctional chemical which avoids multiple steps in the pre-treatment, washing steps and one hot water wash. This results in lower number of baths which save water, time and steam and electricity.

The overall savings range from 23% in water, 15% steam consumption and 14% in electricity consumption compared to conventional pre-treatment process. Overall, the processing cost when comparing conventional vs. greener processing method is about 48% cheaper.

Challenge: No particular challenges were faced during this trial.

Other observations: Using green chemistry has resulted very good absorbency compared with conventional process. Since other parameters have been achieved this chemical can be used for pre-treatment for all shades after conducting the lab trials.

CASE STUDY F

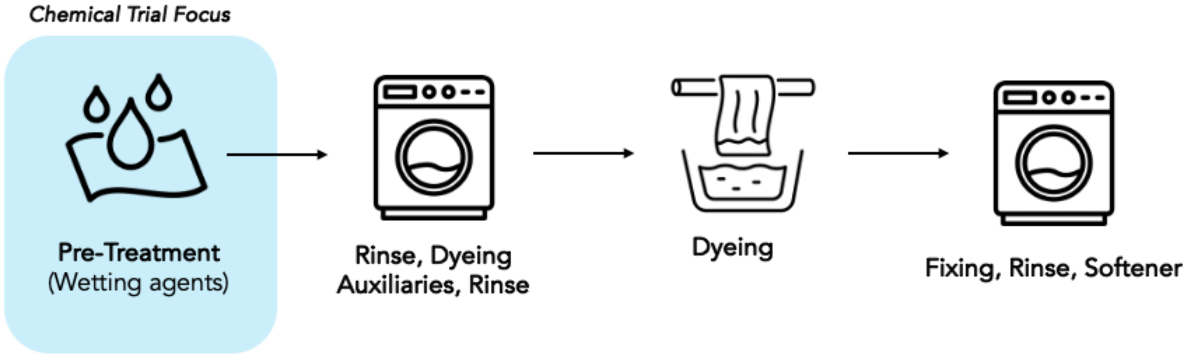
F.1 Profile

Case Study	F
Product Range	Washing and dyeing denims, woven knits and work wear garments,
Processes	Garment dyeing and washing
Machinery	Garment Dyeing and washing machineries

F.2 Introduction

This trial takes place in a garment washing facility, where the garments are already made, and they are to be washed to achieve the desired look and feel.

The processing methods that are being compared at this trial are in the pre-treatment stage – where wetting agents are used. This step is done before garments are to be dyed using pigments.



Technical terms in this section

What are wetting agents? Wetting agents are a type of surfactants that lower the surface tension of a liquid, allowing easier spreading, and lower the interfacial tension between two liquids, allowing better penetration of liquids on fabrics (e.g. dyeing).

	Conventional	Greener Alternative
Process	Conventional Pre-Treatment – wetting agent for garment dyeing using pigments	Modified Pre-Treatment – wetting agent for garment dyeing using pigments

	Chemical Name	***Manufacturer***	***Chemical Name***	***Manufacturer***
Chemicals	Sunmorl BH 1000	S& D Chemical Associates	Allenol PAC	LN chemicals(sample)
	Fel RG-N	S& D Chemical Associates	Altranol GP	

To carry out this assessment, the following processing steps will be evaluated these parameters: 1) Water, 2) Steam, 3) Power, 4) Time in hours, 5) GHG, 6) Costs.

F.3 Hypothesis

The conventional method typically requires multiple washes before starting the dyeing process.

The reason why Allenol PAC and Altranol GP were selected to carry out the pre-treatment process were for several reasons.

- Allenol PAC is low foaming (means less foam is generated in the bath which increases the chemical application better and fewer rinses required)
- Allenol PAC also has added additional emulsifying properties (to help combine two ingredients that do not typically mix easily), and works with well with enzymatic de-sizing.
- Altranol GP, which is a stain removing agent, when paired with Allenol PAC, can work together in a lower temperature (50°C vs. 70°C) compared to the conventional method, and has combined cleaning properties, therefore reducing the number of rinses.

For the greener method, it is anticipated to be a more efficient, and should see a reduction in temperature needed in the pre-treatment baths, a reduction in the number of rinses. Less resources in overall should be needed; thus saving costs.

F.4 Process Evaluation

Processing Steps:

1. Desizing & Washing	2. Dyeing

Process flow:

The diagram shows the comparison between conventional and modified pretreatment process using rewetting agent for garment dyeing using pigments. The diagram is commonly known as a Time-Temperature diagram or a TT diagram where time is plotted on the X-axis and Temperature is plotted on the Y-axis.

The plot in red colour shows the conventional dyeing practice observed by the BluWin experts and the green colour lines show the recipe of the green alternative process. The conventional and greener alternative processes are depicted separately under F.4 Process Evaluation section.

As shown above, the greener alternative shows a faster processing rate, ending the total process at just over 290 minutes. The conventional method finished at just under 370 minutes.

Greener Pre-Treatment Process

The Greener chemistry chemicals used Allenol PAC, Altranol GP – used to combine the pre-treatment and cleaning process has significantly reduced the water consumption as well as energy consumption.

- Water consumption is reduced due to lesser wash-offs
- Energy consumption is lowered due to the lesser requirement in steam, in the processes.
- The reduced processing time has resulted in lesser power consumption.

With the total savings above, the total energy has reduced and GHG emissions are less compared to the conventional process.

Wash dyeing Team

Dyeing machines

data collection

Measuring the data

Washing process

ETP

F.5 Results

When pre-treatment is done using Allenol PAC and Altranol GP (The Greener chemistry system), the results showed a reduction in water consumption and energy consumption in wash off cycles.

This process saved significant amounts of water, chemicals and GHG emissions.

The following are process savings based on an average of 3,000[6] kgs produced per style of garments. Since the garment dyeing / washing / finishing process involves various styles and different fashion requirements, the average quantity for laundry process is considered 3000kg equivalent production on similar process.

Challenge: There were no particular challenges faced for this trial.

S #	Savings by optimising process modification	Standard process	Greener chemistry process	savings %	Savings (3000 kg)	Units
1	Water (In m^3)	450	360	20%	90	m^3/3000 kg
2	Steam (In Tons)	26.76	21.13	21%	5.63	Tons/3000 kg
3	Power (electricity) (In MWh)	3.77	3.57	5%	0.20	MWh /3000 kg
4	Time (in hours)	229.58	182.71	20%	46.87	Hours / 3000 kg
5	GHG (In tCO_{2e})	17.56	14.19	19%	3.37	tCO2e/3000 kg

[6] This figure is considered keeping the average order size of similar recipes with similar processes for same range of shades, which was taken as sample from one shade.
If we can increase the dyeing lots)(batches) the volume of production will also increase but the % savings will remain constant.

6	Total Chemicals Cost	1089360	942480	13%	146880	LKR/3000 kg
					437	Euro/3000 kg
7	Total Costs	1288260	1110780	14%	177480	LKR/3000 kg
					528	Euro/3000 kg

F.6 Conclusion

Savings were made in the areas of water, electrical energy, reduction in GHG, reduction in time processing and overall processing cost. When comparing with the conventional method, the greener method is 14% cheaper.

Other observations:

1) Many factors can play into calculating total processing costs. This case study should not rule out the possibility for savings when switching to sustainable chemicals.
2) Since the garments are made out of pre-treated fabrics, need for full Desizing process is not recommended.

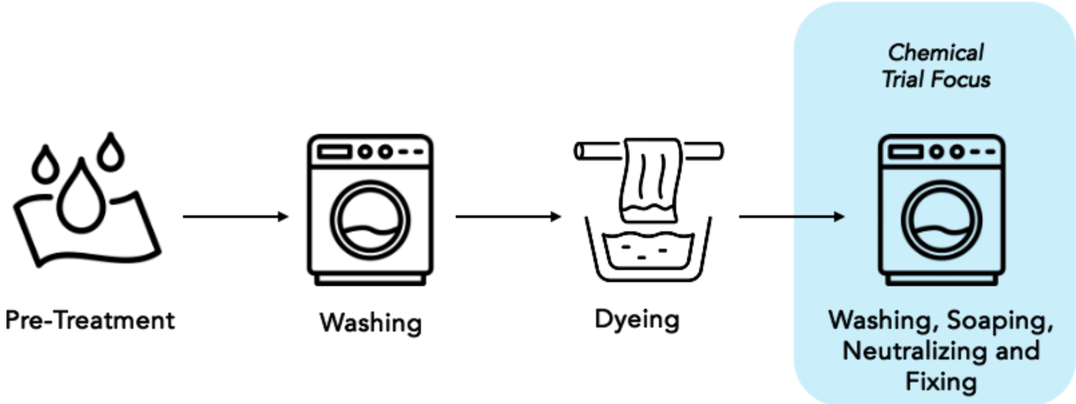
CASE STUDY G

G.1 Profile

Case Study	G
Product Range	The facility makes Knitted fabric dyeing
Processes	Yarn dyeing , Knitted dyeing, printing
Machinery	100% open width & Tubular Knitted fabric processing machine.

G.2 Introduction

For the processing trial at this mill, the comparison of washing off agents used after Reactive Dyeing were carried out. This trail processed cotton knit fabric.



Technical Terms in this section

What are wash off agents? Wash-off agent or soaping agent is used to remove unfixed or hydrolysed dye, and preventing it from re-depositing on the textile, leading to good washing fastness on fabric after dyeing or printing.

	Conventional		Greener Alternative	
Process	Reactive dyeing wash offs		Reactive dyeing wash offs	
	Chemical Name	Manufacturer	Chemical Name	Manufacturer
Chemicals	ALBATEX AD Buffer & (washing off agent)	Huntsman	Cyclonon XCW (washing off agent)	Archroma
	Generic market soap	Local Suppliers	Archroma soaping agent	Archroma

To carry out this assessment, the following processing steps will be evaluated these parameters: 1) Water, 2) Steam, 3) Power, 4, Thermic Heat, 5) Time in hours, 6) GHG, 7, Costs.

G.3 Hypothesis

Conventional wash off products, that is used after reactive dyeing typically uses more water and steam energy to achieve the desired fastness properties compared to modified wash off process.

Normal wash offs use multiple water fills and drains because it does not have the ability to remove all unfixed and hydrolysed dyestuffs on the substrate at lower temperature and less fill and drains.

The greener choice wash off chemical, Cyclonon XCW requires less water fills and drain and improves the colour fastness properties. This additionally reduces the water consumption in wash off process.

Solution: When the facility works with low ratio liquor dyeing machines, the alkali calculation needs to be done according to the pH requirement at lower liquor ratio. Facility may use a core alkali neutraliser before soaping process, or a fixing agent to attain the desired fastness level.

G.4 Process Evaluation

For the conventional trial, the team followed the full current dyeing process from pre-treatment all the way to the finishing, and measured the time and resources it took according to the current recipe – using Albatex AD in the wash off process. For the greener chemistry trial, the team did the same but with the modified recipe using Cyclonon XCW in the wash off process.

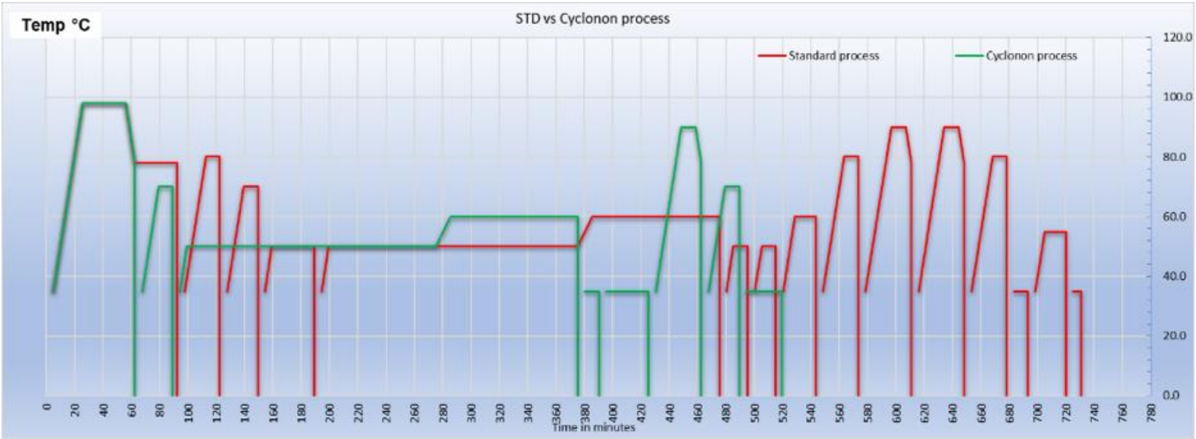
For the conventional process, the mill used generic market soap and made multiple washes for attaining fastness results.

For the greener process, the pH of the dyeing bath during the alkali stage was reduced to maintain the pH to 10.8- 11.2 range. This followed by one wash using acid and core alkali neutraliser to get the pH to 6-7 after which soaping process was performed.

Processing Steps:

1. Dyeing	2. Washing

Process flow:



The diagram shows the comparison between washing offs in conventional Reactive Dyeing and Reactive dyeing with Greener Alternative - Cyclonon XCW. The diagram is commonly known as a Time-Temperature diagram or a TT diagram where time is plotted on the X-axis and Temperature is plotted on the Y-axis.

As shown, the Greener alternative shows less processing time, finishing at 520 minutes. The conventional method requires 730 minutes to process.

Checking the dyeing program while trials

G.5 Results

When the modified wash off was carried out using the soaping process of Cyclonon XCW, the system reduced the water consumption and the alkali concentration along with the energy reduction in washing off cycles.

The following are process savings based on an average of 40,000[7] kgs produced.

SL #	Savings by optimising process modification	Standard process	Optimised process	savings %	Savings (40000 kg)	Units
1	Water-(in m^3)	3600	1920	47%	1680	m^3/40000 kg
2	Steam-(In Tons)	317.13	147.59	53%	169.54	Tons/40000 kg
3	Power (electricity) (In MWh)	9.46	6.45	32%	3.01	MWh /40000 kg
4	Time (in hours)	487.33	346.22	29%	141.11	Hours /40000 kg
5	GHG (In tCO_{2e})	171.61	81.77	52%	89.84	tCO_{2e}/40000 kg
6	Total Chemicals Consumption	28390	27510	3%	880	kg/ 40000 kg
7	Total Chemicals Cost	23470	17420	25.78%	6050	Euro/ 40000 kg
8	**Total Cost**	**36830**	**24090**	**34.60%**	**12740**	**Euro/ 40000 kg**

G.6 Conclusion

The trial was overall successful, and savings were made in total of water, electrical energy, steam, GHG, time processing, the overall processing cost when comparing the conventional 'vs. greener wash off processing method 'Cyclonon XCW' by Archroma.

When calculating the full wet processing costs from start to finish, it can be concluded that the savings show around 35 % cheaper when using greener chemistry.

In addition, the chemical consumption, has been showing marginal reduction per kilogram of fabric when using Cyclonon XCWinstead of conventional soaping agent.

[7] This figure is considered keeping the average production of similar shades produced by multiple orders size of similar recipe with same wash-off sequences for a year. which was taken only for one order in a year.
If we can increase the lots the volume of production will also increase but the % savings will remain constant.

Challenges:

One main disadvantage of greener wash-off chemicals is the limitation on pH during the soaping process. Since the facility uses a lower liquor ratio, the carry-over factor (the water carried over by the substrate in the bath due to its ability to absorb water) may need to be considered during the fill and drain. The wash-offs before the soaping process may not be adequate to reduce the alkaline pH, making the bath less ready for soaping. If alkali remains in the soaping bath, some of the dye that has reacted with the fibres come out in the soaping bath due to the rupture of the bond between the dye and the fibre. This can lead to colour discharge even after the second wash-off.

- The mill is a ZLD (zero liquid discharge) facility.
- The water cost is considered with 100% recovery cost operation.

Has it been the facility with direct discharge to CETP or other discharge norms, the energy for the water recycling will be off setting the manufacturing cost. 3) In mills without ZLD, water costs will decrease since there won’t be any treatment costs for 100% water recovery. However, the treatment costs incurred by the factory for external treatment and incoming water will be approximately the same or less from country to country. Therefore, this is not a significant challenge for the facility.

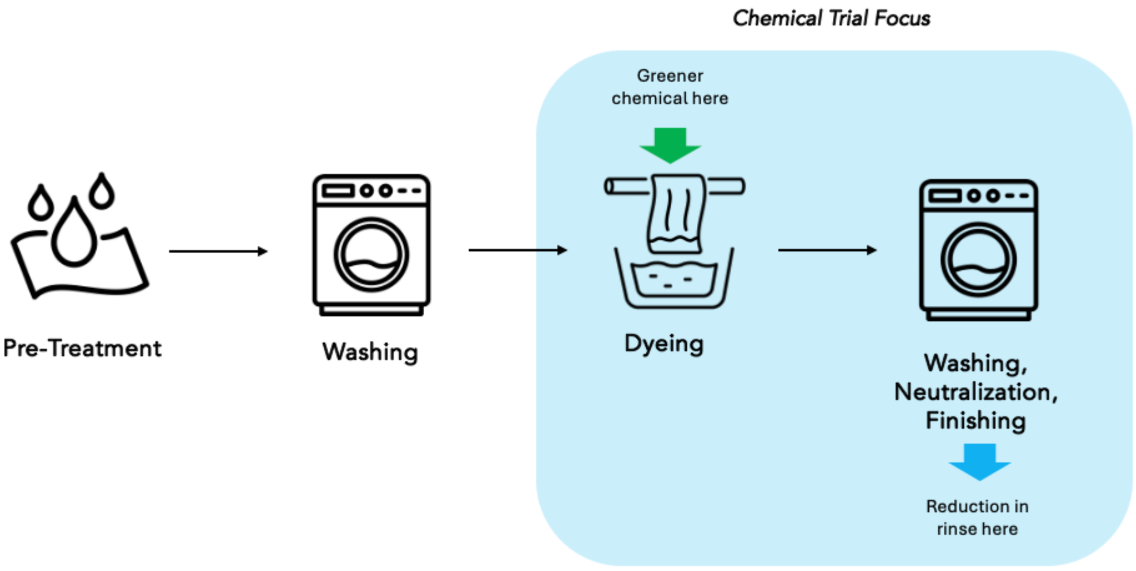
CASE STUDY H

H.1 Profile

Case Study	H
Product Range	Knitted fabric dyeing & Garment manufacturing facility
Processes	Knitted dyeing, printing & Garments
Machinery	100% open width & Tubular Knitted fabric processing machines,

H.2 Introduction

This processing trial compares dyeing of polyester cotton fabric blends. The conventional dyeing process uses disperse and reactive dyes and the greener choice of dyeing with disperse and direct dyes. This greener choice requires less water after treatment washing (wash offs) compared to the greener choice.



Technical Terms in this section

What are disperse and reactive dyes? (Conventional)

Disperse dye is a category of synthetic dye category which is used to transmit colour to polyester and other similar hydrophobic fibres. Similarly, Reactive dye is the dye class that can react with fibre like cotton or viscose (cellulosic) to form a covalent link, that is forming a permanent attachment in the fibre and be stable towards treatment with boiling water under neutral conditions.

What are disperse and direct dyes? (Greener)

In case of Greener choice, trial was taken using Disperse and Direct dye classes to dye the polyester and cotton blend. As the name suggests, Direct dyes are the class of colours which water-soluble compounds that have an affinity for fibre and are taken up directly. Direct dyes are usually cheaper and easily applied, and they can yield bright colours. Wash fastness usually is poor but may be improved by aftertreatment or by proper choice of dyes.

What is wash off?

Washing off is the process of removing the unfixed or hydrolysed dyes from the fabric after dyeing process is over, either by using soap or temperature.

These steps involve multiple washes and hot soap treatments depending upon the colours and process used to improve the fastness properties of the final product.

	Conventional		**Greener Alternative**	
Process	Dyeing process for Polyester/ Cotton using Disperse and Reactive Dyeing		Dyeing process for Polyester/ Cotton using Disperse and Direct dye	
	Chemical Name	*Manufacturer*	*Chemical Name*	*Manufacturer*
Chemicals	Synozol Golden Yellow HF-2GR 150% - reactive dye	Kisco	Argazol Yellow GE Directive dyes	Argus (Shanghai) enterprises
	Everzol Red 6 BN 150%- reactive dye	Everlight	Argazol RED GE Directive dyes	Argus (Shanghai) enterprises
	Synozol Navy Blue KBF- reactive dye	Kisco	Argazol Black GE W - Directive dyes	Argus (Shanghai) enterprises

To carry out this assessment, the following processing steps will be evaluated these parameters: 1) Water, 2) Steam, 3) Power, 4) Time in hours, 5) GHG, 6)Costs.

H.3 Hypothesis

In conventional process, in order to conduct Cotton and Polyester dyeing using Reactive and Disperse dyes, proper choice of disperse dyes is needed to ensure the dyes are stable to the pH of the dye bath is necessary.

In the case of the greener choice, since direct dyes are used, the precaution is not needed to follow due to the dye bath pH needed for direct dye. pH is not a critical factor for direct dyes, as they have a wide range of pH adaptability and can dye effectively between pH 5.5 and 7.5 at higher temperatures for light shades. Direct dyeing typically requires less water fills and drains, and water consumption in the soaping process is also lower.

Solution: The facility can work with low liquor ratio dyeing machines considering the washing properties with the higher liquor ratio during wash offs to avoid the staining to adjacent fibres.

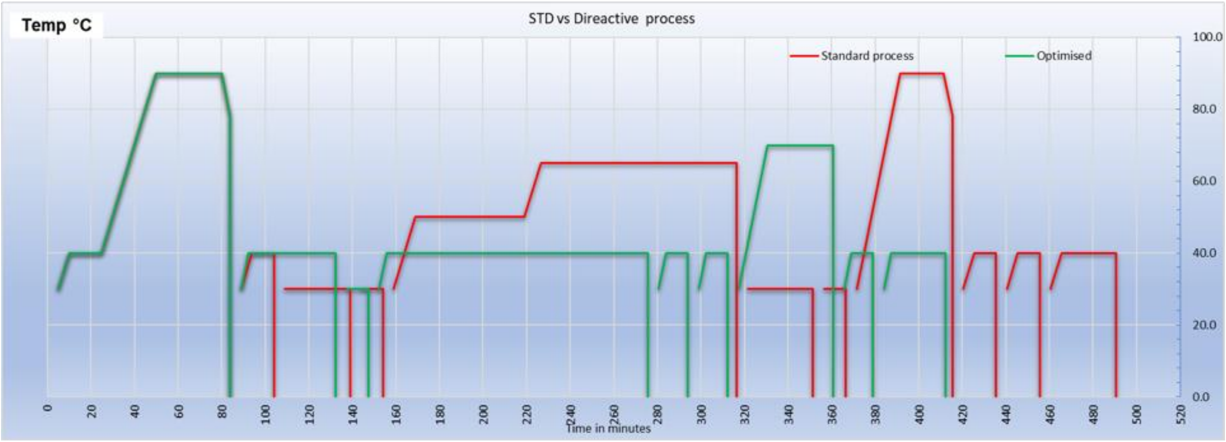
H.4 Process Evaluation

During the trial, the team followed current and modified full dyeing process and measured the time and resources it took according to the current recipe.

Conventional Vs Green Alternative Processing Steps:

1. Reactive Dyeing / Modified reactive dyes – dyeing method	2. Washing

Conventional Vs Green Alternative Processing flow for cotton dyeing:



The diagram shows the comparison between conventional Polyester /cotton Reactive Dyeing and disperse / direct dyes with all in one washing off agent (Greener Alternative). The diagram is commonly known as a Time-Temperature diagram or a TT diagram where time is plotted on the X-axis and Temperature is plotted on the Y-axis.

The plot in red colour shows the conventional dyeing practice observed by the BluWin experts and the green colour lines show the recipe of the green alternative process.

As shown in the graph, the time needed for process is faster using the Greener chemistry, finishing at 410 minutes, compared to the red, finishing at 490 minutes.

Standard conventional & Direct reactive dyeing of black shade

Dyeing machines

Instruments used for trial data collection

Measuring the data

Water level in machine

Dyeing machine

H.5 Results:

The dyeing of cotton polyester blend fabric was carried out using the direct dyes from Argus (Shanghai) enterprises. These range of dyes require only 70ºC hot wash for after treatment. In comparison, normal reactive dyes require on soap at 90ºC hot wash for colourfastness requirements. It was found during trials that, the greener process uses reduced total water, steam, time and power (electricity) with the help of reduced post wash-off cycles resulting in reduced GHG emission.

The following are process savings based on an average of 40,000[8] kgs produced.

S #	Savings by optimising process modification	Standard process	Greener chemistry process	savings %	Annual Savings	Units
1	Water (In m^3)	1294	1083	16%	211	m^3/40000 kgs
2	Steam (In Tons)	113	93	18%	20	Tons/40000 kgs
3	Power (electricity) (In MWh)	6	5	17%	1	MWh /40000 kgs
4	Time (in hours)	818	687	16%	131	Hours /40000 kgs
5	GHG (In tCO_{2e})	64	53	17%	11	tCO_{2e}/40000 kgs
6	Total Chemicals Costs	3216000	4885000	-52%	-1669000	PKR/ 40000 kgs
					-5620	Euro/40000 kgs
7	Total Costs	4408000	5582000	-27%	-1174000	PKR/40000 kgs
					-3953	Euro/40000 kgs

H.6 Conclusion

Although savings were made in the areas of water and electrical energy, reduction in GHG, and reduction in time processing, the overall processing cost was still higher when comparing conventional vs. greener dyeing method. The result was 27% higher when using greener chemistry.

Challenges and way forward.

The cost of the greener process was higher than the conventional process, even though its environmental impact is greater compared to other options for dyeing black shades. The higher cost of the greener process dyes and chemicals is due to single source of dyes from Argus (Shanghai) -where there are no competitive products available. Together with added import cost (for dyes --- the country of origin- China) and cost of distribution (landed cost at factory site-Pakistan) the overall cost of the product was simply too high.

At the moment of the trial, the cost could not be reduced. The greener alternative product cannot be economical unless of a price negotiation from the facility to chemical supplier or mill’s initiative to implement this process in mass production scale, which will allow the mill to

[8] This figure is considered keeping the average order size of similar recipes with similar processes for same range of shades, which was taken as sample from one shade
If we can increase the dyeing lots (batches) the volume of production will also increase but the % savings will remain constant.

consume more chemical allowing better negotiated price. Again, this depends on the order volume from the brands as the material composition is decided and driven by the brands.

Alternatively, mills can work with the lower liquor ratio machines, or alternative dyeing techniques, like pad steam, or CPB (suitable for knits also) – these methods can help reduce the manufacturing cost.

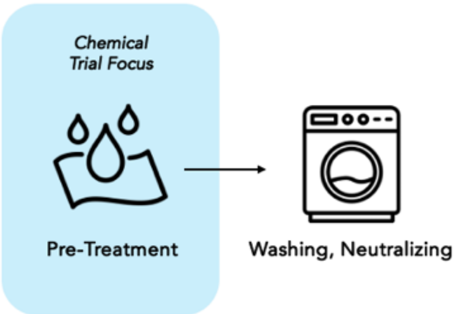
CASE STUDY I

I.1 Profile

Case Study	I
Product Range	The facility makes Yarn Dyeing & Knitted fabric dyeing
Processes	Knitted dyeing, Yarn Dyeing
Machinery	Cheese Yarn dyeing machines,100% open width & Tubular Knitted fabric processing machines.

I.2 Introduction

For the processing trial at this mill, the comparison for pre-treatment using wetting agents and low temperature pre-treatment chemicals are carried out for cotton yarn dyeing.



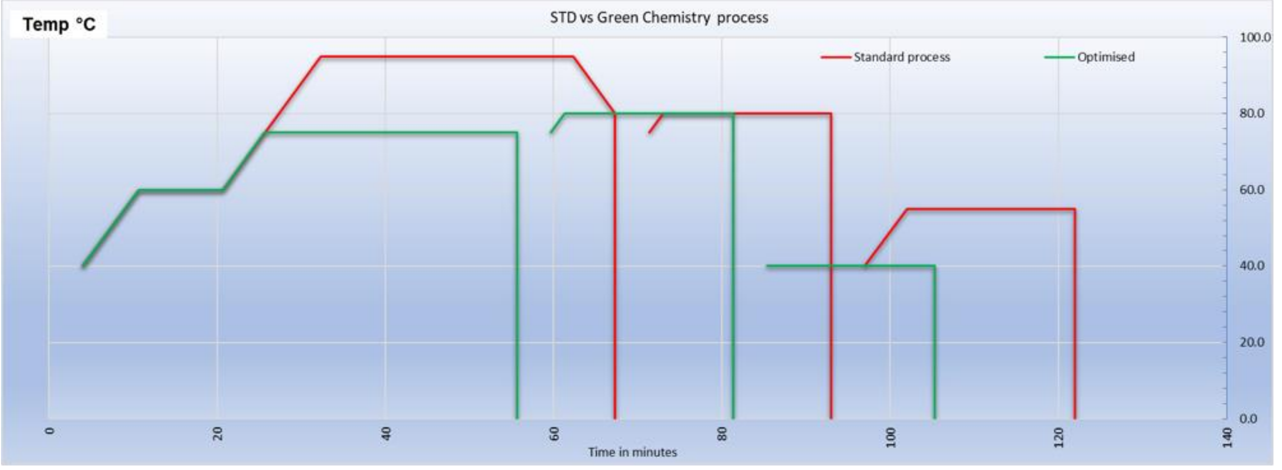
What are wetting agents? Wetting agents are a type of surfactants that lower the surface tension of a liquid, allowing easier spreading, and lower the interfacial tension between two liquids, allowing better penetration of liquids on fabrics (e.g. dyeing).

	Conventional		Greener Alternative	
Process	Wetting agent for yarn pre-treatment – before reactive Dyeing		Wetting agent for yarn pre-treatment-before reactive dyeing	
	Chemical Name	Manufacturer	Chemical Name	Manufacturer
Chemicals	EXOVET HPJ	INTEXSO BIOCHEM PVT LTD.	ALTRANOL LTB RS -NEW Aqueous formulation of fatty alcohol alkoxylates	LN chemicals Pvt Limited.

To carry out this assessment, the following processing steps will be evaluated these parameters: 1) Water, 2) Steam, 3) Power, 4)Time in hours, 5) GHG, 6) Costs.

Conventional Vs Green Alternative Processing Steps:

1. Pretreatment- with conventional and green chemistry



The diagram shows the comparison between conventional process vs. the Greener Alternative for pre-treatment of yarn dyeing in reactive dyeing. The diagram is commonly known as a Time-Temperature diagram or a TT diagram where time is plotted on the X-axis and Temperature is plotted on the Y-axis.

The plot in red colour shows the conventional pre-treatment practice observed by the BluWin experts and the green colour lines show the recipe of the green alternative process.

As shown in the graph, the Green process takes less time, ending at 105 minutes, whereas the conventional process takes more time, ending at 122 minutes. The conventional process also shows the need for a higher temperature to process compared to the greener alternative.

I.3 Hypothesis

The reason why ALTRANOL LTB RS -NEW (greener) was chosen to replace Extrovet HPJ (conventional) in this trial is because the conventional process typically requires higher temperatures to carry out the process – minimum at 95°C to boil and some cases up to 120°C.

It is anticipated that the conventional processes uses more steam water, and time to complete the process and to achieve the desired results.

Alternatively**,** the revised pre-treatment process should require less steam and time. The results should show an increase in productivity and savings in energy.

Technical Terms in this section

What is the whiteness index?

The CIE Whiteness Index, developed by the International Commission on Illumination (CIE), quantifies the perceived whiteness of a material by comparing its spectral reflectance curve to that of a perfect reflecting diffuser under standardized lighting (D65). This index, expressed in 1% -100% indicates how closely the material matches to perfect white. The higher values suggest greater whiteness. This is widely used in industries like textiles, paper and coatings industries and it guides colour quality assessment and control.

Whiteness measurement influences material perception, with lower levels appearing neutral and higher levels showing bluish tones. A perfect white sample scores 100 on this index, crucial for evaluating light reflection quality and guiding textile processing.

I.4 Process Evaluation

The team followed the pre-treatment process from start to finish of yarn dyeing. Measurements were made on the time and resources it took according to the current recipe for the conventional trial, and modified recipe for the green chemistry trial.

For the conventional chemistry trial, the pre-treatment was carried out at a higher temperature 95°C at for 30 mins. This temperature varies with the quality of the cotton and the targe shades

For the green chemistry trial, the pre-treatment was carried out at a lower temperature (at 75°C and at low Liquor ratio). This was followed by one hot wash and neutralisation.

Pretreatment - Standard (top) vs TRAIL Samples (Bottom)

I.5 Results

When the modified pre-treatment was carried out using the greener chemical named Altranol LTB-RS new, the system reduced the steam consumption along with saving in time by avoiding the heating and cooling cycle time & energy.

The following are process savings based on an average of 40,000[9] kgs produced.

S #	Savings by optimising process modification	Standard process	Optimised process	savings %	Savings (40,000 kg)	Units
1	Water (In m^3)	947	859	9%	88	m^3/40000 kg
2	Steam (In Tons)	106	48	55%	58	Tons/40000 kg
3	Power (electricity) (In MWh)	19	16	16%	3	MWh /40000 kg
4	Time (in hours)	203	176	13%	27	Hours /40000 kg
5	GHG (In tCO_{2e})	76	41	46%	35	tCO_{2e}/40000 kg
6	Total Chemicals Cost	2362	2384.5	-1%	-22.50	Euro/ 40000 kg
7	**Total production Costs**	**9166.8**	**6658.6**	**27%**	**2508.2**	**Euro/40000 kg**

I.6 Conclusion

Savings were made in the areas of Water, Steam, Electrical energy, reduction in GHG, and reduction in time processing. The overall processing cost when comparing conventional wetting agent vs. greener wetting agent - the processing method is cheaper when using greener chemistry.

Although the chemical cost slightly increased in the greener choice (by 1%), the total production cost was reduced 27% compared to the conventional process due to high steam reduction in the process along with other resource savings.

[9] This figure is considered keeping the average order size of similar recipes with similar processes for same range of shades, which was taken as sample from one shade.
If we can increase the dyeing lots)(batches) the volume of production will also increase but the % savings will remain constant.

Below are the key challenges presented:

1) The mill is a ZLD (zero liquid discharge) facility.
    a. The water cost is considered with 100% recovery cost operation.
    b. Has it been the facility with direct discharge to CETP or other discharge norms, the energy for the water recycling will still reduce the manufacturing cost.
2) As anticipated, the technical limitation with this process is less white (when matched with the whiteness index) compared to standard conventional process.
    a. The suitability for dyeing very pale, light & bright shades, which still can be tested at the laboratory and carried out with further trials.
3) The absorbency was found to be more than >10 sec, which is less when compared with conventional process, due to the intermittent drying of sampling.
    a. This can be corrected overcome,
        i. Further processing carried out with levelling agents in the dyeing bath.
        ii. Or by marginally increasing the dosage of greener Low temperature bleaching agent used.

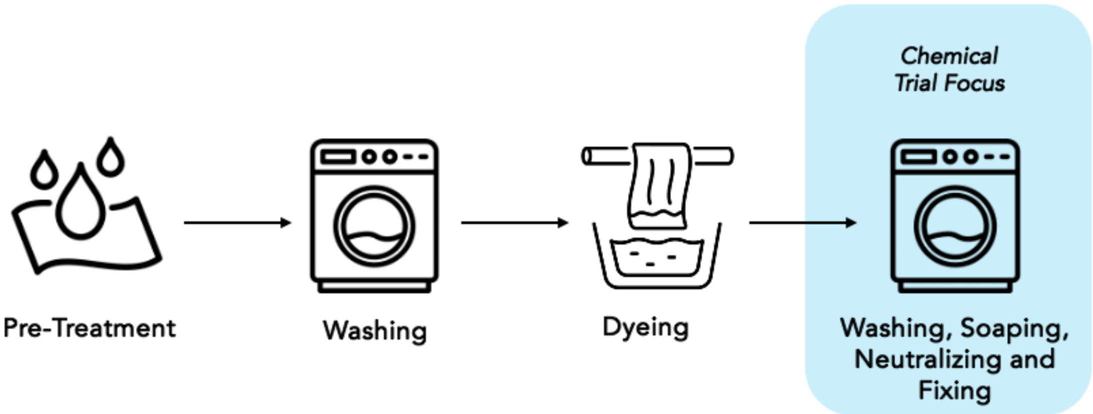
CASE STUDY J

J.1 Profile

Case Study	J
Product Range	The facility makes Knitted fabric dyeing
Processes	Knitted dyeing, printing
Machinery	100% open width & Tubular Knitted fabric processing machine.

J.2 Introduction

For the processing trial at this mill, the comparison conventional and greener wash off agents are carried out for knitted polyester-cotton blend fabric.



What are wash off agents? Wash-off or soaping agents are chemicals which removes unfixed or hydrolysed dye and prevents re-deposition of dye on the fabric during washing off process and improves fastness of fabric.

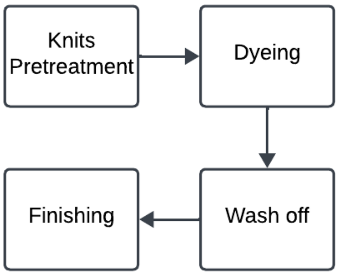
	Conventional Process		**Greener Alternative Process**	
Process	Polyester/ cotton process for knitted fabric		Polyester/ cotton process for knitted fabric	
Chemicals	Chemical	Manufacturer	Chemical	Manufacturer
	ALBATEX AD-Soap ALBATEX WFF – Dye fixing product	Huntsman	ALTRAPLEX-XCW DYMAX-TWE	LN chemicals Pvt Limited

To carry out this assessment, the following processing steps will be evaluated these parameters: 1) Water, 2) Steam, 3) Power, 4, Thermic Heat, 5) Time in hours, 6) GHG, 7, Costs.

Processing Steps:

1. Dyeing	2. Washing

Process flow:



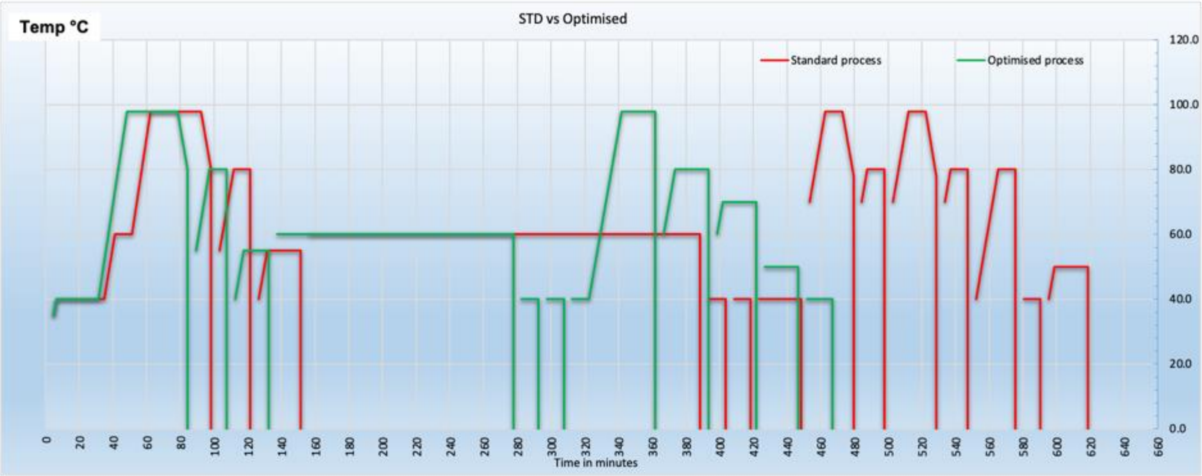
J.3 Hypothesis

Reactive dyeing wash offs such as Albatex AD, typically uses more water and steam energy to achieve the desired fastness properties compared to modified wash off process.

The revised wash off using ALTRAPLEX-XCW and DYMAX-TWE require lesser water fills and drain and improves the colour fastness properties , this additionally reduces the water consumption in soap process wash offs.

Challenge: One of the main disadvantages with greener wash off chemicals are limitation of them performing in higher alkaline pH. Controlling the pH during soaping process below 7.5 is a mandatory requirement. Since the facility will be using lower liquor ratio dyeing machines and considering the carry over factor during the fill and drain, after the wash offs process cycles the pH level may still not be adequate for the next soaping process. As a result, the colour may continue to discharge even after second wash offs. In order to overcome this issue, the alkali requirement need to be calculated keeping the carry over factor and low liquor ratio machine and use a good core neutraliser to achieve better results in soaping step.

J.4 Process Evaluation

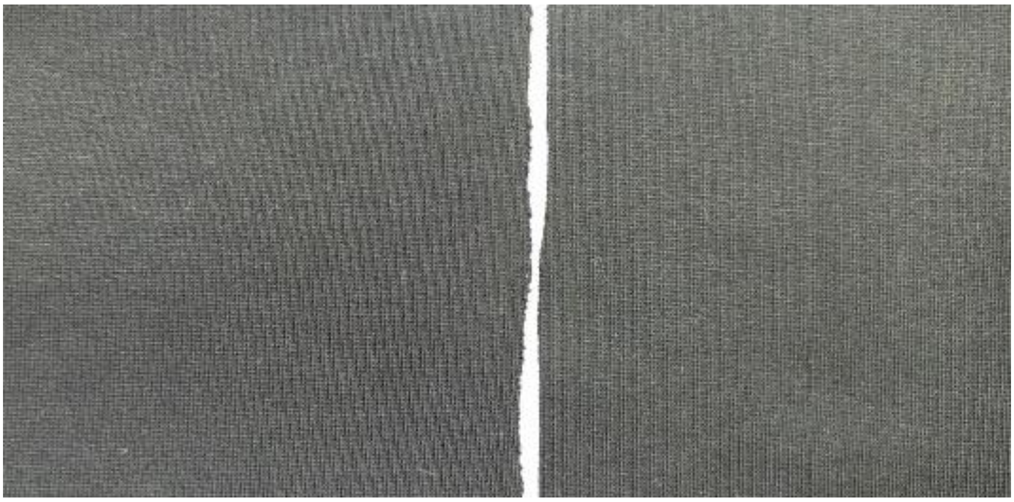


The diagram shows the comparison between conventional process vs. the Greener Alternative for pre-treatment of knitted fabric reactive dyeing process. The diagram is commonly known as a Time-Temperature diagram or a TT diagram where time is plotted on the X-axis and Temperature is plotted on the Y-axis.

The plot in red colour shows the conventional pre-treatment practice observed by the BluWin experts and the green colour lines show the recipe of the green alternative process.

Visit 1 – Conventional Processing – Reactive dyeing with standard washing off process.

On the first visit of the trial, the team followed through from start to finish the conventional dyeing process and measured the time and resources it took according to the current recipe.



Second Trial Samples: Left=Standard. Right=Trial.

Visit 2 –Greener Processing – Greener wash offs. On the second visit the trails for the greener washing off was carried out and the pH of the dye fixing bath during the alkali stage was reduced to maintain the pH to 10.8- 11.2 range. This followed by two washes to achieve the TDS of salt to match the 2 gm/L level , in which the washing , neutralisation and soaping process were carried out.

J.5 Results

When the greener chemical wash off process was carried out using the combination system of Altraplex XCW & Dymax TWE, the system reduced the water consumption and the alkali concentration along with the energy reduction in the wash off cycles.

The following are process savings based on an average of 40,000[10] kgs produced.

S #	Savings by optimising process modification	Standard process	Optimised process	Savings %	Savings (40000 kg)	Units
1	Water (In m^3)	6079	4814	21%	1265	m^3/40000 kg
2	Steam (In Tons)	515	420	18%	95	Tons/40000 kg
3	Power (electricity) (In MWh)	79	56	29%	23	MWh /40000 kg
4	Time (in hours)	1031	778	25%	253	Hours / 40000 kg
5	GHG (In tCO_{2e})	1343	1087	19%	256	tCO_{2e}/40000 kg
6	Auxiliaries	11224	10199	9%	1025	Tons/ 40000 kg
7	**Total Costs**	**68970**	**61670**	**11%**	**7300**	**Euro/ 40000 kg**

J.6 Conclusion

Savings were made in the areas of water and electrical energy ,GHG and reduction in time processing, the overall processing cost when comparing conventional vs. greener wash off processing method is 11 % cheaper when using greener chemistry.

Below are the key challenges presented: The mill is a ZLD (zero liquid discharge) facility.

- The water cost is considered with 100% recovery cost operation.
- Has it been the facility with direct discharge to CETP or other discharge norms, the energy for the water recycling will be off setting the manufacturing cost.

[10] This figure is considered keeping the average order size of similar recipes with similar processes for same range of shades, which was taken as sample from one shade.
If we can increase the dyeing lots(batches) the volume of production will also increase but the % savings will remain constant.

Other observations: The technical limitations are the colour fixation of dyes which depends on the chemistry of the dyes and the dyeing conditions like temperature, water quality and material quality. pH also plays a more important role, which defines the colour yield in final product.

- Any higher pH increases the hydrolyses and it is suggested to have the right pH control.

CASE STUDY K

K.1 Profile

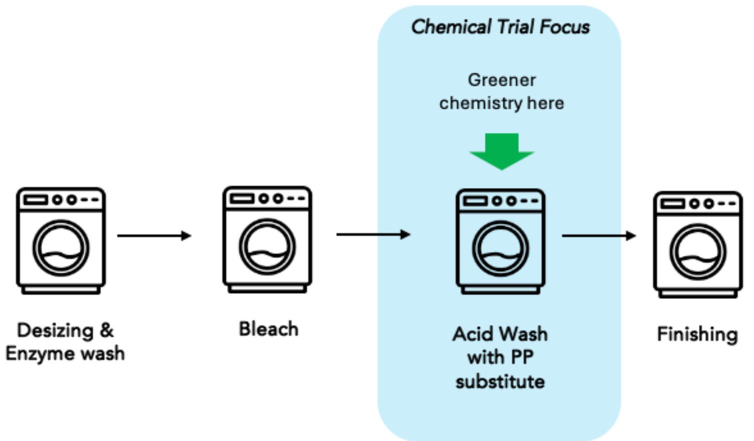
Case Study	K
Product Range	The facility makes garment washing and dyeing
Processes	Garmenting and garment washing
Machinery	Garment washing

K.2 Introduction

For the processing trial at this mill, the comparison of conventional Acid washing process using KMnO4- Potassium Permanganate with enzyme washing was used on denim garment washing process.

This conventional process involves KMnO4- Potassium permanganate (PP). PP is harmful for worker's health (long term exposure can damage the liver and kidneys).

The greener choice of the chemical replaces the KMnO4- Potassium Permanganate with Mud / clay based colour reducer, Novo-Denifade BE 700 which can be applied to Indigo and Sulfur colourants, for denim fading effects mimicking the effects with green chemistry.



Acid Wash Example

	Conventional		Greener Alternative	
Process	Enzyme washing Chlorine bleach PP coated pumice stones washing and bleaching		Enzyme washing Enzymes and PP substitute washing	
	Chemical Name	***Manufacturer***	***Chemical Name***	***Manufacturer***

Chemicals	Reactaze Z40	S& D Chemical Associates	Reactaze Z40	S& D Chemical Associates
	Lanzene	V tex	Lanzene	V tex
	Bleaching liquor	Local Supplier	Novo denifade BE 700	Atlantic Care chemicals
	PP Spray	Local Supplier		

To carry out this assessment, the following processing steps will be evaluated these parameters: 1) Water, 2) Steam, 3) Power, 4) Time in hours, 5) GHG, 6)Costs.

K.5 Hypothesis

Comparative process for denim Acid washing processing using conventional washing with PP coated pumice stones Vs PP substitutes.

Conventional choice:
The conventional choice uses enzymes to impart a smooth surface, with standard detergent, and anti-back staining, followed by acid washing using pumice stones pre coated with $KMnO_4$ – PP solution and neutralisation process using SMBS (sodium meta bisulphite $Na_2S_2O_5$)) to achieve the desired washed look. This wash off process uses multiple water fills and drains.

Greener choice:

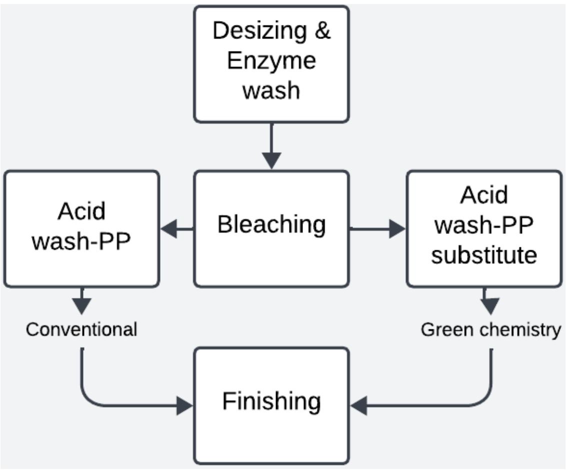
The green process involve Acid washing process without using PP process. The enzyme wash is followed by the chemical Novo denifade BE 700, which is a mud-based colour reducer. Using this chemical results in less process time, less water fills and drain. Because Novo denifade BE 700 can be used to remove colour from textiles and garments, it was selected as a greener product compared to PP.

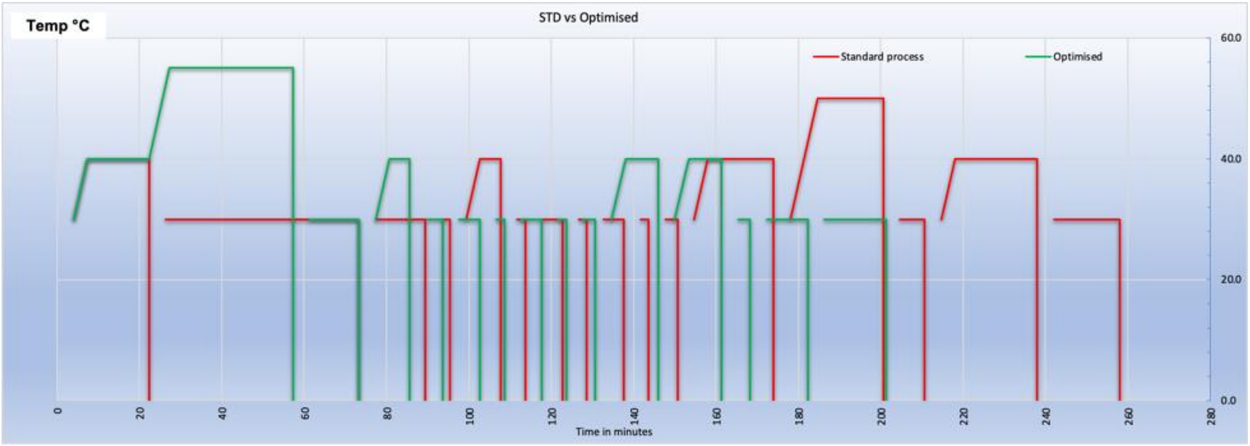
Challenge: The fade look of each style need to be tried specifically and exact matching with lower resource footprint every time is a challenge using the green chemical as it also depend on the yarn dyeing and fabric quality, dye penetration. Wash off efficiency will be depending on the fabric quality as well.

K.4 Processing Steps

1. Enzyme washing	2. Bleaching
3. Acid washing	4. PP substitute
5. washing	6. Tinting and finishing

Process flow:
Comparative process for denim processing using PP Spray/ PP coated pumice stones process and replacement of PP spray using green alternative PP substitute.





The diagram shows the comparison between the standard enzyme wash / acid washing process for denim garment with enzyme wash / washing with PP coated pumice stones in conventional process vs. the Greener Alternative for PP washing program. The diagram is commonly known as a Time-Temperature diagram or a TT diagram where time is plotted on the X-axis and Temperature is plotted on the Y-axis.

The plot in red colour shows the conventional Acid wash program observed by the BluWin experts and the green colour lines show the recipe of the green alternative process using PP spray substitution chemical.

K.5 Results

As anticipated, the acid wash carried out using Novo Denifade BE 700- (greener alternative), resulted the reduction in water consumption, and energy consumption were seen during the wash off cycles.

Overall, the alternative process saved significant amount of water, chemicals and GHG emissions.

The following are process savings based on an average of 3,000[11] kgs of similar style and process followed for the garments with similar process route.

S #	Savings by optimising process modification	Standard process	Greener chemistry process	Savings (3000 kg)	savings %	Units
1	Water (In m^3)	533	467	66.7	13%	m^3/3000 kg
2	Steam (In Tons)	28	10	18.1	65%	Tons/3000 kg
3	Power (electricity) (In MWh)	3	3	0.2	5%	MWh /3000 kg
4	Time (in hours)	189	161	28.3	15%	Hours / 3000 kg
5	GHG (In tCO_{2e})	77	28	48.8	64%	tCO_{2e}/3000 kg
6	Total Chemicals Cost(in thousands)	127	103	24.2	127	SLR/ 3000 kg
				0.076		Euro/3000 kg
7	**Total Costs(in thousands)**	**326**	**207**	**119**		**SLR/ 3000 kg**
				0.37	**37%**	**Euro/3000 kg**

K.6 Conclusion

For this trail, savings were made in the areas of water, electrical energy, reduction in GHG, processing time and overall processing cost when comparing conventional vs. acid washing. This processing method is more than 37% cheaper when using greener chemistry.

Normally the garments with size from the denim fabric are treated with wetting agents and alkali (either caustic soda or soda ash) and anti-back staining agents. To avoid the creases the lubrication agent is added.

Using greener chemical removes the need of additional protections and environmental health hazards associated with the strong oxidising agents like KMnO4- the Potassium permanganate.

Since this requires neutralisation process with normal acids, which directly reduces time which is a direct contributor to lesser power consumption and reduced GHG loads.

[11] This figure is considered keeping the average order size of similar recipe (for similar style) which was taken from one order, which normally represents the 30% of their process in a year, while the volume of processing may vary.
If we can increase the lots the volume of production will also increase but the % savings will remain constant.

Other observations: Many factors can play into calculating total processing costs. This case study should not rule out the possibility for savings when switching to sustainable chemicals, sustainable processes like clean Kore dyed denims, lasers and ozone processes.

Annex

ANNEX FOR CASE STUDY A

Costs breakup for the study

S#	Savings by optimizing process modification	Standard process	Optimization	Savings in BDT /per kg	savings in %	savings in € /per kg
1	Water BDT/kg	5.5	3.3	2.2	40%	0.019
2	Steam BDT/kg	114.4	78.1	36.3	32%	0.308
3	Electricity BDT/kg	37.4	26.4	11	29%	0.093
4	Total chemicals cost BDT/kg	214.5	199.1	15.4	7%	0.131
5	Total cost BDT/kg	371.8	308	63.8	17%	0.541

Costs baseline for the study

Cost of water	44	BDT / m^3	0.37	€ / m^3
Cost of wastewater treatment	88	BDT / m^3	0.75	€ / m^3
Cost of Power	14.3	BDT / kWh	0.12	€ / kWh
Cost of steam	8.8	BDT / kg	0.07	€ / kg

Standard process recipe

No of Step	Step Details	g/L	Amount (gram)	Gradient(°C/min)	Temp (°C)	Time (min)	Water (L)
1	***Scouring +Bleaching***						
	Pre-Treatment (Scouring)						80
	Filling				35	5	
	wetting agent	1.5	120				
	stabiliser	0.3	24	3	50	15	
	caustic soda	1	80	3	100		
	hydrogen peroxide	2	160	2	100	30	
	Heating (100°C)						
	Cooling gradient (°C /min)			3	78		
	Drain						

2	***Hot wash***						
	Filling						80
	Hot wash			3	80	10	
	drain						
3	***acid wash***						
	filling						80
	Samneu CAN (Acetic acid)	0.6	48		55	5	0.2
	peroxide killing	0.8	64		55	15	10
4	***Disperse dyeing***						
	Filling				25	5	80
	Sera Gal PSDS (Polyester levelling)		120			3	
	Laucol SRD		235				
	Dekol ACA		250				
	Albatex AB-45 (Buffer)		100				
	Samneu CAN (Acetic acid)		80				
	pH check						
	Samneu CAN (Acetic acid)		30				
	Runtime					10	
	Heating 60C			4			
	Coralene Yellow Brown 2RFL		148			10 (linear)	
	Coralene Navy MD		223				
	Coralene Black MD		78				
	Runtime					5	
	Heating 80C			4	80		
	Heating 135 C			2	135		
	Runtime					25	
	Cooling 78C			2			
	Seracon PACT		300			1	
	Heating 90C			4	98		
	Runtime					20	
	Cooling 75C			4			
	Drain					1	
5	***Washing***						
	Filling				45		100
	Heating 60C			4	60		
	Runtime					10	
	Drain					1	

6	***Enzyme + Reactive Dyeing***						
	Filling				45		100
	Applizyme UAF		5				
	Heating 50C			4	50		
	Runtime				50	20	
	CFTR (Levelling agent)		100			1	
	SFC (Anticreasing agent)		100				
	Salt		8000				
	Runtime				50	10	
	Rema Ult Carmine RGB		56			15 (linear)	
	Rema Ult Black X-SG		264				
	Runtime				50	10	
	Soda		1000			40 (70% progressiv e)	
	Caustic		150				
	Runtime				50	30	
	Heating 60C			4	60		
	Runtime				60	30	
	Drain						
7	***Washing***						
	Filling				45		100
	Heating 60C			4	60		
	Runtime					10	
	Drain						
8	***Neutralizing***						
	Filling				45		100
	Samneu CAN (Acetic acid)		120			1	
	Heating 60C			4	60		
	Runtime				60	10	
	Drain						
9	***Soaping***						
	Filling				45		100
	Serafast CRD (soaping agent)		80				
	SFC (Anticreasing agent)		50				
	Heating 90C			4	90		
	Runtime					10	
	Drain						
10	***Washing***						
	Filling				45		100

	Heating 60C			4	60		
	Runtime				60	10	
	Drain						
11	***Unload***						

Green process recipe

No of Step	Step Details	g/L	Amount (gram)	Gradient(°C/min)	Temp (°C)	Time (min)	Water (L)
1	***Disperse dyeing***						
	Filling				35	5	80
	Check pH = 7.68 Hardness =3.68 ppm TDS= 67.8						
	Sera Gal PSDS (Polyester levelling)		100				
	Seracon PNR (Mild oxidizing agent)		200				
	SFC (Anticreasing agent)		200			3	
	Albatex AB-45 (Buffer)		100				
	Samneu CAN (Acetic acid)		40				
	Fabric loading					5	
	pH check						
	Samneu CAN (Acetic acid)		60				
	Runtime					10	
	Heating 60C			4			
	Dianix Yellow Brown XF		137				
	Dianix Navy XF-2		209			10 (linear)	7
	Dianix Black XF-2		65				
	Runtime					5	
	Heating 80C			4	80		
	Heating 135 C			2	135		
	Runtime					10	
	Cooling 78C			2			
	Seracon PACT		300			1	
	Heating 90C			4	98		
	Runtime					20	
	Cooling 75C			4			

	Drain					1	
2	***Washing***						
	Filling				45		100
	Heating 60C			4	60		
	Runtime					10	
	Drain					1	
3	***Enzyme***						
	Filling				45		100
	Applizyme UAF		5				
	Heating 50C			4	50		
	Runtime				50	20	
	CFTR (Levelling agent)		100			1	
	SFC (Anticreasing agent)		100				
	Salt		8000				
	Runtime				50	10	
	Rema Ult Carmine RGB		56			15 (linear)	
	Rema Ult Black X-SG		264				
	Runtime				50	10	
	Soda		1000			40 (70% progressive)	
	Caustic		150				
	Runtime				50	30	
	Heating 60C			4	60		
	Runtime				60	30	
	Drain						
4	***Washing***						
	Filling				45		100
	Heating 60C			4	60		
	Runtime					10	
	Drain						
5	***Neutralizing***						
	Filling				45		100
	Samneu CAN (Acetic acid)		120			1	
	Heating 60C			4	60		
	Runtime				60	10	
	Drain						
6	***Soaping***						
	Filling				45		100

	Serafast CRD (soaping agent)		80				
	SFC (Anticreasing agent)		50				
	Heating 90C			4	90		
	Runtime					10	
	Drain						
7	***Washing***						
	Filling				45		100
	Heating 60C			4	60		
	Runtime				60	10	
	Drain						
8	***Unload***						

ANNEX FOR CASE STUDY B

Costs breakup for the study

S#	Savings by optimizing process modification	Standard process	Optimization	Savings in BDT /per kg	savings in %	savings in € /per kg
1	Water BDT/kg	7.7	5.5	2.2	29%	0.019
2	Steam BDT/kg	70.4	41.8	28.6	41%	0.242
3	Electricity BDT/kg	16.5	16.5	0	0%	0.000
4	Total chemicals cost BDT/kg	42.9	38.5	4.4	10%	0.037
5	Total cost BDT/kg	134.2	100.1	34.1	25%	0.289

Costs baseline for the study

Cost of Fresh water	44	BDT / m^3	0.37	€ / m^3
Cost of Recycling	88	BDT / m^3	0.75	€ / m^3
Cost of Power	14.3	BDT / kWh	0.12	€ / kWh
Cost of steam	8.8	BDT / kg	0.07	€ / kg
Cost of Thermic heat	28.6	BDT / kWh	0.24	€ / kWh

Conventional acid washing process.

Wash Recipe: OLD											
Sl.	Process	Chemical	Doges /gm	Batch Lot	Quantity (gm)	L. Ratio	Water (L)	Time (Min)	Temp (°C)	pH	Remarks
1	Desize:	Anti slipping Agent AP New	3		1200	01:04	400	5'	50° C		CHECK
		ABS X-7	1		400						
		Dyex DPH	0.75		300						
2		Rinse X1				01:06	600	5'	RT		
		▼			▼		▼		▼		
3	Enzyme:	Setenzyme GAN	2		800	01:04	400	30'	40° C		CHECK
		ABS X-7	2		800						
		New Stone			2 bag						
		Use Stone			1 bag						
4		Rinse X1				01:06	600	10'	RT		
5	Clean:	ONURWET PWD 100	1.25		500	01:04	400	5'	40° C		CHECK
		ABS X-7	1.25		500						
6		Rinse X1				01:06	600	10'	RT		
7	Bleach:	STABLE BLEACHING POWDER (KCl)	10		6000	01:06	600	10'	40° C		CHECK
9		Rinse X2				01:06	1200	10'	RT		

10	Neutral:	Sodium Meta Bisulphite	2.5		1000	01:04	400	10'	40°C		CHECK
		ABS X-7	0.75		300						
12		Rinse X2				01:06	1200	10'	RT		
13	Binder:	BOND SD	1.25		500	01:04	400	5'	RT		CHECK
14		Rinse X1				01:06	600	5'	RT		
			HYDRO + DRYER + PP SPRAY								
15	Bleach:	STABLE BLEACHING POWDER (KCI)	3.33		2000	01:06	600	10'	40°C		CHECK
17		Rinse X2				01:06	1200	10'	RT		
18	PP Neutral:	Sodium Meta Bisulphite	2.5		1000	01:04	400	10'	40°C		
		ABS X-7	2.5		1000						
20		Rinse X2				01:06	1200	10'	RT		
21	Tint:	Red BWS	0.0005		0.2	01:04	400	5'	RT		
		Brown GTL	0.0013		0.5						
		SODIUM SULPHATE (Glauber Salt)	2.5		1000						
		▼			▼		▼		▼		
22	Softener:	BASE ASUMINTER (Antiozon)	1		400			10'	RT	5	OUT

		Dyex DPH	0.5		200	01:04	400				
			HYDRO - 10' min								

Greener acid washing process

Wash Recipe: Green chemistry											
Sl.	Process	Chemical	Doges /gm	Batch Lot	Quantity (gm)	L. Ratio	Water (L)	Time (min)	Temp (°C)	pH	Remarks
1	Desize:	Altranol-DSZL	2.5		1000	01:04	400	5'	40°C		CHECK
		ABS X-7	2		800						
		Dyex DPH	0.75		300						
	Enzyme:	Setenzyme GAN	2		800	01:04		30'	40°C		CHECK
		New Stone			2 bag						
		Use Stone			1 bag						
2		Rinse X1				01:06	600	10'	RT		
3	Clean:	Altranol-DSZL	1		400	01:04	400	5'	40°C		CHECK
		ABS X-7	1		400						
4	Bleach:	STABLE BLEACHING POWDER (KCl)	10		6000	01:06	600	5'	40°C		CHECK
5		Rinse X1				01:06	600	10'	RT		
6		Rinse X1				01:06	600	10'	RT		
7	Neutral:	Sodium Meta Bisulphite	2.5		1000	01:04	400	10'	50°C		CHECK
8		Rinse X1				01:06	600	10'	RT		

9	Binder:	BOND SD	1.25		500	01:04	400	5'	RT		CHECK
10		Rinse X1				01:06	600	10'	RT		
HYDRO + DRYER + PP SPRAY											
11	Bleach:	STABLE BLEACHING POWDER (KCl)	3.33		2000	01:06	600	5'	40° C		CHECK
13		Rinse X2				01:06	1200	10'	RT		
14	PP Neutral:	Sodium Meta Bisulphite	2.5		1000	01:04	400	10'	40° C		
		ABS X-7	2.5		1000						
16		Rinse X2				01:06	1200	10'	RT		
17	Tint:	Red BWS	0.0005		0.2	01:04	400	5'	RT		
		Brown GTL	0.0013		0.5						
		SODIUM SULPHATE (Glauber Salt)	2.5		1000						
		▼			▼		▼		▼		
18	Softener:	BASE ASUMINTER (Antiozon)	1		400			5'	RT	5	OUT
		Dyex DPH	0.5		200	01:04	400				
HYDRO - 10' min											

ANNEX FOR CASE STUDY C

Costs breakup for the study

S#	Savings by optimizing process modification	Standard process	Optimization	Savings in PKR /per meter	savings in %	savings in € /per meter
1	Water PKR/meter	3.98	1.76	2.22	56%	0.007
2	Steam PKR/meter	72.7	40.91	31.79	44%	0.107
3	Electricity PKR/meter	4.33	4.14	0.19	4%	0.001
4	Thermic Heat PKR/meter	6.94	6.27	0.67	10%	0.002
5	Total chemicals cost PKR/meter	26.02	19.45	6.57	25%	0.022
6	Total cost PKR/meter	113.98	72.53	41.45	36%	0.140

- The total chemicals cost is only for the conventional dyeing and pigmentura process.
- Chemicals for the other process not included in the price.

Costs baseline for the study

Cost of water	58	PKR / m^3	0.20	€ / m^3
Cost of wastewater treatment	12	PKR / m^3	0.04	€ / m^3
Cost of Power	17	PKR / kWh	0.06	€ / kWh
Cost of steam	7.5	PKR / kgs	0.03	€ / kgs

Standard process recipe

<table>
<tr><td colspan="4" rowspan="2">Thermosol Dyeing, Reactive Dyeing</td><td colspan="2">Route Status:</td><td>Complete</td><td>Production :</td><td>2,920</td></tr>
<tr><td colspan="4">Actual Padder Pickup :</td><td>72%</td></tr>
<tr><td>F Date</td><td>27-Dec-23</td><td>L Date</td><td>27-Dec-23</td><td rowspan="2">Rate</td><td colspan="3">Actual With Solution Of</td><td>787.29</td></tr>
<tr><td colspan="4">Dyes & Chemicals</td><td>Recipe</td><td>Quantity</td><td>Amount</td><td>Linear</td></tr>
<tr><td colspan="4">LEUCOPHOR BMF LIQ. (CTN OBA) (OEKO)</td><td>505.03</td><td>3.01</td><td>2.37078</td><td>1,197.32</td><td>0.41</td></tr>
<tr><td colspan="4">ARTEX 1000 (ALGINATE)</td><td>2995.25</td><td>2.34</td><td>1.84196</td><td>5,517.13</td><td>1.8894</td></tr>
<tr><td colspan="4">MIGROSTOP CPA (ANTIMIGRATING AGENT)</td><td>411.7</td><td>14.15</td><td>11.14089</td><td>4,586.75</td><td>1.5708</td></tr>
<tr><td colspan="4">NOVACRON BROWN NC (OEKO) (REACTIVE DYES) BI-FUNCTIONAL</td><td>7129.28</td><td>1.61</td><td>1.26501</td><td>9,018.61</td><td>3.0886</td></tr>
<tr><td colspan="4">NOVACRON OLIVE NC (OEKO)
(REACTIVE DYES) BI-FUNCTIONAL</td><td>7993.5</td><td>2.37</td><td>1.86736</td><td>14,926.75</td><td>5.1119</td></tr>
</table>

PRODER M A.C. NUEVO (DETERGENT)	1399.99	1.21	0.95069	1,330.96	0.4558
SYNOZOL GREY K-RF (REACTIVE DYES)	3219.33	9.62	7.57373	24,382.30	8.3501
Process Chemical Cost				60,959.82	20.8767
Pad Steam Dyeing-1, Washing	Route Status:	Complete	Production :		2,930
	Actual Padder Pickup :				51%
F Date 27-Dec-23 L Date 27-Dec-23	Rate	Actual With Solution Of			552.68
Dyes & Chemicals		Recipe	Quantity	Amount	Linear
Antischiuma Neopat NT (OEKO)	1179.4	0.14	0.07893	93.09	0.0318
CHEMITOL WS GRANULES (MILD OXIDIZING)	1031.25	1.57	0.86824	895.37	0.3056
Caustic Soda Liq (50 Percent)	76.23	10	5.52518	421.16	0.1437
Common Salt (Coarse Grade - A50)	8.43	249.93	138.12945	1,164.62	0.3975
PERLAVIN SRD (WASHING AGENT)	598.29	5.71	3.15724	1,888.96	0.6447
Soda Ash (ICI)	95.06	25.71	14.2076	1,350.56	0.4609
Process Chemical Cost				5,813.76	1.9842
Stenter-02 (8F), Finishing	Route Status:	Complete	Production :		2,880
	Actual Padder Pickup :				72%
F Date 28-Dec-23 L Date 28-Dec-23	Rate	Actual With Solution Of			768.67
Dyes & Chemicals		Recipe	Quantity	Amount	Linear
ALKASOFT PEN (POLYETHYLENE)	720	10	7.68673	5,534.44	1.9217
Acetic Acid 99.5%	245.28	1	0.76867	188.54	0.0655
Antischiuma Neopat NT (OEKO)	1179.39	0.26	0.19956	235.36	0.0817
DYMAFIX DM-2558 (FIXER)	622.46	10	7.68673	4,784.70	1.6614

Green Chemistry 'Pigmentura' recipe

Pigmentura 1500	75	g/L
Pigmentura 2000	25	g/L
BezaPrint Blue CCL	2.84	g/L
BezaPrint Red CCG	1.5	g/L
BezaPrint Yellow CCO	1.8	g/L

JobCard.#	**D14703-1223_ P**	**Customer**	Pigmentura black					GSM	119	GLM	373
Design / Color	Dyed / GRIS1		**DyeStuff**	Pigmentura				W.O.F	1,013	JOB Mtrs	2,715
Construction	30/1 COTTON 100% CARDED A/C GOTS X 30/1 COTTON 100%		**G.W**	123"	**P.W**		**F.W**	117" Sqr Mtrs	8,482	Issue Mtrs	2,734
								Job Status:		Complete	
Shade Catego											

Thermosol Dyeing, Pigmentura	**Route Statu**	Complete	**Production :**		2,920	**Recipe :**	D-5068	**Revision :**	1
	Actual Padder Pickup :				72%	**Order Padder Pickup :**			69%
F Dat 29-Dec-23 **L Dat** 20-Dec	**Rate**	**Actual With Solution Of**			787.29	**Order Solution Of**			709.25
Dyes & Chemicals		**Recipe g/l**		**Amount**	**Linear**	**Recipe**	**Quantity**	**Amount**	**Linear**
Pigmentura 1500	680	75	55068.23	37,446.40	13.70	75.00	52,773.72	35,886.13	13.13
Pigmentura 2000	790	25	18356.08	14,501.30	5.30	25.00	17,591.24	13,897.08	5.08
BezaPrint Blue CCL	900	2.84	2085.25	1,876.73	0.69	2.84	1,998.36	1,798.53	0.66
BezaPrint Red CCG	750	1.5	1101.36	826.02	0.30	1.50	1,055.47	791.61	0.29
BezaPrint Yellow CCO	650	1.8	1321.64	859.06	0.31	1.80	1,266.57	823.27	0.30
Process Chemical Cost				**55,509.51**	**20.30**			**53,196.61**	**19.46**

ANNEX FOR CASE STUDY D

Costs breakup for the study

S #	Savings by optimizing process modification	Standard process	Optimization	Savings in BDT /per kg	savings in %	savings in € /per kg
1	Water BDT/kg	1.1	1.1	0	0%	0.000
2	Steam BDT/kg	19.8	14.3	5.5	28%	0.047
3	Electricity BDT/kg	7.7	5.5	2.2	29%	0.019
4	Total chemicals cost BDT/kg	83.6	28.6	55	66%	0.466
5	Total cost BDT/kg	112.2	49.5	62.7	56%	0.531

Costs baseline for the study

Cost of water	44	BDT / m^3	0.37	€ / m^3
Cost of wastewater treatment	88	BDT / m^3	0.75	€ / m^3
Cost of Power	14.3	BDT / kWh	0.12	€ / kWh
Cost of steam	8.8	BDT / kg	0.07	€ / kg

Standard process recipe

1	***Pretreatment***	**%**	**Amount (kg)**	**Gradient (°C/min)**	**Temp (°C)**	**Time (min)**	**Water (L)**
	Filling				40	2	60
	Loading					2	
	EXOVET HPJ	0.70	0.07				
	OPTAVON MEX	0.50	0.05				
	CEFAFLEX ENN	0.20	0.02				
	CAUSTIC SODA	1	0.1		60		
	Run time		0		~~60~~	10	
	HYDROGEN PEROXIDE	1.50	0.15		95	30	
	Cooling		0	4	80		
	Drain					2	
2	***Hot washing***						
	fill				75		60
	Run time	0		3	80	20	
	drain					2	
3	***Neutralising***						
	Filling				40	3	60
	ACETIC ACID	0.50	0.05		40	20	
	Levacol N.conc	0.20	0.02				
	Drain						
4	***unload***		***0.46***				

Green process recipe

No of Step	Step Details	%	Amount (kg)	Gradient (°C/min)	Temp (°C)	Time (min)	Water (L)
1	***Pretreatment***						
	Filling				40	2	60
	Loading					2	
	Biotex NELA	1.50	0.15				
	CAUSTIC SODA	0.65	0.039	3.5			
	Run time		0		60	10	
	HYDROGEN PEROXIDE	8.00	0.48	3.5	105	25	
	Drain			3	78	0	
2	***Neutralization***						
	fill				35		68
	Biotex 50T	0.20	0.02		35	15	
	drain					2	
3	***unload***		***0.689***				

ANNEX FOR CASE STUDY E

Costs breakup for the study

S #,	Savings by optimizing process modification	Standard process	Optimization	Savings in BDT /per kg	savings in %	savings in € /per kg
1	Water BDT/kg	6.6	5.5	1.1	17%	0.009
2	Steam BDT/kg	50.6	42.9	7.7	15%	0.065
3	Electricity BDT/kg	28.6	25.3	3.3	12%	0.028
4	Total chemicals cost BDT/kg	313.5	136.4	177.1	56%	1.501
5	Total cost BDT/kg	399.3	209	190.3	48%	1.613

Costs baseline for the study.

Cost of water	44	BDT / m^3	0.37	€ / m^3
Cost of wastewater treatment	88	BDT / m^3	0.75	€ / m^3
Cost of Power	14.3	BDT / kWh	0.12	€ / kWh
Cost of steam	8.8	BDT / kg	0.07	€ / kg

Standard process recipe

No of Step	Step Details	g/L	QTY (kg)	Gradient (°C/min)	Temp (°C)	Run time (min)	Water (L)
1	**Pre-Treatment**						
	fill				35	3	60
	Fabric loading			3	35	15	
	ALBAFLOW JET	0.05	3				
	FEROL-ZUM	1.2	72		35	3	
	PERSOCLAN STN	0.4	24				
	SCOUR-ZYME	1	60				
	ENZYME BIOZEP 8000L	0.50	30	2	55	40	
	heating			3	95	30	
	Cooling			3	80		
	Drain						
2	**washing**						
	Fill				35	3	60
	Run time			4	35	6	
	Cooling				35		
	Drain						
3	**Dyeing**						
	fill				35	3	60
	SAMNEU CAN	0.6	36	3	60	16	
	PERSOTEX AFC	1	60				
	Areon Extra	0.20	12				
	PERSOTEX -DBN	1.5	90				
	GLAUBER SALT	100.00	6000		60	30	
	Novacron Ruby S-3B	0.084	8.4				
	Nova Dark Blue S-GL	2.20	220				
	Novacron Super Black G	7.70	770	3	60	50	
	SODA ASH	5	300				

	CAUSTIC SODA 20	1.5	90	1	60	105	
	Overflow rinse			6	35	10	60
	drain						
4	**Rinsing**						
	Fill				35	3	60
	Overflow rinse				50	6	
	Drain						
5	**Rinsing**						
	Fill				35	3	60
	Overflow rinse				35	6	
	Drain						
7	**Neutralising**						
	Fill				35	3	60
	SAMNEU CAN	1.50	90	3	40	6	
	Drain						
9	**Soaping**						
	Filling				35	3	60
	Areon Extra	0.2	12				
	RUCOGEN-NZA	0.50	30	4	95	20	
	Over flow washing			2	50	6	60
	drain					2	
10	**Rinsing**						
	Filling				35	3	60
	Rinsing				35	6	
	Drain						
11	**Rinsing**						
	Filling				35	3	60
	Rinsing				50	6	
	Drain						
12	**Rinsing**						
	Filling				35	3	60
	Rinsing				35	6	
	Drain						
13	**Fixing**						
	Filling				35	3	60
	AlBAFIX FRD-T	1.00	60.00				
	SAMNEU CAN	0.60	36.00	2	40	30	
	Drain						

Green process recipe

No of Step	Step Details	g/L	QTY (kg)	Gradient (°C/min)	Temp (°C)	Run time (min)	Water (L)
1	**Pre-Treatment**						
	fill				35	3	60
	Fabric loading			3	35	15	
	FEROL-ZUM	1	60		35	3	
	PERSOCLAN STN	0.4	24				
	Black Diamond	2%	2				
	heating			3	95	30	
	Cooling			3	80		
	Drain						
2	**washing**						
	Fill				35	3	60
	Run time			4	35	6	
	Cooling				35		
	Drain						
3	**Dyeing**						
	fill				35	3	60
	SAMNEU CAN	0.5	30	3	60	16	
	Black Diamond	1%	0.5				
	GLAUBER SALT	80.00	4800		60	30	
	Novacron Ruby S-3B	0.084	8.4				
	Nova Dark Blue S-GL	2.20	220				
	Novacron Super Black G	7.70	770	3	60	50	
	SODA ASH	5	300				
	CAUSTIC SODA 20	1.2	72	1	60	105	
	Overflow rinse			6	35	10	60
	drain						
4	**Rinsing**						
	Fill				35	3	60
	Overflow rinse				35	8	
	Drain						
5	**Rinsing**						
	Fill				35	3	60
	Overflow rinse				50	8	
	Drain						
6	**Neutralising**						
	Fill				35	3	60
	SAMNEU CAN	1.30	78	3	50	10	
	Drain						
7	**Soaping**						
	Filling				35	3	60
	Black Diamond	1.00%	1		95	10	
	drain			3	80	2	
8	**Rinsing**						
	Filling				35	3	60
	Rinsing			3	60	6	
	Drain						
9	**Rinsing**						
	Filling				35	3	60

	Rinsing			3	40	6	
	Drain						
10	**Fixing**						
	Filling				35	3	60
	AlBAFIX FRD-T	1.00	60.00				
	SAMNEU CAN	0.40	24.00	2	40	30	
	Drain						

ANNEX FOR CASE STUDY F

Costs breakup for the study

S#	Savings by optimizing process modification	Standard process	Optimization	Savings in LKR /per kg	savings in %	savings in € /per kg
1	Water LKR/kg	3.06	3.06	0	0%	0.000
2	Steam LKR/kg	45.9	33.66	12.24	27%	0.036
3	Electricity LKR/kg	18.36	15.3	3.06	17%	0.009
4	Total chemicals cost LKR/kg	364.14	315.18	48.96	13%	0.146
5	Total cost LKR/kg	428.4	370.26	58.14	14%	0.173

Costs baseline for the study

Cost of Fresh water	30.0	LKR / m3	0.09	€ / m^3
Cost of water recycling	59.7	LKR / m3	0.18	€ / m^3
Cost of Power	14.1	LKR / kWh	0.04	€ / kWh
Cost of steam	4.9	LKR / kg	0.01	€ / kg
Cost of Thermic Heat	3.1	LKR / kWh	0.01	€ / kWh

Conventional pigment dyeing process

BOM No : FG-08706		Style No : K35379					
Colour :	Pink Interloop	Total fabric :	206				
Step No	**Step Details**	**g/l or %**	**Total Qty In KG**	**Gradient (°C/min)**	**Temp (^{0}C)**	**Time (min)**	**Water**
1	Pre-treatment						
	Sunmorl BH 1000	1g/l	1.2		35	2	1200L
	Felosan RG-N	1g/l	1.2			3	
	Running time			1.5	70	28	
	Drain					2	
2	Hot Rinse				35	2	1200L
	Running time				70	20	

	Drain time					2	
3	Enzyme						
	Biogreen BCGL	0.5g/l	0.6		35	2	1200L
	Acetic acid 99.9%	0.2g/l	0.24			1	
	Running time			1.5	50	29	
	Drain Time					2	
4	Rinse				35	2	1200 L
	Running Time				35	2	
	Drain Time					2	
5	Dyeing Auxilaries						
	Perintrol FHB Conc	2g/l	2.4		35	1	1200 L
	Besol OED	6%	3.6			1	
	Caustic Soda Flakes / Prills	1.5g/l	1.8		50	1	
	Running Time			1.5	50	53	
	Drain Time					2	
6	Rinse				35	2	1200 L
	Running Time				35	2	
	Drain Time					2	
7	Rinse				35	2	1200 L
	Running Time				35	2	

	Drain Time					2	
8	Dyeing						
	Perintrol FHB Conc	2g/l	2.4		35	2	1200 L
	PSI Pink EXF 17	0.41%	0.3313			1	
	PSI Red EXF 13	5.35%	4.28056			0	
	PSI Violet EXF 67	0.05%	0.04056			0	
	Running time			1.5	60	50	
	Dye Fixing						
	Lyoprint PSB	4%	3.2		60	1	
	Binder Rex	4%	3.2			1	
	Acetic acid 99.9%	0.4g/l	0.48			1	
	Running time			1.5	60	30	
	Drain time					2	
9	Rinse				35	2	1200 L
	Running Time			1.5	35	2	
	Drain Time				35	2	
10	Softener						
	Ablusoft ACSK	13.3333g/l	16		35	3	1200 L
	Running Time			1.5	35	5	
	Drain Time				35	2	

Greener pigment dyeing process

BOM No : FG-08706	Style No : K35379					

Colour :	Pink Interloop	Total fabric :	206				
Step No	**Step Details**	**g/l or %**	**Total Qty (Kg)**	**Gradient (°C/min)**	**Temp (^{0}C)**	**Time (min)**	**Water**
1	Pre-treatment						
	Atranol PAC	0.4gpl	0.48				1200L
	Altranol GP	0.4 gpl	0.48		35	2	
	Biogreen BCGL	0.5g/l	0.6		35	2	
	Acetic acid 99.9%	0.2g/l	0.24			1	
	Felosan RG-N	1g/l	1.2				
	Running time			1.5	50	30	
	Drain					2	
2	Rinse				35	2	1200 L
	Running Time				35	2	
	Drain Time					2	
3	Dyeing Auxilaries						
	Perintrol FHB Conc	2g/l	2.4		35	1	1200
	Besol OED	6%	3.6			1	
	Caustic Soda Flakes / Prills	1.5g/l	1.8		50	1	
	Running Time			1.5	50	53	
	Drain Time					2	
4	Rinse				35	2	1200 L
	Running Time				35	5	
	Drain Time					2	
5	Dyeing						

	Perintrol FHB Conc	2g/l	2.4		35	2	1200 L
	PSI Pink EXF 17	0.41%	0.3313			1	
	PSI Red EXF 13	5.35%	4.28056			0	
	PSI Violet EXF 67	0.05%	0.04056			0	
	Running time			1.5	60	50	
	drain						
6	Dye Fixing						1200
	Lyoprint PSB	4%	3.2		35	1	
	Binder Rex	4%	3.2			1	
	Acetic acid 99.9%	0.4g/l	0.48			1	
	Running time			1.5	60	30	
	Drain time					2	
7	Rinse				35	2	1200 L
	Running Time			1.5	35	2	
	Drain Time				35	2	
8	Softener						
	Ablusoft ACSK	3	2.4		35	3	1200 L
	Running Time			1.5	35	10	
	Drain Time				35	2	

ANNEX FOR CASE STUDY G

Costs breakup for the study

S#	Savings by optimizing process modification	Standard process	Optimization	Savings in PKR /per kg	Savings in %	savings in € /per kg
1	Water PKR/kg	5.04	2.64	2.4	48%	0.008
2	Steam PKR/kg	33.73	22.92	10.81	32%	0.036
3	Electricity PKR/kg	39.58	19.57	20.01	51%	0.067
4	Total chemicals cost PKR/kg	84.62	29.86	54.76	65%	0.184
5	Total cost PKR/kg	162.96	74.98	87.98	54%	0.296

Costs baseline for the study

Cost of water	40	Rs / m^3	0.27	€ / m^3
Cost of recycled water	90	Rs / m^3	0.20	€ / m^3
Cost of Power	9.36	Rs / kWh	0.06	€ / kWh
Cost of steam	2.5	Rs / kg	0.03	€ / Kgs
Ratio of fresh water to recycled water		10% : 90%		

Conventional Process

	Process Recipe Details							
Bath	Process	Chemical	dosage	unit	Kg	Value	Time (minutes)	temp
1	Scouring	Wetting Agent	1.50	gpl	9.00		30	98*C
		Lubricant	0.7	gpl	4.20			
		Sequestering Agent	0.5	gpl	3.00			
		Scouring Agent	3.0	gpl	18.00			
		Bleaching Agent	3.0	gpl	18.00			
		Stabilizer	0.3	gpl	1.80			
2	Hot.Wash						10	80*C
3	Hot.Wash						10	70*C
4	Neutralising	Acetic acid	1.8	gpl	10.50		30	50*C

		Core Alkali	0.5	gpl	3.00			
		Killer	0.3	gpl	1.80			
5	Dyeing	Sequestering Agent	0.3	gpl	1.50			
		Levelling Agent	0.3	gpl	1.50			
		Lubricating Agent	0.5	gpl	3.00			
		Jakazol Black CECL	9.5	%	95		146	50*C
		Jakazol Red CE	1.00	%	10			
		Jakazol Yellow CE	0.70	%	7			
		Salt	66	gpl	396.00			
		Soda	10	gpl	60.00			
		Caustic soda Lye	0.75	gpl	4.50		60-90	60*C
6	Cold wash						10	50*C
7	Cold wash						10	50*C
8	Neutralising	Acetic acid	3.5	gpl	21.00		15	60*C
		Core alkali	0.5	gpl	3.00			
9	Hot wash						10	80*C
10	1st Soaping	Soaping Agent	1.5	gpl	9.00		10	90*C
11	2nd Soaping	Soaping Agent	1.5	gpl	9.00		10	90*C
12	Hot wash						10	80*C
13	Cold wash						10	RT
14	fixing	Fixing Agent	2.0	%	20		15	55*C
15	Cold wash						6	RT
	Unloading						10	

Greener chemical Process

	Process Recipe Details							
Bath	**Process**	**Chemical**	**dosage**	**unit**	**Kg**	**Value**	**Time (minutes)**	**temp**
1	Scouring	Wetting Agent	1.50	gpl	9.00		30	98*C

		Lubricant	0.7	gpl	4.20			
		Sequestering Agent	0.5	gpl	3.00			
		Scouring Agent	3.0	gpl	18.00			
		Bleaching Agent	3.0	gpl	18.00			
		Stabilizer	0.3	gpl	1.80			
2	H.Wash						10	70*C
3	Neutralising	Acetic acid	1.8	gpl	10.50		15	50*C
		Core Alkali	0.5	gpl	3.00			
		Killer	0.3	gpl	1.80		15	50*C
	Same bath							
	Dyeing	Sequestering Agent	0.3	gpl	1.50		60-90	60*C
		Levelling Agent	0.3	gpl	1.50			
		Lubricating Agent	0.5	gpl	3.00			
		Jakazol Black CECL	9.5	%	95			
		Jakazol Red CE	1.00	%	10			
		Jakazol Yellow CE	0.70	%	7			
		Salt	66	gpl	396.00			
		Soda	10	gpl	60.00			
		Caustic soda Lye	0.75	gpl	4.50			
4	Cold wash						10	
5	Neutralising	Acetic acid	3.5	gpl	21.00		30	
		Core alkali	0.5	gpl	3.00			
6	1st Soaping	Cyclanon® XCW	1	gpl	6.00		10	90*C
7	Hot wash						10	70*C
8	Cold wash						10	
	Same bath	Fixing Agent	1.0	%	10		15	
	unloading						10	

ANNEX FOR CASE STUDY H

Costs breakup for the study

S#	Savings by optimizing process modification	Standard process	Optimization	Savings in PKR /per kg	savings in %	savings in € /per kg
1	Water PKR/kg	2.59	2.17	0.42	16%	0.001
2	Steam PKR/kg	23.64	19.42	4.22	18%	0.014
3	Electricity PKR/kg	2.97	2.4	0.57	19%	0.002
4	Total chemicals cost PKR/kg	80.4	122.12	-41.72	-52%	-0.140
5	Total cost PKR/kg	110.19	139.55	-29.36	-27%	-0.099

Costs baseline for the study

Cost of water	80	PKR / m^3	0.27	€ / m^3
Cost of wastewater treatment	60	PKR / m^3	0.20	€ / m^3
Cost of Power	18.3	PKR / kWh	0.06	€ / kWh
Cost of steam	8.4	PKR / Kg	0.03	€ / Kg

Standard process recipe

No of Step	Step Details	% owf	**Amount** (gms)	Gradient **(°C/min)**	Temp **(°C)**	Run time **(min)**	Water **(L)**
1	**Pre-Treatment**						
	Argaprep PAST 109 (Wetting agent)	1	788	2	40	3	3900.0
	JINLUBE ECO N825-N (Anti-crease)	0.15	1185				
	SODA ASH	2	16000				
	Raise Temperature 40 to 90			2	90		
	Run Time (30 Mins)				90	30	
	Drain						
2	Filling (for Cold wash)				40		2180.0
	Run time (10 Mins)					10	
	Formic Acid (Neutralizing)	0.6	5000				2180.0
	Run Time (30 mins)					30	
	Drain						
3	Filling						2180.0
	Run time (10 mins)					10	
	Drain						
	Dyeing						
4	JINLUBE ECO N825-N (Anti-crease)	0.1	790				2180.0

	Jinlev CL 250 (Leveler)	0.125	1000				
	Synozol Golden Yellow HF-2GR 150%	0.26	2104				
	Everzol Red 6 BN 150%	0.197	1555				
	Synozol Navy Blue KBF	1.864	14692				
	Refine Salt	38	300000				
	SODA ASH	8	63000				
	Running Time (90 mins)			2	65	90	
	Drain						
5	Formic Acid (Neutralizing)	1.5	16000				2180.0
	Run Time (30)					30	
	Drain						
6	Cold Wash				40		2180.0
	Hot Wash (90 centigrade) for 20 mins			3	90	20	
	Drain						
7	Cold Wash				40		2180.0
	Drain						
8	Cold Wash				40		2180.0
	Drain						
	Neutralising						
9	Citric Acid	0.15	1850		40		2180.0
	Argasoft AC 67 (Softener)	1.5	11820				
	CERANINE CHC 400% PASTILES(Softener)	0.4	3155				
	Drain						
	Unload						

Green process recipe

No of Step	Step Details	% owf	**Amount (**gms)	Gradient **(°C/min)**	Temp **(°C)**	Run time **(min)**	Water **(L)**
1	**Pre-Treatment**						
	Argaprep PAST 109 (Wettting agent)	1	7880	2	90		3877
	JINLUBE ECO N825-N (Anti-crease)	0.15	1182				
	SODA ASH	2	15760				
	Raise Temperature 40 to 90	0					
	Run Time (30 Mins)	0				30	
	Drain	0					

2	Filling (for Cold wash)	0			40		2180
	Run time (10 Mins)	0				10	
	Formic Acid (Neutralizing)	0.6	4728				
	Run Time (30 mins)	0				30	
	Drain	0					
3	Filling	0					2180
	Run time (10 mins)	0				10	
	Drain	0					
	Dyeing	**0**					
4	JINLUBE ECO N825-N (Anti-crease)	0.1	788		40		2180
	Jinlev CL 250 (Leveler)	0.125	985				
	Argazol Yellow GE	0.5	3940				
	Argazol RED GE	0.28	2206.4				
	Argazol Black GE W	4.5	35460				
	Refine Salt	60	472800				
	ASP (Alkali)	2.1	16548				
	Running Time (90 mins)	0			90		
	Drain	0					
5	Cold Wash	0			40		2180
	Drain	0					
6	Cold Wash	0			40		2180
	Drain	0					
7	Hot Wash (70 degree)	0		3	70	30	2180
	Drain	0					
8	Cold Wash	**0**			40		2180
	Drain	**0**					
9	Citric Acid	0.15	1182				2180
	Argasoft AC 67 (Softener)	1.5	11820				
	CERANINE CHC 400% PASTILES(Softener)	0.4	3152				
	Drain						
	Unload						

ANNEX FOR CASE STUDY I

Costs breakup for the study

S #	Savings by optimizing process modification	Standard process	Optimization	Savings in Rs /per kg	Savings in %	Savings in € /per kg
1	Water Rs/kg	2.01	1.83	0.18	9%	0.002
2	Steam Rs/kg	8.63	3.92	4.71	55%	0.053
3	Electricity Rs/kg	4.48	3.75	0.73	16%	0.008
4	Total chemicals cost Rs/kg	5.25	5.29	-0.04	-1%	0.000
5	Total savings Rs/kg	20.37	14.8	5.57	27%	0.063

Costs baseline for the study

Cost of water	40	Rs / m^3	0.45	€ / m^3
Cost of wastewater treatment	90	Rs / m^3	1.01	€ / m^3
Cost of Power	9.3	Rs / kWh	0.10	€ / kWh
Cost of steam	3.25	Rs / kg	0.04	€ / Kg

Standard process recipe

No of Step	Step Details	%	Amount (Kg)	Gradient (°C/min)	Temp (°C)	Time (min)	Water (L)
1	***Pretreatment***						
	Filling				40	2	75
	Loading					2	
	EXOVET HPJ	0.70	0.0665				
	OPTAVON MEX	0.50	0.0475				
	CEFAFLEX ENN	0.20	0.019				
	CAUSTIC SODA	1	0.095		60	~~10~~	
	Run time		0			10	
	HYDROGEN PEROXIDE	1.50	0.1425		95	30	
	Cooling		0	4	80		
	Drain					2	
	Hot washing						
	fill				75		75
	Run time	0		3	80	20	
	drain					2	
4	***Neutralising***						
	Filling				40	3	75
	ACETIC ACID	0.50	0.0475		40	20	
	Levacol N.conc	0.20	0.019				
	Drain						

5	***unload***		***0.437***				

Green process recipe

No of Step	**Step Details**	**%**	**Amount(kg)**	**Gradient (°C/min)**	**Temp (°C)**	**Time (min)**	**Water (L)**
1	***Pretreatment***						
	Filling				40	2	68
	Loading					2	
	ALTRANOL LTB-RS NEW	1.50	0.1425				
	OPTAVON MEX	0.40	0.038				
	CEFAFLEX ENN	0.10	0.0095				
	CAUSTIC SODA	0.8	0.076	3.5	60	~~10~~	
	Run time		0			10	
	HYDROGEN PEROXIDE	1.20	0.114	3.5	75	30	
	Drain					2	
	Hot washing						
	fill				75		68
	Run time	0		3	80	20	
	drain					2	
4	***Neutralising***						
	Filling				40	2	68
	ACETIC ACID	0.50	0.0475		55	20	
	N.conc	0.20	0.019				
	Drain						

ANNEX FOR CASE STUDY J

Costs breakup for the study

S#	Savings by optimizing process modification	Standard process	Optimization	Savings in Rs /per kg	savings in %	savings in € /per kg
1	Water Rs/kg	4.86	3.85	1.01	21%	0.011
2	Steam Rs/kg	0.06	0.05	0.01	17%	0.000
3	Electricity Rs/kg	0.41	0.34	0.07	17%	0.001
4	Total chemicals cost Rs/kg	55.98	50.6	5.38	10%	0.060
5	Total savings Rs/kg	61.32	54.83	6.49	11%	0.073

Costs baseline for the study

Cost of water	80	Rs / m^3	0.90	€ / m^3
Cost of Power	9.35	Rs / kWh	0.11	€ / kWh
Cost of steam	2.3	Rs / Kg	0.03	€ / Kgs

Standard process

No of Step	Step Details	%	Amount(gm)	Gradient (°C/min)	Temp (°C)	Time (min)	Water (L)
1	***PRETREATMENT***						
	Filling				40	3	840
	Loading					10	
	Run time			3	40	12	
	Celldet R	0.50	700				
	Lufibrol 2UD	0.25	350				
	Biavin BPA	1.5	2100				
	Inject		0		40	3	
	CAUSTIC SODA	1.20	1680		60	10	
	Inject						
	PEROXIDE	1.00	1400	3.5	98	30	
	Cooling			3	80		
	Drain						
2	***HOT WASHING***						
	Filling				75	3	590
	Run time			3	80	10	
	Drain					3	
3	***Neutralisation***						
	Filling				40	3	590
	Acetic acid	0.45	630				

	Puranol AR	0.05	70				
	Jintexyme OEM	0.30	420				
	Run time				55	20	
	Drain					3	
4	***Reactive dyeing***						
	Filling			3	60	3	400
	INJECT ADD						
	Setavin RCO	0.500	420				
	BAIVIN BPA	2.000	1680	3	60	10	
	ALABTEX AD	0.500	420				
	ALBATEX AB 55	0.500	420				
	RUN TIME			3	60	10	
	JAKOZOL Yellow DDR	0.100	140				90
	BODACTIVE BLACK PGR	8.000	11200				
	DOSING				60	20	
	RUN TIME				60	30	
	ETP salt	85.00	71400				
	RUN BACK&MIX & INJECT				60	10	
	RUN TIME				60	20	
	SODA ASH	5.00	4200				50
	DOSING				60	10	
	SODA ASH	10.00	8400		60	36	50
	CUASTIC SODA	1.20	1008		60	6	
	DOSING				60	20	
	RUN TIME				60	60	
	Drain					3	
5	***COLD WASH***						
	Filling						590
	Run time				40	10	
	DRAIN					3	
6	***COLD WASH***						
	Filling						590
	Run time				40	10	
	DRAIN					3	
7	***NEUTRALISING***						
	FILLING				40	3	590
	ACETIC ACID	0.45	630		30		
	PURANOL AR	0.05	70				
	RUN TIME					20	
	DRAIN					3	
8	**SOAPING**						
	FILLING				75	3	590
	ALBATEX AD	1.2	1680				
	RUN TIME			3.5	98	10	
	COOLING			3	78		

	DRAIN					3	
9	**SOAPING**						
	FILLING				75	3	590
	ALBATEX AD	1.2	1680				
	RUN TIME			3.5	98	10	
	COOLING			3	78		
	DRAIN					3	
10	***Hot washing***						
	fill				75	3	590
	Run time			3	80	10	
	drain					2	
11	***Cold Washing***						
	Filling				40	5	590
	Runtime				40	10	
	Drain					2	
12	***Dye Fixing***						
	FILLING				50	5	590
	ALBATEX WFF	1	1400		50	20	
	ACETIC ACID	0.1	140				
	Drain					2	
13	***Unload***						

Greener process

No of Step	**Step Details**	**%**	**Amount(gm)**	**Gradient (°C/min)**	**Temp (°C)**	**Time (min)**	**Water (L)**
1	***PRETREATMENT***						
	Filling				40	3	840
	Loading					10	
	Run time			3	40	12	
	Celldet R %	0.50	700				
	Lufibrol 2UD	0.25	350				
	Biavin BPA	1.5	2100				
	Inject		0		40	3	
	CAUSTIC SODA	1.20	1680		98	30	
	Cooling			3	80		
	Drain						
2	***HOT WASHING***						
	Filling				75	3	590
	Run time			3	80	10	
	Drain					3	
3	***Neutralisation***						
	Filling				40	3	590
	Acetic acid	0.45	630				
	Puranol AR	0.05	70				

	Run time				55	15	
	Drain					3	
4	***Reactive dyeing***						
	Filling			3	60	3	400
	INJECT ADD						
	Setavin RCO	0.500	420				
	BAIVIN BPA	1.000	840				
	ALABTEX AD	0.500	420	3	60	10	
	ALBATEX AB 55	0.500	420				
	ETP salt	80.00	67200				
	RUN TIME			3	60	10	
	JAKOZOL Yellow DDR	0.100	140				90
	BODACTIVE BLACK PGR	8.000	11200				
	DOSING				60	20	
	RUN TIME				60	10	
	SODA ASH	15.00	12600		60	10	50
	DOSING						
	CUASTIC SODA	0.90	756		60	20	
	DOSING						
	RUN TIME				60	60	
	Drain					3	
5	***COLD WASH***						
	Filling						590
	Run time				40	10	
	DRAIN					3	
6	***COLD WASH***						
	Filling						590
	Run time				40	10	
	DRAIN					3	
7	***NEUTRALISING***						
	FILLING				40	3	590
	ACETIC ACID	0.60	354		40	10	
	Altraplex XCW	1.00	1400	3	98	20	
	RUN TIME			3	80	5	
	DRAIN					3	
8	**SOAPING**						
	FILLING				75	3	590
	Altraplex XCW	0.40	236				
	RUN TIME			3	80	20	
	COOLING			3	78		
	DRAIN					3	
9	**HOT WASHING**						
	FILLING				75	3	590

	HOT WASHING			3.5	80	10	
	COOLING			3	78		
	DRAIN					3	
10	***Cold Soaping***						
	fill				50	3	590
	Dymax TWE	0.8	472	3	50	20	
	drain					2	
11	***Cold Washing***						
	Filling				40	5	590
	Runtime				40	10	
	Drain					2	
13	***Unload***						

ANNEX FOR CASE STUDY K

Costs breakup for the study

S#	Savings by optimizing process modification	Standard process	Optimization	Savings in LKR /per kg	savings in %	savings in € /per kg
1	Water LKR/kg	42.30	34.24	8.07	19%	0.025
2	Steam LKR/kg	5.33	4.67	0.67	13%	0.002
3	Electricity LKR/kg	14.51	13.78	0.73	5%	0.002
4	Total chemicals cost LKR/kg	46.49	16.28	30.21	65%	0.094
5	Total cost LKR/kg	108.64	68.97	39.67	37%	0.123

Costs baseline for the study

Cost of Fresh water	30	LKR / m^3	0.093	€ / m^3
Cost of Power	14	LKR / kWh	0.016	€ / kWh
Cost of steam	5	LKR T / kg	0.093	€ / kg

Conventional acid washing process

Process step	RPM	MLR 1:X	Water (L)	Time (min)	Temp (ºC)	%	g/l	pH	CHEMICALS & DYESTUFF
DESIZE	28	11.1	1000	15	40	0.6	0.5	-	Rectaze 240
						0.4	0.35		Kaya premium G
RINSE	28	11.1	1000	2	RT	-	-		NOCHEMICAL
ENZYME	28	-		45	RT			6-7	LANZENEVTEX
RINSE	28	11.1	1000	2	RT				Kava premium G
ENZYME	28	-		10	RT			6-7	LANZENEVTEX
RINSE	28	11.1	1000	2	RT	-	-		NOCHEMICAL
WASH	28	8.9	800	5	40	0.4	0.5		SODA ASH

						0.3	0.38		SCAVIN N60
						0.4	0.5		Kava premium G
RINSE	28	11.1	1000	2	RT	-	-		NOCHEMICAL
BLEACH	28	7.8	700	5	RT	1.7	2.14	10 - 11	Bleach Ca(OCL) 2-35%
RINSE	28	11.1	1000	2	RT	-	-		NO CHEMICAL
NEUTRALIZE	28	7.8	700	5	RT	0.9	1.14		Sodium meta Bi sulphate
RINSE	28	11.1	1000	2	RT	-	-		NO CHEMICAL
WASH	28	7.8	700	3	RT	0.8	1.00		Asugal RSL
30 SECOND HYDROACID WASH									
01 TIME PER 15 PCS ACID WASH									
ACID WASH FOR 15pcs									
ACID WASH	28	-		18		0.306			PP washing with pumice
									Sodium sulphate
									(MIX)
ACID WASH / KEEP 10 MIN									
ACID WASH 10 MIN CLEAN									
100 pcs WASH FOR RAMSONS									
NEUTRALIZE	28	5.6		8	40	0.6	1.00		NOVO chlor Neutra AA
						0.6	1.00		Sodium Meta Bi Sulphate
RINSE	28	6.7		8	50	0.3	0.5		SCAVIN N60
									Novo Bio Bright 02
RINSE		6.7		3	RT	-	-		NO CHEMICAL
Tint	28	5.6		1	RT	0.889	4		AsugaL RSL
				1	RT	0.003	0.015		ZETADIRECT BROWN GTL
						0.000	0.002		Solarus Yellow PG

				8	40	2.222	10.000		Sodium sulphate
SOFTNER	28	4.4	400	5	RT	0.10	0.30	5.5	NEUTRACB
									PERRSUSTOL IPS (1:4)
				3	RT	1.10	2.50		Novofinish PF

	Process step	**RPM**	**MLR 1:X**	**Water (L)**	**Time (min)**	**Temp (ºC)**	**%**	**g/l**	**pH**	**CHEMICALS & DYESTUFF**
1	DESIZE	28	11.1	1000	15	40	0.6	0.5		Rectaze Z40
							0.4	0.35		Kaya premium G
	ENZYME	28	-		30	55	1		6-7	LANZENE VTEX
2	ENZYME	28	11.1	1000	12	RT	0.4	0.35		Kaya premium G
						RT	0.3		6-7	LANZENE VTEX
3	WASH	28	8.9	800	5	40	0.4	0.5		SODA ASH
							0.3	0.38		SCAVIN N60
4	RINSE	28	11.1	1000	4	RT				NO CHEMICAL
5	BLEACH	28	7.8	700	5	RT	1.5	2.14	10-11	Bleah Ca(OCL) 2-35%
	RINSE	28	11.1	1000	2	RT				NO CHEMICAL
7	NEUTRALIZE	28	7.8	700	5	RT	0.65	1.14		Sodium meta Bi sulphate
8	RINSE	28	11.1	1000	2	RT				NOCHEMICAL
9	WASH	28	7.8	700	3	RT	0.7	1		Asugal RSL
30 SECOND HYDROACID WASH										
01 TIME PER 15 PCS ACID WASH										
ACID WASH FOR 15pcs										
	ACID WASH	28			18		0.25			Novo-denif&de BE 700
							0.4			Acetic Kid

										(MIX)
ACID WASH / KEEP 10 MIN										
ACID WASH 10 MIN CLEAN										
100 pcs WASH FOR RAMSONS										
10	NEUTRALIZE	28	5.6	500	8	40	0.6	1.00		Novo chlor Neutra AA
							0.4	0.40		Quench - EPN
11	RINSE	28	6.7	600	8	50	0.3	0.50		SCAVIN NGO
							0.4			Novo Bio Bright 02
12	RINSE	28	6.7	600	3	RT	-	-		NOCHEMICAL
13	Tint	28	5.6	500	1	RT	0.889	4		Asugal RSL
					1	RT	0.003	0.015		ZETADIRECTBROWNGTL
							0.000	0.002		Solarus Yellow PG
					8	40	2.222	10.000		Sodium sulphate
14	SOFTNER	28	4.4	400	5	RT	0.10	0.30	5.5	NEUTRA CB
							3.50	2.00		Persustol IPS (1:4)
					3	RT	1.10	2.50		Novofinish PF

Greener acid washing process

	Process step	RPM	MLR 1:X	Water (L)	Time (min)	Temp (ºC)	%	g/l	pH	CHEMICALS & DYESTUFF
1	DESIZE	28	11.1	1000	15	40	0.6	0.5		Rectaze Z40
							0.4	0.35		Kaya premium G
	ENZYME	28			30	55	1		6-7	LANZENE VTEX
2	ENZYME	28	11.1	1000	12	RT	0.4	0.35		Kaya premium G
						RT	0.3		6-7	LANZENE VTEX
3	WASH	28	8.9	800	5	40	0.4	0.50		SODA ASH
							0.3	0.38		SCAVIN N60
4	RINSE	28	11.1	1000	4	RT	-	-		NO CHEMICAL

5	BLEACH	28	7.8	700	5	RT	1.5	2.14	10-11	Bleah Ca(OCL) 2-35%
	RINSE	28	11.1	1000	2	RT	-	-		NO CHEMICAL
7	NEUTRALIZE	28	7.8	700	5	RT	0.65	1.14		Sodium meta Bi sulphate
8	RINSE	28	11.1	1000	2	RT	-	-		NOCHEMICAL
9	WASH	28	7.8	700	3	RT	0.7	1.00		Asugal RSL
30 SECOND HYDROACID WASH										
01 TIME PER 15 PCS ACID WASH										
ACID WASH FOR 15pcs										
	ACID WASH	28			18		0.25			Novo-denif&de BE 700
							0.4			Acetic Kid
										(MIX)
ACID WASH / KEEP 10 MIN										
ACID WASH 10 MIN CLEAN										
100 pcs WASH FOR RAMSONS										
10	NEUTRALIZE	28	5.6	500	8	40	0.6	1.00		Novo chlor Neutra AA
							0.4	0.40		Quenth EPN
11	RINSE	28	6.7	600	8	50	0.3	0.50		Scavin N60
							0.4			NOVO Bio Bright02
12	RINSE	28	6.7	600	3	RT	-	-		NOCHEMICAL
13	Tint	28	5.6	500	1	RT	o.889	4		Asugal RSL
					1	RT	0.003	0.015		ZETADIRECT BROWN GTL
							o,ooo	0.002		Solarus Yellow PG
					8	40	2.2220	10.000		Sodium sulphate
14	SOFTNER	28	4.4	400	5	RT	0.10	0.30	5.5	NEUTRA CB
							3.50	2.00		Persustol IPS (1:4)
						RT	1.10	2.50		Novofinish PF