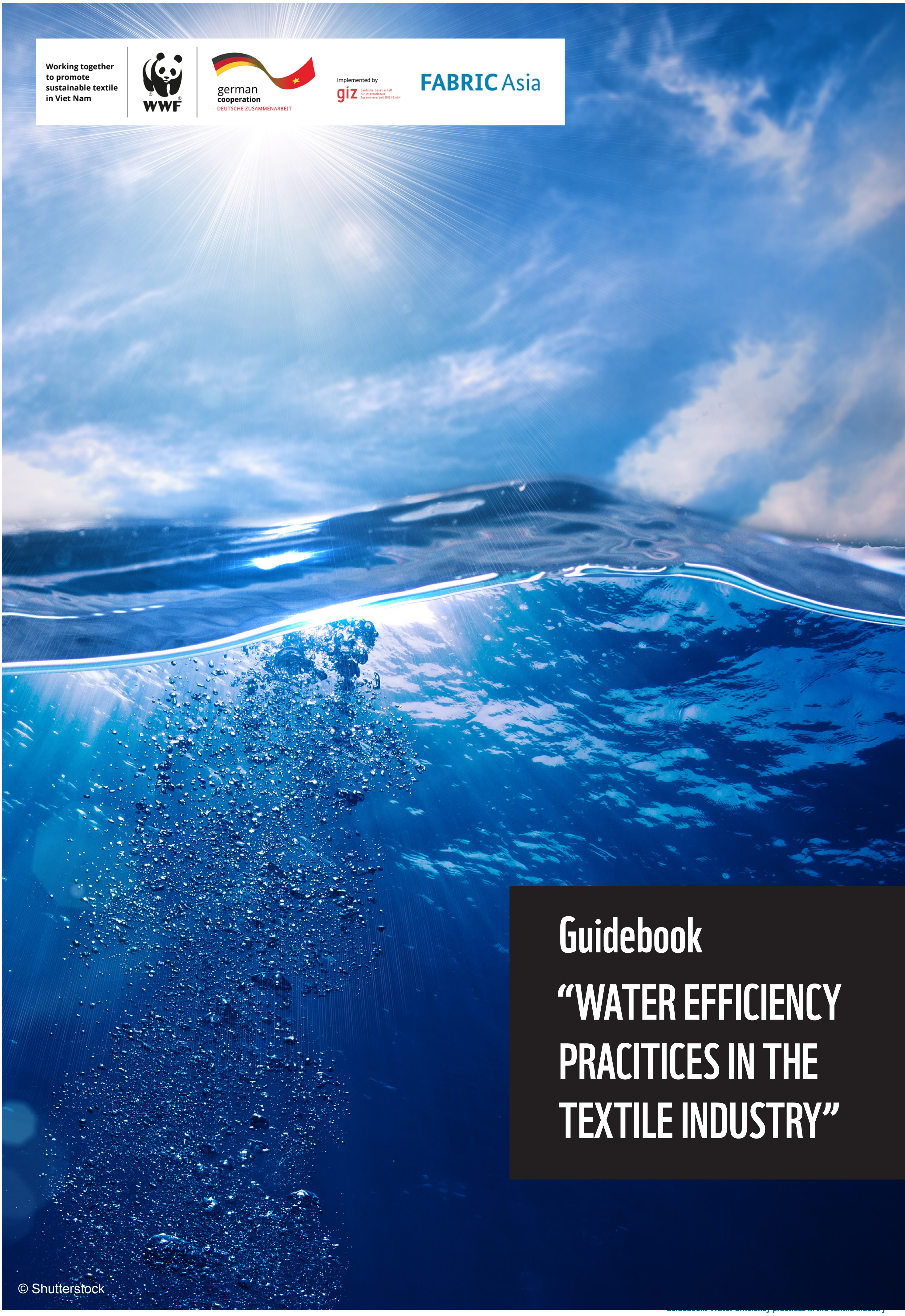
Working together to promote sustainable textile in Viet Nam



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Guidebook

"WATER EFFICIENCY PRACITICES IN THE TEXTILE INDUSTRY"

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01.

General introduction

Domestic fabric production and finishing has abundant space to expand in the context Viet Nam aims for more added value from international trade of textile and garment goods. Fabric makes up high proportion in total value of apparel products. In addition, new generation trade agreements such as CPTPP and EVFTA set rules to cut down tariffs if manufacturers meet the sourcing requirements, either "from yarn forward" or "from fabric forward". Obstacle to the textile expansion is the concern of government authorities and communities on its environmental impacts, including large water and energy consumption, and wastewater pollution. Depletion of natural resources will lead the government action to tighten environmental regulations, by cutting down withdrawal threshold, and increasing resource prices and discharge fees. This is a paramount operational risk for textile factories. Now is the right time for businesses in the industry to seek and invest in water and energy efficient and circular solutions to reduce production costs, increase competitiveness, ensure business continuity and sustainability, and at the same time, enhance business image and brand value regarding environment performance.

According to the theory of change, behavior change begins with a change in awareness and knowledge for stakeholders. This **Guidebook of water efficiency practices in the textile industry** is a compilation of good practices in textile dyeing factories to equip technical teams and managers with the technical knowledge and tools on water saving solutions. These practical down-to-the-ground contents aim to provide guidance on the suitability of each practice to specific factory context and analysis of environmental and cost-benefit effectiveness, as a basis for factories to make investment decisions and then implement technical and management processes to apply a practices.

This product is the most important output of the Project "Enhancing Water Efficiency in the Textile industry", funded by the Fabric Asia Project of the German Agency for International Cooperation (GIZ) and implemented by World Wide Fund for Nature (WWF). The Deutsche Gesellschaft für Internationale Zusammenarbeit (GIZ) GmbH implements the project FABRIC Asia (Promotion of a Sustainable Textile and Clothing Industry in Asia) on behalf of the German Federal Ministry for Economic Cooperation and Development (BMZ). FABRIC Asia supports the Asian textile industry in its transformation towards fair production for people and the environment. Together with other training materials of WWF-Viet Nam's "Greening the Textile and Garment Industry" Program, we look forward to contributing to the transformation of the textile and garment industry to be more sustainable and environmentally friendly, realizing the new brand "Sustainable Made in Viet Nam" instead of "Made in Viet Nam" as nowadays.

This guidance document was compiled by the Research and Development Center for Energy Efficiency (ENERTEAM) based on aggregated information from water and energy audits at textile dyeing plants, collection of water efficiency practices and related data shared by textile dyeing mills, training materials and lectures in relevant workshop, as well as from materials from GIZ's Fabric Asia Project and technical contributions of various organizations.

1.1. Objectives

The objective of this document is to synthesize good practices on reduction of water consumption and wastewater discharge in textile dyeing process for factories to consider adopting, aiming to mitigate the water footprint of the textile dyeing industry and at the same time, save water-related production costs, wastewater, chemicals and energy for business.

Specific objectives include:

• To provide technical knowledge on potential water-saving practices for textile wet processing factories;

• To assess the applicability of practices to specific factory condition and production system;

• To suggest the calculation of potential savings and analysis of cost-benefit for each practice;

• To introduce example, or case study of successful application of each practice;

• To list out application restrictions of each practice for factories to be aware of before making decisions.

1.2. Target audience

The guidebook introduces water efficiency solutions for textile and garment factories with wet processes such as dyeing and finishing fabric or washing garments.

Target audience of this guidebook include:

• Technical staff in charge of wet processes such as fabric dyeing and finishing, garment washing;

•Officer in charge of water supply and wastewater treatment system

• Maintenance officers of equipment and machinery systems

• Environmental compliance team

• Production manager, system manager

• Factory leaders

1.3. Document structure

This guidebook is structured into four parts as follows:

Part 1: General Introduction

Part 2: Water use in textile factories

Part 3: Water saving solutions in the production process

Part 4: Water saving solutions outside the production process

02. Water use in textile factory

Fabric dyeing and finishing process consists of many different stages depending on the type of fabric, dyed color and product characteristics. It is often divided into 3 main stages:

• Pretreatment: including stages such as singeing, desizing, scouring and bleaching, mercerising;

• Dyeing, printing: color fixation on fabric or fiber, including washing

• Finishing: drying, stentering, calendering, softening and other dry finishing stages.

Fabric is often washed several times between stages.

The Figure below describes typical stages in the fabric dyeing process.

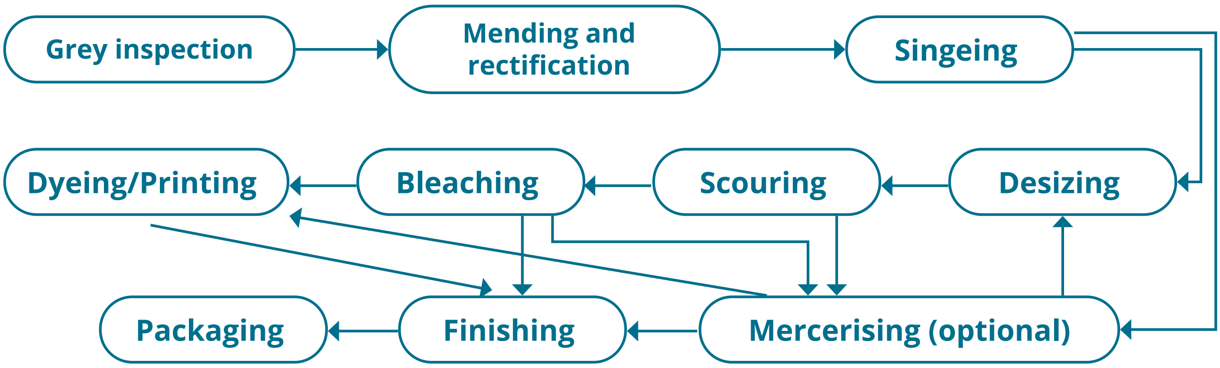


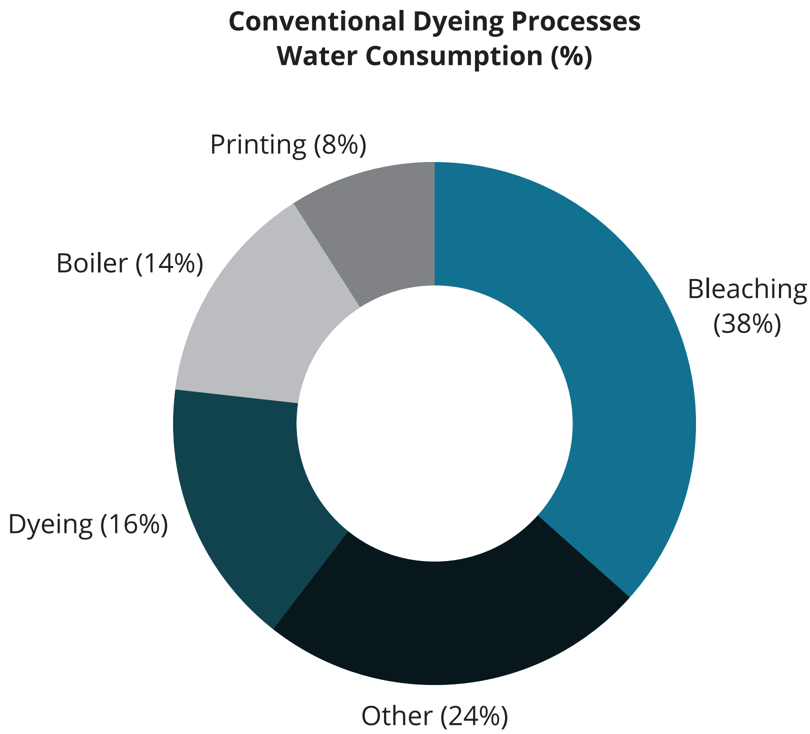
Figure 1. *Basic stages in dyeing cotton fabric*

In the wet process, water is used mainly for two purposes. Firstly, as a solvent for processing chemicals. Secondly, it is used as a means of washing, rinsing and sanitizing. In addition, water is consumed during ion exchange, boilers, cooling water, drying and steam cleaning.

Dyeing process can take place at different players in the supply chain, from fiber manufacturer, yarn spinner, fabric mill or garment factory. The environmental impact of the dyeing process depends on the type of dyestuffs, of textile material, deployed method, and the overall desired effect on dyed object. In general, the treatment process requires a significant amount of water and energy due to the use of various chemical and hot washing baths. Numerous chemicals used in the wet process exhausted to wastewater also causes degradation in natural water quality.

Water supply required for textile wet processing is large and varies from factory to factory, depending on fabric type, dyeing technology, recipe, equipment and dyestuffs. The longer the treatment sequence, the higher the amount of water consumed. Much of the water is used for washing at the end of each process.

A typical textile company uses approximately 350-500 kg of chemicals for a ton of fabric, but only 15-20% is fixed to the product. Rigorous testing of dyeing and washing formulations, replacing toxic chemicals with less hazardous ones and reducing the number of auxiliaries is some most important and effective measures to mitigate the pollution casued by the dyeing process. In addition, improving the use of chemicals in each process has been shown to have a significant effect on reducing some washing steps. Thermal energy is mainly used for heating water and drying step. Therefore, energy savings can also be achieved through reducing water consumption.



Source: Birla cellulose

Figure 2. *Water use in dyeing factory [1]*

03.

Water saving practices in the production processes

Water efficiency practices introduced in this guidebook are divided into three groups based on technical characteristics, including:

• Production process improvement and optimization practices;

• Water recovery and reuse practices;

• Technology and water-saving equipment investments

3.1. Production process improvement and optimization practices

3.1.1. REDUCING MATERIAL LIQUOR RATIO (MLR) OF DYEING AND WASHING MACHINES

Technical description

Material Liquor Ratio (MLR) is the ratio of material weight to water, an operating parameter to determine the volume of water loaded into the machine for each bath of the non-continuous dyeing or washing process. The lower the ratio, the more water is saved. The ratio is applied depending on machine configuration, product characteristics, and operator experience. MLR ranges from 1:4 to 1:20, of which the most common is 1:8-1:10. MLR affects the quality or intended results of the dye batch, for which factories often choose to operate at a high ratio. This choice causes waste of water, chemicals used for the recipe and energy to heat the water. To save resources in dyeing and washing plants, the ratio should be applied as low as possible without affecting the quality or intended results of the dye batch.

How low MLR can be reduced depends on:

• Whether dyeing machine configuration is suitable for low ratio dyeing;

• Type, weight, and fabrication of dyed materials (easily broken, creased);

• Category of dyestuffs (disperse, reactive, vat). Certain vat dyes cannot be used at low ratio as once fabric is more exposed to air, it is prone to uneven color.

Some factories have gradually tested and successfully applied lower MLR on existing dyeing/washing machines, thus be able to avoid high investment on new machines. Today, the low ratio commonly practiced at existing dyeing/ washing machines is 1:6. Some factories invest in modern dyeing machines, which can lower the ratio to 1:3, or 1:5, but this application is still limited.

The factory can flexibly apply different ratios in the process, depending on each stage's sophistication and expected product quality.

Benefits/impacts

Operating dyeing machines and washing machines at low MLR offers the following benefits:

• Saving water costs and wastewater treatment

• Saving energy for heating water in the process

• Saving chemicals, reducing pollutants load in wastewater

• Shortening processing time for heating up and cooling down water

Scope of application

Apply to discontinuous washing, dyeing machines.

Data to be measured/collected to calculate economic benefit

To calculate environmental and economic benefits for the practice of Reducing Material Liquor Ratio (MLR) of dyeing and washing machines, Table 1 lists out parameters to be collected.

Table 1. *Calculation of economic benefits for the solution of Reducing MLR of dyeing and washing machines*

No.	Parameter	Unit	Source
1	Production volume applied for the solution	kg/year	Propose
2	Gap between high versus newly-applied low MLR	kg of water/ kg of fabric	Factory
3	Number of water refills in the process	times	Factory
4	Water savings	m^3/year	(6)=(2)*(5)*((3)/1000
5	Water costs (supply water and wastewater costs)	VND/m^3	Factory
6	Water cost savings	million VND/ year	(6)=(4)*(5)
7	Heat savings	MJ/year	Calculate
8	Fuel savings	tons/year	Calculate
9	Fuel price	VND/kg	Factory
10	Fuel cost savings	million VND/ year	(10)=(8)*(9)/1000
11	Total cost savings	million VND/ year	(11)=(6)+(10)
12	Greenhouse gas emissions reduction	tons of CO_2/ year	Calculate

The water and steam saving benefits from applying this practice vary depending on the type of dyeing machines, dyeing techniques and product property requirements.

• Water savings: 1%-12%

• Steam savings: 0.5%-5%

Case study:

A textile dyeing factory has the total fabric output of around 21,500 tons in 2021. The factory uses 17 A.K high pressure dyeing machines for polyester fabric dyeing and 30 Dong A low pressure dyeing machines for cotton fabric dyeing. The factory has successfully tested and applied low MLR of the A.K series from 1:10 to 1:7-8 and the Dong A series from 1:6 to 1:4-5, bringing the following saving values:

• Water savings: 3.8%, equivalent to 79,919 m^3/year

In particular, 2.6% water saving from applying low MLR to cotton fabric, 1.2% saving from polyester fabric.

• Steam savings: 1.7%, equivalent to 9,100 tons/year

In particular, 0.9% steam saving from applying low MLR to cotton fabric, 0.8% saving from polyester fabric.

• Savings amount: 3.75 billion VND/year (including water and steam cost savings). *In particular, 3.4 billion VND saving from applying low MLR to cotton fabric, 1.35 billion VND saving from polyester fabric.*

• Payback period: Instant

Application restrictions

• Machine configuration: for Jet machines which use water force to push the fabric, the amount of water pumped into the machine must be above the minimum water level that the machine can operate. Therefore, it is necessary to consider the configuration of the machine to determine the appropriate minimum ratio.

• Type of fabric: thickness, water absorbency and fabric characteristics.

- If the fabric is too thick, the fabric surface is easily broken, creating wrinkles that cannot be repaired.

- If the fabric is too thin: To use a desired low ratio, more fabric should be loaded into one batch. Fabric rope will be very long, likely to cause dyeing faults such as color unlevelling or fabric tangling.

• Type of dyestuffs: depending on the color fixation ability of dye to the fabric, an appropriate ratio must be chosen to ensure even color. Dyeing cotton fabric with reactive dyes is more susceptible to fading due to color fixation by alkali. Applying low-ratio dyeing on polyester is less problematic than cotton fabric.
• Some employees are hesitated to operate at low ratio due to quality control challenges.

3.1.2. IMPROVING PRETREATMENT PROCESS

Technical description

Polyester fiber and fabric are usually pre-scoured by preliminary continuous scouring machine or discontinuous dyeing machines to remove oil and contaminants before dyeing. To save resources, some factories has combined oil removal and dyeing in one bath. The modified process is as follows:

Table 2. *Modified process*

Step No.	Traditional process	Tem-perature	Time	New process suggested for lab and bulk trial	Tem-perature	Time	Notes
1	Water input			Water input			
2	Fabric loading			Fabric loading			
3	Oil removal	80°C	20 mins				Skip
4	Drain off						Skip
5	PES dyeing	130°C		PES dyeing	130°C		Combine oil removal and disperse dyeing
6	Cooling down and draining off	80°C		Cooling down & drain	80°C		
7	Alkali reduction clearing	70°C		Alkali reduction clearing	70°C		
8	Neutralise			Neutralise			
9	Hot rinsing			Warm rinsing			
10	Fabric unloading			Fabric unloading			

To successfully apply this combination, it is necessary to select appropriate specialized sufactants, which works effectively at a high disperse dye temperature (130°C) to wash and help absorb and emulsify oil.

Benefits/impacts

• Save water and steam costs;

• Save time from combing process steps, which in turn increase machine productivity

Scope of application

• Applicable to factories that have knitted polyester fabric

• Dyeing process comprises of oil removal step

Data to be measured/collected to calculate economic benefit

Calculation of the environmental and economic benefits for the solution of improving pretreatment process is guided in Table 3.

Table 3. *Calculation of economic benefits for the solution of improving pretreatment process*

No.	Parameter	Unit	Source
1	Polyester fabric volume applied	kg	Factory data
2	Material liquor ratio	liter/kg	Factory data
3	Number of washing baths skipped off	step	2
4	Water savings in 1 year	m^3	(4)=(1)*(2)*(3)/10^6
5	Water price	VND/m^3	Factory data
6	Water cost savings	million VND/ year	(6)=(4)*(5)/10^6
7	Heat savings	MJ/year	Calculate
8	Steam savings	tons/year	(8)=(7)*boiler efficiency%/ steam latent heat
9	Average steam price	VND/tons of steam	Factory data
10	Steam cost savings	million VND/ year	(10)=(8)*(9)/10^6
11	Total cost savings	million VND	(11)=(6)+(10)
12	Investment costs	million VND	None, only changes in operating costs due to oil removing agent changes
13	Payback period	year	Immediately

Applying this practice in some factories brings about following savings:

• Water savings: 0.4-3.1%

• Steam savings: 0.4-4%

Case study:

A factory has the dyeing output of 10,890 tons/year, of which polyester fabric is 3,668 tons/year. It combined oil removal and disperse dyeing in one bath for 30% of polyester output and realized the following benefits:

• Water savings: 1.3%, equivalent to 15,406 m^3 of water/year

• Steam savings: 1.3%, equivalent to 819 tons/year

• Savings amount: 586 million VND/year

Application restrictions

• This practice is more suitable for knitted polyester yarn and fabric as no sizing is applied at the knitting stage. Other contaminants remaining on yarn or fabric such as machine oil, silicone oil can be easily removed by sufactants with washing, padding and emulsifying functions

• Unlike knitted material, woven polyester fabric contains sizing agent such as polyvinyl alcohol, polyacrylic ester which is not easily washed off by ordinary sufactants

• Specialized sufactants play an important role for this combination practice. Factory needs to work with chemical suppliers for advice and testing.

• No special pH is required for wet absorbents and specialized oil emulsifiers to work. pH at 4 to 4.5 creates good effect for disperse dyeing

3.1.3. IMPROVING WASHING PROCESS AFTER REACTIVE DYEING

Technical description

Removing unfixed dye on fabric and fiber surfaces is an important point for obtaining dyed products with high color fastness.

After reactive dyeing, cotton fibers, salts and unfixed dyes remain on the surface of the fabric are washed several times, usually 6-8 times at different temperatures, including 1 or 2 hot washes at 85-95^{o}C depending on dyed color. Some new soaping and fixing agents can shorten the process by up to 2 washes, saving water, energy and shortening process time. In the figure below, the usual process on the left has 5 washes after dyeing at different temperature levels, from 50oC to 100oC. When testing new washing chemicals and fixing agents, washing process can be reduced to 3 times, with a maximum temperature of 50^{o}C.

Traditional laundry

New detergents

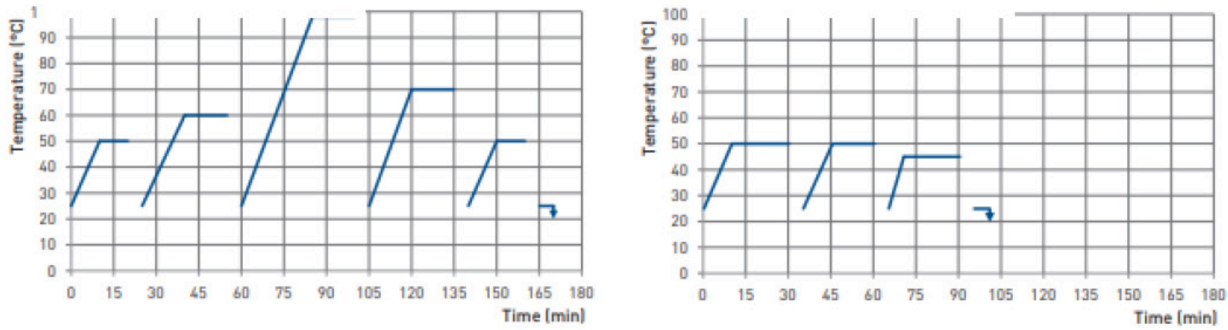


Figure 3. *Improvement of the washing process after active dyeing*

Benefits/impacts

• Save water and steam costs

• Reduce the number of washes, shorten production time, increase productivity

• Reduce greenhouse gas emissions

Scope of application

Applied to active dyeing factories for cotton fabrics, yarns, shirts, pants, etc.

Data to be measured/collected to calculate economic benefit

Calculation of the environmental and economic benefits for the solution of improving washing process after reactive dyeing is guided in Table 4.

Table 4. *Calculation of economic benefits for the solution of improving washing process after reactive dyeing*

No.	Parameter	Unit	Source
1	Production volume applied for this solution	kg	Factory data
2	Material liquor ratio	liter/kg	Factory data
3	Number of washing steps skipped	step	(depending on the existing process of the factory, 1-3 steps)
4	Water savings in 1 year	m^3	(4)=(1)*(2)*(3)/10^6
5	Water price	VND/m^3	Factory data
6	Water cost savings	million VND/ year	(6)=(4)*(5)/10^6
7	Heat savings	MJ/year	Calculate
8	Steam savings	tons/year	(8)=(7)*boiler efficiency%/ steam
9	Average steam price	VND/tons of steam	Factory data
10	Annual steam cost savings	million VND	(10)=(8)*(9)/10^6
11	Total savings	million VND	(11)=(6)+(10)
12	Total cost savings	million VND	None, only changes in operating costs due to dyeing agent changes
13	Payback period	year	Immediately

Note: *Steam latent heat = steam enthalpy – Enthalpy of boiler feed water (Two enthalpy values can be searched in the following table: Saturated Steam - Properties for Pressure in Bar (engineeringtoolbox.com)) [2]*

Case study:

A garment washing factory improved the post-dyeing washing process, using a new detergent system, and realized the following economic benefit:

- Water savings: 32% of water used for washing
- Washing time: 13%, from 75 minutes to 65 minutes
- Thermal energy saving: 40%, from reduction of washing temperature from 80°C to 50°C

Specifically, the improvement process and results are illustrated in the table and figure below:

Table 5. *Experimental washing process at a factory*

Stage	H_20_2 (l)	T°C	Time (mins)	Stage	H_20_2 (l)	pH	T°C	Time (mins)	Notes
POST-DYEING WASHING PROCESS (CURRENT WASHING AGENT)				POST-DYEING WASHING PROCESS (NEW WASHING AGENT)					
1st water draining	1,200		5	1st water draining	1,200			5	
2nd water draining	1,200		5	2nd water draining	1,200			5	
Neutralizing (0.8kg)	800		5	Washing at 60°C (0.8kg)	800			15 + 10	
3rd water draining	1,200		5	Neutralizing (0.5kg)	800			5	
4th water draining	1,200		5	3rd water draining	1,200			5	
Washing at 80°C (0.8kg)	800	80	30 + 10		5,200 liters H_2O_2			43	Skip to the Silicon softening process if color fixing is not required
5th water draining	1,200		5	Color fixing	800		45	20	
6th water draining	1,200		5						
Total	8,800 liters H_2O_2		75	Color fixing	6,000 liters H_2O_2			65	

Figure 4. *Fabric pattern after color fixing*

Application restrictions

This solution requires change in washing chemicals, fixing agents and specific application process, depending on the current dyeing formula (dark, medium dark, special, etc.) and dyed objects (fabrics, yarns). Therefore, the factory should work with chemical suppliers to provide a laboratory test sample, or start with small batch first.

References – Appendix

Engineering ToolBox (2003), Saturated Steam - Properties for Pressure in Bar, URL: <https://www.engineeringtoolbox.com/saturated-steam-properties-d_457.html>

3.1.4. AUTOMATIC WATER SUPPLY CONTROL FOR WET TREATMENT EQUIPMENT

Technical description

Discontinuous washing and dyeing machines are filled up with water several times during the wet treatment process. Due to diverse requirements for product quality, dyeing and washing recipes need to be followed exactly on the machine. Hence, the amount of water supplied to the machine is an important parameter to control.

Figure 5. *Manual water supply washing machine at a factory*

Majority of fabric dyeing machines are equipped with automatic water supply valves. However, some garment washing factories still use belly washing machines that are not equipped with automatic water supply control systems.

In a manual water supply washing machine, worker opens the manual water pump valve, observes the water level showed by the water level gauge, and then locks the valve. If more water is pumped to the machine than required, excess water will be discharged, thus wasting clean water and increasing the volume of wastewater to be treated. This manual water supply operation is more likely to cause wrong amount of water in the machine, leading to wrong chemical to water dosing compared to the standard recipe, affecting product quality and doubling production resources for rework.

A garment washing factory that is using horizontal washing machines has installed an automatic water supply system for existing washing machines to enable more accurate water refilling (Figure 6). The new controller, however, can only set 4 levels of water supply, including 1,000 liters, 1,200 liters, 1,500 liters and 1,600 liters, thus limiting the flexibility to apply low liquior ratios for different steps in the process.

Figure 6. *4-level automatic water supply system at a factory*

Figure 7. *Automatic water supply controller at a factory*

Figure 7 illustrates the automatic water supply controller installed on horizontal drum washers to accurately supply water to the washing machine and optimize the liquor ratio for each stage. The system consists of a microcontroller and radar sensors that can flexibly set different water levels.

Benefits/impacts

• Accurately determine the amount of water pumped to each batch of washing /dyeing, avoiding excess water waste.

• Reduce the costs for incoming water, wastewater treatment and environmental protection fees for wastewater.

Scope of application

Factories that use manual dyeing/ washing machines.

Data to be measured/collected to calculate economic benefit

Calculation of the environmental and economic benefits for the solution of installing automatic water supply unit (Automatic water supply control for wet treatment equipment) is guided in Table 6.

Table 6. *Calculation of economic benefits for the solution of installing automatic water supply unit*

No.	Parameter	Unit	Source
1	Production volume applied	kg/year	Factory data
2	Average number of water refill times	times	Factory data
3	Current material liquor ratio		Factory data
4	% water savings	%	5 - 10
5	Water savings	m^3/year	(5)=(1)*(2)*(3)*(4)/10^6
6	Water and wastewater treatment costs	VND/m^3	Factory data
7	Total water cost savings	million VND/year	(7)=(5)*(6)/10^6
8	Total investment costs	million VND	Supplier
9	Payback period	year	(9)=(8)/(7)

Installing an automatic water supply controller often save from 1-10% water compared by manual water supply.

Case study:

A laundry factory has invested in automatic water supply controllers for 20 horizontal washing machines. These washing machines are operated at the MLR of 1:10 and take 7 baths per washing process. The factory applied this practice for an year production of 2,185,120 kg fabric and was able to cut down water use to 260,575 m^3 year. The savings values brought are as follows:

- Water savings: 1.9%, equivalent to 7,648 m^3 of water/year
- Savings amount: 206 million VND/year
- Investment costs: 728 million VND (20 controllers)
- Payback period: 3.5 years

Application restrictions

• Water level of automatic controller should be standardized on a periodic maintenance schedule.

• The amount of water supplied to washing/dyeing machine should be accurately calculated based on production output and Material Liquor Ratio per wash/dye.

• Observation of water level gauge: Actual water level in the machine might be different to the water level observed through the water gauge due to the pump operation. The gauge is usually standardized by the machine engineer by putting a specified amount of water into the empty drum when the pump is not working. When the machine is in operation, its drum contains dry or wet fabric, and pump is running, the observation of water level through the gauge is no longer accurate. Therefore, water level gauge must be re-standardized by the factory.

• It is recommended to install water meter for each machine to define the exact amount of water supplied to the machine.

• Setting the volume of water for following bath should subtract the water amount absorbed by processed fabric. The absorbency capacity of fabric items varies, with the usual level being 100% fabric weight (1 liter of water is absorbed in 1kg of fabric).

• Dyeing or washing machines with manual water supply are often outdated model and operate at high MLR. Therefore, even if an automatic water supply controller is equipped, they still consume a great amount of water. Facilities need to consider for replacement with new models which have low ratio and

3.2. Water recover and reuse practices

3.2.1. RECIRCULAT ING COOLING WATER OF DYEING MACHINE

Technical description

This practice can be applied to discontinuous dyeing process at high temperatures above 70°C such as polyester disperse dyeing at 120-135°C, post-dyeing reduction clearing at 80°C - 85°C, cotton bleaching at 95°C, reactive washing at 95°C, etc. When these processes end, water in the machine must be lowered to 70-80°C before draining off or for taking sample of processed fabric to check the color shade.

Water in dyeing machine is cooled down by exchanging heat with clean water at room temperature and then this flow of heated clean water is often drained off, which is a waste of resource. Therefore, to collect this amount of water, there needs a heat exchanger, collection tank and pipeline. Using heat exchanger, clean water is heated to the temperature of about 50-60°C. This amount of hot water can then be stored in hot water tanks and supplied to the dyeing and washing process, saving water, as well as energy and time for heating the feed water. [3]

Figure 8. *Heat exchanger and cooling water pipeline to the storage tank for circulation*

Most of the new dyeing factories have already built in the cooling water recovery system. Old machines without this sytem are highly recommended for this practice.

Benefits/impacts

• Water saving: By applying the above solution, the factory can save the cost of water supplied into the process, the cost of wastewater treatment when discharged and the discharge fee into the industrial park for treatment.

• Reduce steam consumption to heat feed water into the dyeing process, reduce greenhouse gas emissions.

• Save a great amount of time executing technological processes.

Scope of application

Suitable to apply to discontinuous dyeing machines cooled by indirect water and not yet designed with cooling water recovery systems.

Data to be measured/collected to calculate economic benefit

Calculation of the environmental and economic benefits for the solution of recirculating cooling water of dyeing machine is guided in Table 7.

Table 7. *Calculation of economic benefits for the solution of recirculating cooling water from dyeing machine*

No.	Parameter	Unit	Source
1	Amount of cooling water[1]	m^3/year	Measure or estimate
2	Water costs (including supply water and wastewater)	VND/m^3	Factory
3	Water cost savings	million VND/year	(3)=(1)*(2)/10^6
4	Heat savings	MJ/year	(4)=4.18*(1)*(60-30)
5	Steam savings	tons/year	(5) =(4)*boiler efficiency%/ steam latent heat
6	Average steam price	VND/tons of steam	Factory
7	Steam cost savings	million VND/year	(7) =(5)*(6)/10^6
8	Total cost savings	million VND/year	(8) =(3)+(7)
9	Investment costs (storage tanks, pipelines)	million VND	Supplier
10	Payback period	year	(10)=(9)/(8)

Factories build a cooling water recovery system and gain following saving benefits: Water savings: 2-10% and steam savings: 0.1-1.5%.

Case study:

At a textile dyeing factory majors in polyester fabrics has an annual output of 6,000 tons. The factory applied this practice on its Jet machines (MLR of 1:8) by installing 2 more overhead storage tanks and connecting pipelines to dyeing machines and sanitary areas. The saving values are as follows:

- Water savings: 7%, equivalent to 57,800 m^3 of water/year
- Steam savings: 0.7%, equivalent to 878 tons/year
- Savings amount: 1.38 billion VND/year
- Investment costs: 1 billion VND
- Payback period: 0.7 years

[1] The amount of hot water recovered can be calculated based on the amount of hot water discharge from the process, including the amount of used water for dyeing (between 130-135°C down to 80°C), for PES reduction clearing (from 80°C down to 70°C), for reactive washing (from 98°C down to 70°C) and cotton bleaching (from 98°C down to 70°C).

Application restrictions

• There needs hot water tank with sufficient volume to store cooling water;

• Pipeline and hot water tanks should be insulated.

• As cooling water is reused for the dyeing and washing process, the collection pipeline and heat exchanger must be in good quality, free from rust to prevent contamination of feed water.

• In polyester dyeing factories, the amount of hot water is usually excess, which is discharged or cooled and mixed with the water supply. To fully optimize the heat from this water, factories should consider making the most use out of this hot water source.

• This solution requires the dyeing equipment to have a warm water call button and hot water supply hose as well as a corresponding change in the dyeing process (call and feed hot water instead of just feeding water as before). The table below shows some stages where hot water can be used.

References – Appendix

Dr. – Ing. Harald Schönberger và Shafqat Ullah (7/2021), Water efficiency in textile wet processing industries, GIZ (pp. 26 -27).

3.2.2. RECOVERING COOLING WATER FROM SINGEING, STENTERING, SANFORIZING, CONTINUOUS WASHING MACHINES

Technical description

• *Sanfor Machines:* At Sanfor machine, rubber belts needs to be cooled directly by water, while the palmer belts are cooled indirectly by water running inside rotating roller. Cooling water for palmer belts is clean water, at the temperature of 50°C. Cooling water for rubber belts might be mixed with fibers from the fabric, at the temperature below 45°C.

This cooling water can be recovered and recirculated by installing tanks, fiber filters and cooling towers.

• *Singeing machine:* Singeing machines have rotating shafts that are cooled with clean water. Cooling water, instead of being dispose off, can be recovered and reused for the following 2 purposes: To lower the temperature of cooling water

Figure 9. *Post-cooling water of the Sanfor machine is filtered before being pumped to the cooling tower and recirculated to cool the machine*

by cooling tower and recirculate to cool the shaft; To use this water source for stamping out dust at the singeing machine

• *Stenter machine:* Depending on the type of machine and product requirements, fabric after being stretched and thermal shaped is cooled by air, by water spray, or by indirect cooling water in rotating shafts. Cooling water that enters indirect

Figure 10.
Singeing machine

cooling batches is clean water, so it should be recovered and reused for different purposes at factories such as cleaning machineries, feeding dyeing machine, or recirculating to cool stenter machine.

• _Desizing machine, scouring and bleaching machine, continuous washing machine:_ Fabric, after being washed through continuous washing tanks, will be steam dried through drying drums. In the last drum, water is fed to the drum to cool down the

Figure 11. *Cooling water pipeline for stenter machine*

fabric. This cooling water is clean water at the temperature of around 50^{o}C that can be recovered and supplied to the hot washing tank of the same machine.

Benefits/impacts

• Save cost and fees for reduced water and wastewater to be treated and discharged.

Figure 12. *Cooling with water at a continuous machine*

• Save fuel costs to heat process water.

Scope of application

Suitable for equipment and production processes which use cooling water.

Data to be measured/collected to calculate economic benefit

Calculation of the environmental and economic benefits for the solution of recovering cooling water from singeing, stenter, sanfor, and continuous washing machines is guided in Table 8.

Application restrictions

• Consider the locations of cooling water source and of hot water tanks to decide

Table 8. *Calculation of economic benefits for the solution of recovering cooling water from singeing, stentering, sanforizing, continuous washing machines*

No.	Parameter	Unit	Source
1	Cooling water flow	liter/minute	Survey
2	Machine operating hours	hours	Factory
3	Water savings in 1 day	m^3/day	(3)=(1)*(2)/60
4	Cooling water savings in 1 year	m^3/year	(4)=(3)*Number of operating days in 1 year
5	Water costs (including supply water and wastewater)	VND/m^3	Factory
6	Total cost savings	million VND/ year	(6)=(5)*(4)/10^6
7	Investment costs (cooling tower, filter)	million VND	Supplier
8	Payback period	year	(8)=(7)/(6)

Case study:

At a textile dyeing factory, cooling water flow for palmer belts of a Sanfor machine is about 15 liters/minute. Cooling water flow for rubber belts is about 30 liters/minute. Recovering these two flows of cooling water is estimated to gain the following savings:

• Water savings: 0.35%, equivalent to 3,120 m^3 of water/year

• Savings amount: 62 million VND/year

• Investment costs: 100 million VND

• Payback period: 2.0 years

reuse purposes, in order to minimize the travel distance of hot water and save energy.

• In the case of recirculating cooling water to the machine, there need space for installing cooling tower and fiber filter (for Sanfor machine).

3.2.3. RECOVERING CONDENSATE

Technical description

Multiple stages in washing and dyeing process performed at high temperature are often heated by saturated steam produced by boiler. After indirectly releasing heat to equipment through a heat exchanger, steam will condense into condensate.

Condensate is clean water at a high temperature above 90°C. In some factories, this water is discharged into the wastewater collection system or partially recovered. The recovery of condensate delivers a large amount of heat to the boiler system, thus improving energy efficiency.

In factories of which boiler area is far from the steam use area, or boiler is operated by a contractor with whom the contractual arrangement does not

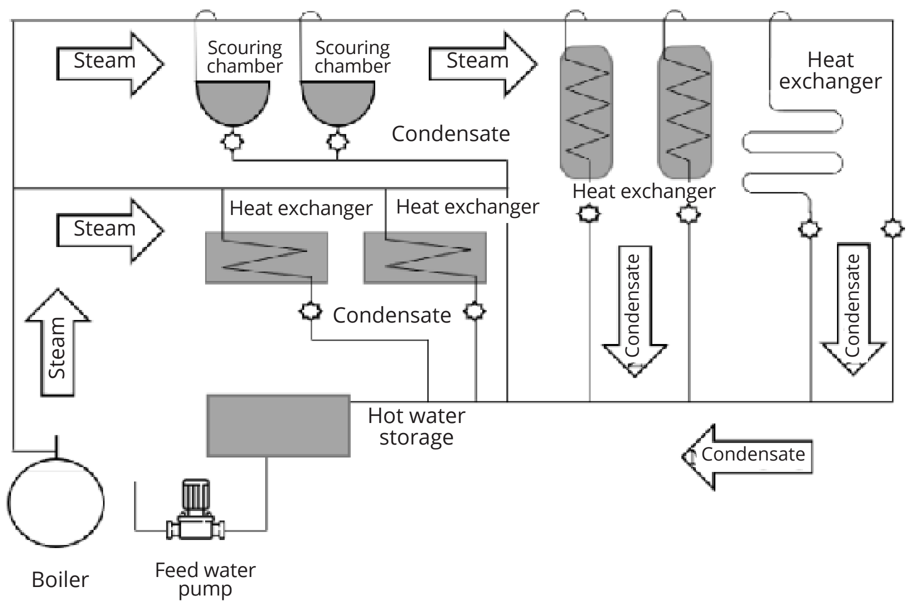


Figure 13. *A typical steam distribution system [4]*

include reuse of condensate, recovered condensate can be used for different purposes within the factory site.

Condensate can be recoverred from following processes in a dyeing factory:

• Recovery of condensate from discontinuous dyeing machines: Steam is deployed to heat up water inside the machine through an indirect heat exchanger. Collected condensate from heat exchangers can return to hot water tanks and feed to dyeing machines.

• Recovery of condensate from drying drums: at continuous wet treatment machines such as desizing, scouring, mercerising, continuous washing dyeing machines, fabric is dried in drying drums using steam. Then steam convert into condensate. Condensate from these drying drums can be connected to hot wash baths of dyeing machines as incoming heated water.

Figure 14. *Recovering condensate from Jet machines*

Figure 15. *Recovering condensate from drying batches*

Benefits/impacts

• Reduce steam and fuel costs.

Figure 16. *Recovering condensate from an oil remover*

• Remove dissolved oxygen from boiler feed water, thus reducing steam leakage.
• Reduce the amount of compensated water supply into the boiler system, thus reduce the TDS of boiler water, minimize treatment chemicals for the original feed water, and reduce boiler bottom discharge, and reduce steam loss.
• Save the cost for wastewater treatment at factory level and fee for wastewater discharge
• Reduce operating costs and maximize boiler efficiency.

Scope of application

Applicable to equipment using indirectly heated steam and condensate discharge

Data to be measured/collected to calculate economic benefit

Calculation of the environmental and economic benefits for the solution of recovering condensate is guided in Table 9.

Application restrictions

• The practice is more effective if condensate is returned to boiler. However, in

Table 9. *Calculation of economic benefits for the solution of recovering condensate*

No.	Parameter	Unit	Source
1	Amount of steam supplied to the equipment	tons of steam/year	Factory
2	Condensate recovery rate	%	Depending on the current state of the factory, about 60-70%
3	Amount of condensate recovered	m^3/year	(3)=(1)*(2)
4	Unit price of water and water treatment	VND/m^3	Factory
5	Water cost savings	million VND/year	(4)=(2)*(3)/10^6
6	Total heat savings	MJ/year	(5)=(2)*4.18*ΔT ΔT: temperature difference between condensate and feed water
7	Steam savings when recovering condensate	tons of steam/year	(6)=(5)/2755
8	Average steam price	VND/tons	Factory
9	Steam cost savings	million VND/year	(8)=(6)*(7)/10^6

No.	Parameter	Unit	Source
10	Total cost savings	million VND/year	(9)=(4)+(8)
11	Total investment costs (insulation pipelines)	million VND	Supplier
12	Payback period	year	(11)=(10)/(9)

Case study:

At a textile dyeing factory, steam is supplied to drying drums in the finishing workshop with a total amount up to 12.723 tons per year. 60% steam condensate can be recovered, bringing following saving values:

• Water saving: 1.29%, equivalent to 7,634 m^3/year

• Steam saving: 1.47%, equivalent to 695 tons of steam/year

• Saving amount: 223 million VND/year (including saving water, fuel, chemical costs)

• Investment costs: 200 million VND (Including insulation pipe cost)

• Payback period: 0.9 year

certain factories, the distance from steam use area and the boiler is too far, for which more heat is lost in the long pipeline;

• Many factories buy steam from contractors that do not receive condensate. The factory can negotiate with the contractor to buy recovered condensate and reduce steam costs.

• Consider the required temperature of feeding water in the wet process to assess the possibility of using condensate directly for the process. In cases where the factory already has excess hot water supplied to the wet process, condensate heat can be utilized to dry products through an indirect water-gas heat exchanger.

• Collection pipes need to be insulated to recover maximum heat from condensate and for safety purpose. Consider location and length of the pipeline system as well.

• Conduct regular maintenance of the steam distribution and condensate recovery system to avoid leakage and loss.

3.2.4. REUSING LAST BATH WATER

Technical description

Discontinuous dyeing process often consumes a lot of water as multiple water refills and draining off are carried out. Draining off of multiple baths to sewage ditch, some of which are far less polluted that the average pollution value of the entire sewage is a waste of wastewater treatment cost. This practice considers the possibility of recovering draining off streams for reuse as feed water for the process.

Amongst many post-dyeing treatment baths, the last bath before shipment usually contains low contamination load of chemicals and color, hence can be recovered and reused for the next batch of dyeing.

For processing recipes that need not to drain the last washing bath before unloading fabric or yarn, the last bath can be retained in the dyeing machine to use for the next dyeing batch. This application does not require new storage tank. The practice is applicable under the smart arrangement of orders or products of same cover tint on the same dyeing machine.

A more viable application is to build tank for storing the collected last bath water, and later feed to the machine for pre-treatment steps and/or middle laudry baths of the next batch, or to clean the machine. When reusing water for the next batch, it is better to apply to the product of the same cover tint. For polyester fabric that is not treated with color fixing agent, the final bath can be reused for most of the colors from medium to dark.

To recover the last bath water, dyeing machines should have 2 drainage pipes and a storage tank. Some dyeing machines already have 2 bottom drainage pipes, one connected to the sewage ditch and one to storage tank. Dyeing machines with only one bottom exhaust pipe need to be reconstructed to add one more drainage pipe, and install the control switch to call for and drain water off the machine.

Some new generation dyeing machines already have a built-in tank. Water stored in this tank is be heated before feeding to the machine. Factories may store recover last bath water in this tank. As for the dyeing machine without a ready-made tank, the factory can consider 2 options:

• Use a separate tank for each machine or a cluster of 2 - 3 machines.

• Use a shared tank for the whole workshop.

Figure 17. *Reusable water tank at a factory*

Figure 18. *Dividing the discharge stream from the dyeing process at another factory*

Fairly clean bath water (light color and low chemical contamination) can be separated and discharged to the storage tank of the entire dyeing workshop, mixing up with utility water or recycled water and then together feeding the dyeing process. The volume of last bath water recovered can reach 5-20% of the total water supply to the workshop, depending on the type of order.

Benefits/impacts

• Reduce wastewater flow, hence save wastewater treatment and discharge costs.

• Save clean water fed to the factory's production process.

• The solution provides a large amount of reusable water, helping factory to satisfy customer requirement on water reuse rate.

Scope of application

• Applicable to discontinuous dyeing machines, repeated washing, final wash with few chemicals and little yarn residue

• Applicable to factory with arrangement of dyeing machine for specific color tint;

• Availability of tanks, or space for tank installation.

Data to be measured/collected to calculate economic benefit

Calculation of the environmental and economic benefits for the solution of reusing last bath water.

Table 10. *Calculation of economic benefits for the solution of reusing last bath water*

No.	Parameter	Unit	Source
1	Applicable production output	kg/year	Factory data
2	Material liquor ratio of dyeing machine	liter/kg	Factory data
3	Number of water bath recovered	step	Factory data
4	Water savings in 1 year	m^3	(4)=(1)*(2)*(3)/10^6
5	Water costs	VND/m^3	Factory data
6	Total cost savings	million VND/year	(6)=(4)*(5)/10^6
7	Investment costs (tanks, valves, pipelines)	million VND	(Depending on the current state of the factory)
8	Payback period	năm	(8)=(7)/(6)

Case study:

A factory deployed discontinuous dyeing machine that operated at MLR of 1:10. It applied the last bath water reuse for a dyeing output of 2,200kg/year and realized the following benefits :

• Water savings: 2.2%, equivalent to 17,639 m^3 of water/year

• Savings amount: 234 million VND/year

• Investment costs: 450 million VND (including 3 tanks, pumps, pipes)

• Payback period: 1.9 years

Application restrictions

• To reuse water, last bath water should be collected from the light color dyeing process or reuse for the batch of the same color tint product.

• Check to understand the drainage design of each machine line to modify the drainage stream separation system;

• When using the built-in overhead tank of each dyeing machine, a system for pumping water to the tank is required.

• This practice is more suitable for polyester fabric dyeing as less fiber residual mixed in wastewater compared to that of cotton fabric dyeing.

• The water feeding and drainage control system should be friendly and convenient for machine operator.

3.3. Investment on water-saving technology and equipment

3.3.1. INVESTMENT OF LOW MATERIAL LIQUOR RATIO (MLR) DYEING MACHINE

Technical descript

Material Liquor Ratio (MLR) is the parameter that shows the ratio between the volume of water supplied for each bath and a unit weight of fabric. This parameter makes the most sense with discontinuous dyeing machines, since each step in the dyeing process is carried out in a single bath, requiring one intake and one drainage of water. At present, low ratio is the most competitive feature advertised by Jet dyeing machine manufacturers.

Common MLR practied in dyeing factories is 1:8-1:10. Some factories use old dyeing machines, operating at high ratio of 1:15 to 1:20. In response to the brand's requirements for sustainable development and cost savings, many factories have converted to using newer dyeing machine line, operating at low ratio of 1:6. MLR at 1:4 has also been applied in a few factories through investment in modern dyeing machines.

MLR not only affects the amount of water supplied, energy consumed during the dyeing process but also plays an important role in the dosing optimization of dyestuffs and auxiliary chemicals. The applicable ratio depends on the dyeing machine configuration and product type. The table below lists out some popular dyeing machine lines and respective operating MLR.

Table 11. *MLR levels by product type and dyeing machine [5]*

Material		Process	Equipment		Liquor ratio
Loose/stock fibre (also card sliver and tow)		Loose stock dyeing	Autoclave (loose stock dyeing)		1:4 - 1:12
Yarn	Bobbins/cones	Yarn dyeing	Autoclave (package dyeing)		1:8 – 1:15
	Hank	Hank dyeing	Hank dyeing machines		1:12 – 1:25
Woven and knitted fabrics, floating velvet carpets	Rope	Piece dyeing in rope form	Winch beck		1:15 – 1:40
			Overflow		
	Open-width	Piece dyeing in open-width sheet	Jet	For fabric	1:4 – 1:10
				For carpet	1:6 – 1:20
			Airflow		1:2 – 1:5
			Jig dyeing		1:3 – 1:6
			Jigger + washing machine		1:10
Ready-made goods (e.g., garments, rugs, bathroom-sets, etc.)		Piece dyeing	Paddle		1:60 (not exceptional)
			Drum		Very variable

Dyeing machine suppliers have been developing dyeing machine lines capable of operating at low MLR for numerous types fabrics; for example, improved the fabric and water transform system, air flow dyeing machines, or new technologies such as AM-ICD (Intelligent Conveyer Drive Dyeing Machine), etc.

Below are example pictures of low ratio dyeing machine and high ratio ones at a factory.

__Figure 19.__ Low MLR Jet dyeing machine

__Figure 20.__ High MLR Jet dyeing machine

Benefits/impacts

The investment in low MLR dyeing machines provides the following benefits:

• Save cost of input water, wastewater treatment and discharge fee;

• Low MLR reduces the volume of water that needs to be heated, thus saving heat and time;

• Reduction of water use for each step allows smaller amount of dye, auxiliaries and laundry chemicals;

• Dye fixing efficiency on fiber increases thanks to higher concentration of dyes in the trough. [6]

• Reduce the time to heat and cool water, which improves machine productivity and boost factory income.

Scope of application

• Suitable for factories with secured financial ability to invest in low MLR machines and the willingness to phase out high MLR lines

• Refer to Table 5 to select suitable MLR range for each type of fabric

Data to be measured/collected to calculate economic benefit

Calculation of the environmental and economic benefits for the solution of low MLR dyeing machine investment is guided in Table 12.

Table 12. *Calculation of economic benefits for the solution of low MLR dyeing machine investment*

No.	Parameter	Unit	Source
1	Number of new machines to be invested	machine	Factory
2	Production volume applied	kg/year	(2)=(1)*3*300
3	MLR of the new machines	kg of water/kg of fabric	Factory
4	Average number of water refills	times	Factory
5	Water savings	m^3/year	(5)=(2)*(4)*((3)/1000
6	Water costs (supply water and wastewater)	VND/m^3	Factory
7	Annual water cost savings	million VND/year	(7)=(6)*(5)
8	Heat savings	MJ/year	Calculate
9	Steam savings at low MLR	tons of steam/ year	(9)=(8)*boiler efficiency%/ steam latent heat
10	Average steam price	VND/tons of steam	Factory
11	Steam cost savings	million VND/ year	(11)=(9)*(10)/10^6
12	Chemical consumption for 1 kg of fabric	kg/kg fabric	Factory
13	Chemical saving rate	%	Calculate
14	Chemical savings	tons/year	(14)=(2)*(12)*(13)/1000
15	Average chemical unit price	VND/kg	Factory
16	Chemical cost savings	million VND/ year	(16)=(14)*(15)/1000
17	Total cost savings	million VND/ year	(17)=(7)+(11)+(16))
18	Investment costs	million VND	Supplier
19	Payback period	year	(19)=(18)/(17)

Some factories have made instalment or one-off investment to replace entire high MLR dyeing machines with low MLR lines. They reported to gain following saving values:

• Water savings: 3%-25%

• Steam savings: 1.5-6%

Case study:

A Jet dyeing factory operates at a ratio of 1:8-1:12 to dye Polyester and TC fabric with multiple refills (4 to 10 times). In 2021, the factory produced an output of about 6.029.692 kg. The factory has invested in 4 low MLR dyeing machines with a design capacity of 800kg, operating at a capacity of 500kg/batch with a ratio of 1:4.

• Water savings: 8.7%, equivalent to 72.000 m^3/year

• Steam savings: 2.2%, equivalent to 2.840 tons/year

• Savings amount: 4.87 billion VND/year (including the amount of money from saving water, fuel, chemicals)

• Investment costs: 24 billion VND

• Payback period: 5.1 years

Application restrictions

• Technical error due to unfamiliarity with machine operation.

• Productivity loss in machine transfer period.

• Certain products do not work properly with= low ratio dyeing.

• Some other notes when applying low ratio:

(1) Adjust the fabric running speed. This depends on the fabric length. The lower the liquor ratio, shorter the cycle is required and hence the faster the velocity;

(2) Pressure of the Jet nozzle, determined by the pump speed, helps pushing the fabric down the machine body;

(3) Wheel speed to load the fabric;

Points (2) and (3) must be aligned with point (1) so that fabric runs evenly without entanglement, jamming or hanging, resulting in uneven color. In addition, fabric running speed must be adjusted to avoid excessive mechanical pressure that might cause fabric surface to ruffle or uneven color.

References – Appendix

AEE INTEC (2022), Assessment document of low-liquor ratio dyeing machines with efficient washing processes URL: < http://wiki.zero-emissions.at/index.php?title=Dyeing_in_textile_industry>

Dao Duy Thai (2015), Introduction to Textile Chemistry Technology, National University Press, Page 103

3.3.2. INVESTING IN LOW MATERIAL LIQUOR RATIO (MLR) WASHING MACHINE

Technical description

Similar to dyeing machines, Material Liquor Ratio (MLR) is an important parameter in garment washing machines. Many factories use belly washing machines that operate at fairly high MLR, chemicals, energy and auxiliaries. Some factories have transferred to front-loading automatic washing machines that can operate at a MLR as low as 1:2 depending on the requirements of the washing process. These washing machines are equipped with automatic control, and faster in washing and squeezing garments.

Improved design minimize the amount of water between the inner and outer cages. Garments are fairly distributed and rotated around the drum. Chemical spray system infiltrate chemicals evenly into products, reducing mechanical force and pump-induced water circulation.

Here are some of the low MLR washing machines deployed at laundry factories:

Figure 21.
Low MLR washing machine

Benefits/impacts

• Save on electricity cost, production costs, chemicals, energy.

• Save cost of input water, wastewater treatment and discharge fee;

• Save processing time thanks to faster drum operation.

• Higher laundry quality and improved the smoothness of clothes surface (less ruffled).

• Automated operation reduces labor deployment.

Scope of application

• Applicable to laundry of active or exhaust dyed garments, and denim garments

• Suitable for factories with secured financial ability to invest in low MLR machines and the willingness to phase out high MLR lines

Data to be measured/collected to calculate economic benefit

Calculation of the environmental and economic benefits for the solution of low MLR washing machine investment is guided in Table 13.

Table 13. *Calculation of economic benefits for the solution of low MLR washing machine investment*

No.	Parameter	Unit	Source
1	Output of 1 new washing machine	kg/year	Machine supplier
2	Number of new washing machines to be invested	machine	Propose
3	Number of washing batches in 1 day	batch	Factory
4	Production volume applied	kg/year	(4)=(3)*(1)*(2)*number of working days in 1 year
5	Average number of water refills	times	Factory
6	MLR of new machine	liter/kg	Factory
7	Water savings	m^3/year	(7)=(5)*(4)*(6)/1000
8	Water and wastewater treatment costs	VND/m^3	Factory
9	Water cost savings	million VND/ year	(9)=(7)*(8)/10^6
10	Chemicals savings	tons/year	Calculate
11	Average chemical unit price	VND/kg	Factory

No.	Parameter	Unit	Source
12	Chemical cost savings	million VND/ year	(12)=(10)*(11)/10^6
13	Heat savings	MJ/year	Calculate
14	Steam savings	tons of steam/year	(14)=(13)*boiler efficiency%/steam latent heat
15	Average steam price	VND/tons of steam	Factory
16	Steam cost savings	million VND/ year	(16)=(14)*(15)/10^6
17	Labor cost savings	million VND/ year	Factory
18	Total cost savings	million VND/ year	(18)=(17)+(16)+(12)+(9)
19	Total investment costs	million VND	Suppliers
20	Payback period	year	(20)=(19)/(18)

Case study:

At a denim washing factory with annual productivity of 3,375,734 products, switching from belly washing machines to low MLR front-loading line brings about the following saving values:

• MLR reduced from 1:10 to 1:5

• Water savings: 13.4%, equivalent to 28,392 m 3 /year

• Heat (steam) savings: 15%, equivalent to 421 tons/year

• Chemical savings: 10%, equivalent to 88.6 tons/year

• Savings amount: 2.4 billion VND/year (including savings of water, fuel, chemical costs)

• Investment costs: 7.4 billion VND (4 machines with capacity of 100 kg each)

• Payback period: 3 years

Application restrictions

• Some factories have low MLR front-loading washing machines but still apply high MLR on these machines. They should consider carrying out low MLR tests to optimize machine performance.

• Technical errors due to unfamiliarity with new automatic machines, especially a number of steps that workers used to manually perform on belly machines.

3.3.3. COLD PAD BATCH (CPB) DYEING TECHNOLOGY

Technical description

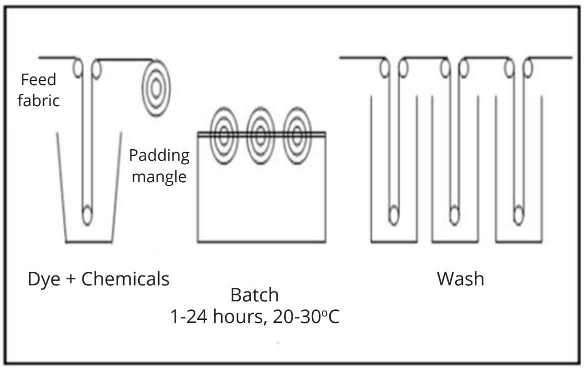
Cold Pad Batch (CPB) dyeing brings economic efficiency and good processing quality on active dyeing of cotton fabric. CBP dyeing gains a higher level of color yield than Jet dyeing or other continuous dyeing processes. It does greatly to save dyestuffs and water. This process also uses little energy, only for running padding and pivoting machines during cold incubation. [7]

The CPB method is a reliable process for woven cotton fabric, providing high quality dyed products with low consumption of resources.
Each stage of this method includes:
• Padding process: The fabric passes through the dye trough containing dyestuffs and alkaline solvent, then be "padded" by a pair of specialized shafts, ensuring equal padding on the fabric width for even color distribution on fabric.
• Cold incubation or reaction process: After being padded, the fabric is wrapped onto an A-Frame, divided into batch and sealed with a polyethylene sheet. This sealing is to prevent dyes from evaporation that might cause uneven dyeing of fabric. Incubation conditions depend on workshop temerature and ventilation environment but it is best to keep it consistent throughout the year. Fabric roll on A-Frame is plugged into a motor that move the fabric roll evenly during the cold incubation process. It is crucial to control the fabric movement and avoid the wet fabric roll from being drooped, causing the amount of dyes on fabric inside and outside and consequently uneven tailing.
• Washing stage: After the incubation ends, fabric is washed in continuous washing machine for removing hydrolyzed dyes not fixing to cotton fabric.

Diagram of cotton CPB dyeing is shown in the figure below.

Benefits/impacts

• Water savings: Padding technology uses a padding level lower than 100%,



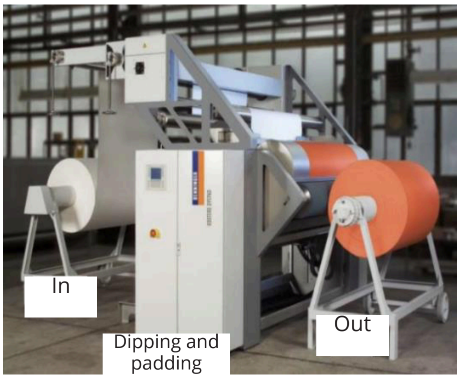


Figure 22. *Cotton dyeing diagram by cold pad batch dyeing technology [8]*

which is equivalent to a dyeing ratio lower than 1:1. With this level of padding, dyes are fixed on the fabric far better than Jet dye and less reactive dyes are hydrolyzed. Consequently, following washing is easier and consumes less water. Salt-free technology in the dyes trough also saves water and makes the washing step easier.

• Chemical saving in dyeing formulations thanks to low padding level. Usually, only one absorbent agent and one alkaline system are used. Unlike other dyeing technologies such as exhaust or continous, no other chemicals are used.

• Electrical energy saving: CPB uses electricity only to operate the machine and the pivot during the cold incubation.

• Thermal energy saving: the CPB does not use any thermal energy to fix color as it is cold incubation.

• CPB technology is applied on smaller batch compared to continuous dyeing, but can also be used for large batches when Jet dyeing machine needs to be divided into many batches for easy color differentiation between batches.

• Workshop space saving: One CPB dyeing machine can have the same capacity as many Jet dyeing machines but only occupies a very small factory space.

• In general, this is the dyeing technology that can be considered sustainable, compared to traditional technologies.

Scope of application

• This technology was often applied to woven fabric as until recently, the CPB dyeing equipment has not met the specific requirements of knitted fabric. However, there have been breakthroughs in dyeing machine manufacturing technologies to help overcome these difficulties and now the technology has also been widely and successfully applied to open-width knitted fabrics.

• Applicable to factories that are using pretreatment and continuous washing machines.

Data to be measured/collected to calculate economic benefit

Calculation of the environmental and economic benefits for for the solution of CPB dyeing technology is guided in Table 14.

Table 14. *Calculation of economic benefits for the solution of CPB dyeing technology*

No.	Parameter	Unit	Source
1	Applicable fabric output	kg/year	Factory data
2	Amount of water used for continuous dyeing stage	liter/kg	Factory data
3	Water consumption in CPB	liter/kg	1
4	Water savings in CPB	m^3/year	(4)=(1)*((2)-(3))/1000
5	Water costs	VND/m^3	Factory data
6	Water cost savings	million VND/year	(6)=(4)*(5)/10^6
7	Heat savings (heat consumed by dyeing technology other than CPB)	MJ/year	Factory
8	Steam savings	tons/year	(8)=(7)*boiler efficiency%/ steam latent heat
9	Average steam price	VND/tons of steam	Factory data
10	Annual energy cost savings	million VND	10)=(8)*(9)/10^6
11	Total cost savings	million VND	(11)=(6)+(10)
12	Investment costs	million VND	Factory data
13	Payback period	year	(8)=(7)/(6)

Note: *Steam latent heat = steam enthalpy – Enthalpy of boiler feed water*
(Two enthalpy values can be searched in the following table
https://www.engineeringtoolbox.com/saturated-steam-properties-d_457.html)

Case study:

A continuous dyeing factory with an output of 4,769 tons/year has applied CPB technology to 40% of the output and gained the following savings:

- Water savings: 30%, equivalent to 59.229 m^3 of water/year
- Steam savings: 1.302 tons/year
- Savings amount: 1.7 billion VND/year
- Investment costs: 8.4 billion VND
- Payback period: 4.5 years

Application restrictions

• To promote all the saving advantages, factories need to sufficiently plan the capacity of pretreatment system (scouring, bleaching) to ensure adequate fabric output for the large batch of CPB dyeing and the following counter-current continuous washing step;

• In the case of knit fabric, there should have pretreatment and continuous washing machines for knitted open-width fabric that can handle wide fabric size;

• Get prior customer acceptant to the quality of CPB dyed fabric instead of exhaust dyeing , especially for knitted fabrics;

• Dyeing technique to be guided by equipment supplier;

• Laboratory technicians should be trained by both equipment and dyes suppliers and be skillful for making of CPB dyes formulations in laboratories;

• It is difficult to correct the wrong color shade. Therefore, the dyeing process must strictly follow with laboratory's one to ensure Right the First Time (RFT);

• Sourcing fabric material with sufficient roll length of a dyeing batch, thus no need to join two rolls. This is to avoid color unlevelling at the joint line between rolls;

• The incubation room temperature needs to be stably maintained, preferably in an air-conditioned room. Dyeing quality is vulnerable to temperature changes.

References – Appendix

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• M. M. El-Molla, K. Haggag, and Z. M. Mahmoued (2015), Cold Pad-Batch Dyeing Method for Dyeing Cotton Fabric with Reactive Dye Using Microwave Irradiation Technique, International Journal of Science and Research (IJSR), vol. 4 issue 4, URL: <https://www.ijsr.net/archive/v4i4/SUB152642.pdf>

3.3.4. OZONE TECHNONOLOGY IN DENIM WASHING

Technical description

Ozone (O3) is a potent oxidant that can be used to bleach denim garments. After being used for garment processing, ozone is converted to normal oxygen before releasing into the environment, thus no pollutants are released into the environment.

Currently, it is common amongst denim washing factories to use dry Ozone fading technology for fixing the color smearing error on jean back pocket or on non-dyed weft yarn, and for product deodorization. In dry Ozone application, garments are dried up and loaded into the machine vessel where Ozone gas is injected for a few seconds. Another application of Ozone is background color removal in the washing process, replacing the traditional technology of bleaching with chemicals such as NaOCl, HOCl, $KMnO_4$, H_2O_2, etc. In this wet Ozone technology, garments are moisturized, then loaded into the machine vessel and exposed to ozone gas to achieve the effect of wet Ozone bleaching. However, applying Ozone to bleach the background color has only been tested and applied in some factories.

The Ozone finishing process reduces the consumption of water, chemicals, and energy for heating water in the normal washing process. The Ozone bleaching process requires only 2-3 washes compared to 6 to 7 washes under the chemical bleaching or stone washing scheme. Therefore, replacing some traditional washing and finishing methods with Ozone helps reduce the amount and contamination level of wastewater, as well as pumic sludge. At an optimal concentration, Ozone generates the bleaching effect on denim background color in roughly 15 minutes, compared to 30 to 45 minutes in traditional methods, which increase output per shift.

Benefits/impacts

Figure 23. *Ozone G2 machine can be operated in dry and wet conditions*

- Reduce water use.
- Reduce the use of toxic cleaning chemicals.
- Reduce the use of pumice stone and its side effects on machinery and environment.
- Save production time and increase productivity.
- Reduce energy used to heat water in the background bleaching with chemicals.
- Ozone machine is a new high-tech equipment, hence the process is better controlled, ensuring the even quality of mass production.
- Reduce the amount of wastewater and pollutants load in wastewater.
- No AOX (Organic Halogen), and low load of chlorine-based chemicals in wastewater.

Scope of application

Applicable to denim washing factories, which are practicing background bleaching using chemicals.

Data to be measured/collected to calculate economic benefit

Calculation of the environmental and economic benefits for the solution of Ozone technology in denim washing is guided in Table 15.

Application restrictions

Table 15. *Calculation of economic benefits for the solution of Ozone in denim washing*

No.	Parameter	Unit	Source
1	Number of Ozone machines to be invested	machine	Factory data
2	Ozone machine output	kg/batch	Supplier
3	Number of batches per year	batches	Factory data
4	Production volume applied	kg/year	(4)=(2)*(3)
5	Current MLR (bleaching stage)	liter/kg	Factory data
6	Number of water refills reduced (bleaching, neutralizing, washing)	times	Factory data
7	Water savings	m^3/year	(7)=(4)*(5)*(6)/10^6
8	Water and wastewater treatment costs	VND/m^3	Factory data
9	Water cost savings	million VND/year	(9)=(7)*(8)/10^6
10	Chemical savings	tons/year	Calculate
11	Chemical costs	VND/kg	Factory data
12	Heat savings	MJ/year	Calculate
13	Steam savings	tons/year	(13)=(12)*boiler efficiency%/ steam latent heat
14	Average steam price	VND/tons of steam	Factory data
15	Steam cost savings	million VND/year	(15)=(14)*(13)/10^6
16	Total cost savings	million VND/year	(16)=(15)+(9)
17	Total investment costs	million VND	Supplier
18	Payback period	year	(18)=(17)/(16)

Case study:

A denim factory switches from dry to wet ozone process and has applied for a production volume of 906,000 kg/year. Specific saving parameters are as follows:

• Water savings: 5.4%, equivalent to 27,180 m^3 of water/year

• Chemical savings: 108 tons/year

• Fuel savings: 0.73%, equivalent to 54.3 tons of compressed wood/year

• Savings amount: 935 million VND/year

• Investment costs: 4.8 billion VND (1 Ozone machine)

• Payback period: 5.1 years

• It is necessary to minimize risk of ozone exposure and automatic safety devices be switched on during the operation;
• Ozone concentration, product moisture content and timing are important parameters that affects the color shade and product durability. Therefore, experimental lab is needed before mass production.
• Ozone is highly reactive and can cause severe damage to machinery, connectors, plastics, pipes... Therefore, components exposed to Ozone should be made of appropriate materials and with automatic safety settings.
• Indigo dyes oxidated by Ozone may cause yellow smudge on garment surface. Hence, Ozone can be partially applied in parallel to chemical bleaching.

3.3.5. EFLOW TECHNOLOGY IN DENIM WASHING

Technical description

Nano Bubble technology is a new technology in the denim washing industry widely known as Eflow, invented and patented in 2012 by Jeanologia, a Spanish company. In the Eflow system, the air is converted into nano bubbles and used as a carrier for chemicals to absorb evenly into fabric. Nano bubbles can break down Indigo molecules from the surface of the denim fabric, creating a pre-shrinkage of the fabric, which helps mitigate further shrinkage during clothes laundry by end users. The final product is soft and comfortable to wear and improves friction color fastness.

This technology can generate best finishing effects with the least amount of water and discharge. All chemicals are injected into the fabric by nano bubbles, so no residual chemicals are discharged into the wastewater or into the environment. Eflow can be applied to many processing steps such as dyeing, enzymerization, softening, rinsing and PP background bleaching. Some denim wash factories in Viet Nam have applied Eflow in such steps. Other factories have invested in Eflow machines at the request of customers but then stop using, giving the excuse that more testing of Eflow application is needed to safeguard product quality.

Benefits/impacts

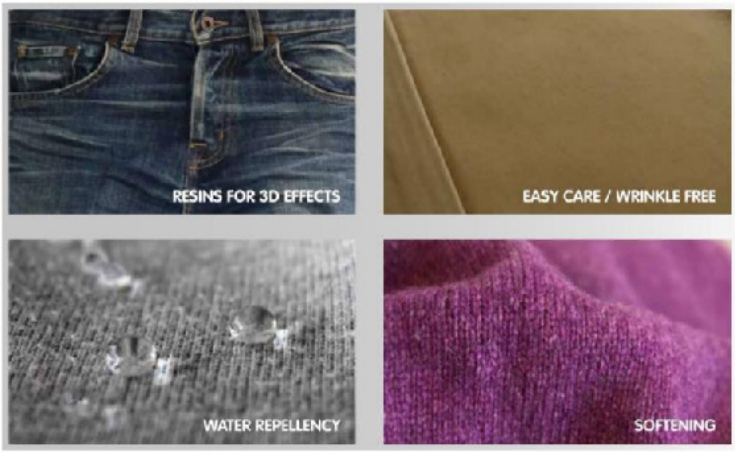


Figure 24. *Some Eflow applications*

Figure 25. *Eflow machine and Eflow connected washing machine at a factory*

• Save water costs;

• Save chemical costs;

• Save energy;

• Reduce wastewater volume and chemical pollution;

• Reduce production time, increase output.

Scope of application

Applicable to stages such as dyeing, enzymerization, softening, resining and PP spraying.

Data to be measured/collected to calculate economic benefit

Calculation of the environmental and economic benefits for the solution of Eflow technology in denim washing is guided in Table 16.

Table 16. *Calculation of economic benefits for the solution of Eflow in denim washing*

No.	Parameter	Unit	Source
1	Recommended number of Eflow machines	machine	Factory data
2	Washing machine output when applying Eflow	kg	Supplier
3	Number of batches per year	batches	(4)=(1)*(2)*(3)
4	Production volume applied	kg/year	(4)=(2)*(3)
5	Current MLR (softening, enzyme)	liter/kg	Factory data
6	MLR after applying Eflow	liter/kg	1
7	Number of steps applied (softening, enzyme)	steps	Factory data
8	Water savings	m^3/year	(8)=(4)*((5)-(6))*(7)
9	Water and wastewater treatment costs	VND/m^3	Factory data
10	Water cost savings	million VND/year	(10)=(8)*(9)/10^6
11	Chemical savings	tons/year	Calculate
12	Chemical unit price	VND/kg	Factory data
13	Chemical cost savings	million VND/year	(13)=(11)*(12)/10^6
14	Steam savings	tons/year	Calculate
15	Average steam price	VND/kg	Factory data
16	Steam cost savings	million VND/year	(16)=(15)*(14)
17	Total cost savings	million VND/year	(17)=(16)+(13)+(10)
18	Total investment costs	million VND	Supplier
19	Payback period	year	(19)=(18)/(17)

Case study:

A factory applies an Eflow machine with an output of 453.000 kg/year for enzyming and softening stages in jeans washing process:

• Water savings: 2%, equivalent to 8.154 m^3 of water/year

• Chemical savings: 11 tons/year

• Coal savings: 4.1%, equivalent to 136 tons/year

• Total savings amount: 767 million VND/year

• Investment costs: 1.645 million VND

• Payback period: 2.1 years

Application restrictions

• Testing is required before mass production as Eflow effects on garments are different from traditional technology.

• Some applications (e.g., enzymes) require new chemicals that are more costly than traditional ones.

• Since Eflow is connected to a washing machine, in order to maximize its capacity, there should arrange separate washing machines for Eflow stage. Otherwise, it takes time and labor to load and unload garments to switch the machine between stages.

04.

Water saving solutions outside the production process

4.1. Recycle wastewater by reverse osmosis system

Technical description

Textile dyeing wastewater often varies in pollution composition and discharge volume, depending on products, dyeing stage, chemicals used in the production process and machine operation. Textile dyeing wastewater before and after treatment is described in the table below:

Table 17. *Characteristics of untreated dyed textile wastewater*

Parameter	Unit	Value	Column value A, QCVN 40:2011/BTN-MT [9]
pH		6-10	6-9
Temperature	^oC	35-45	40
TDS	mg/l	1.000-12.000	-
COD	mg/l	150-12.000	75
BOD	mg/l	80-6.000	30
TSS	mg/l	15-8.000	50
Chloride	mg/l	1.000-6.000	500
Residual chlorine	mg/l	<10	1
Grease	mg/l	10-30	5
Total Kjeldahl Nitrogen	mg/l	70-80	20
Nitrate (NO_3-)	mg/l	<15	-
Residual ammonium	mg/l	<10	5
Sulphate (SO_4^{2-})	mg/l	600-1.000	-
Color temperature	Pt-Co	50-2.500	50
Heavy metals	Pt-Co	<10	50

Source: ZDHC Document on Wastewater Treatment Technology

This solution applies to factories with the wastewater treatment plant. Effluent from the wastewater treatment plant is treated until it meets feed water standards for washing and dyeing process. Each factory has different feed water quality requirements. According to different surveys in Vietnamese textile sector, most factories require feed water of the similar quality to the national domestic water standard (specified in QCVN 02:2009/BYT). Table 18 shows the feed water quality ranges:

Table 18. *Feed water quality requirement in the dyeing process*

Parameter	Unit	Value
pH		7-8
TSS	mg/l	< 50
TDS	mg/l	< 300
Total iron (Fe)	mg/l	< 0,1
Manganese	mg/l	< 0,02
$N\text{-}NO_3$	mg/l	< 50
Hardness	mg $CaCO_3$/l	< 100
Color temperature	Pt-Co	Commonly used according to QCVN 02-2009/BYT

Source: Consultant survey

Wastewater quality after being treated, which meets the standards for discharge into the environment (Column A, QCVN 40:2011/BTNMT or QCVN 13:2015/ BTNMT), has not yet met the feed water requirements for wet process, including hardness, pH, Total Dissolved Solids and iron. Therefore, using RO membrane is the best solution for investors to recycle wastewater for the production process and cut down virgin water withdrawal.

To increase the proportion of reusable wastewater, wastewater recycling system installed in some factories consist of the following components:

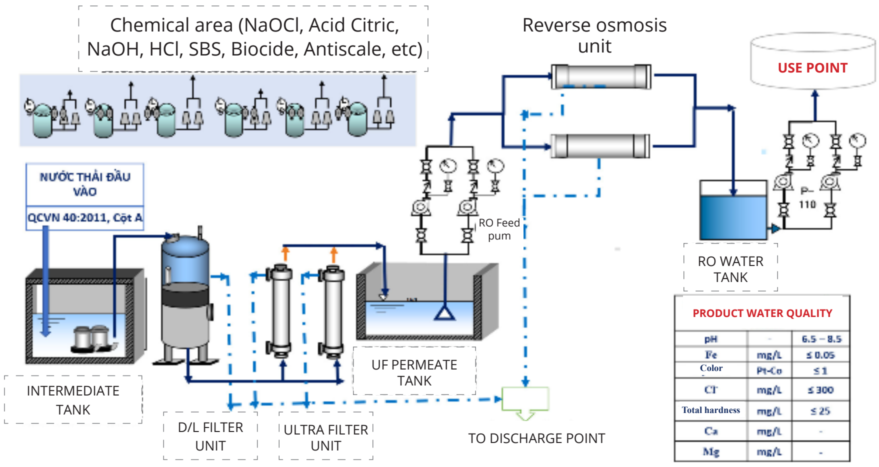


Figure 26. *Diagram of a typical RO wastewater treatment system*

Wastewater after being treated with physiochemical/biological treatment in accordance with QCVN 40:2011/BTNMT for column A will be directed to the wastewater recycle system, including the following components:

Pressure filter tank:

At the inlet water tank, water is pumped to the pressure filter tank and is channeled through layers of filter units made of coal, sand, and stone in order to filter suspended solids, colloidal particles, color, odor, microbiology from the water, eliminating the risk of clogging the filter membrane of the following treatment stages.

Filter tanks are made of composite materials, stainless steel or plastic. After a period of filtration, we need to backwash layers of filter materials to avoid clogging. Clogging causes increase of filtration pressure and reduces the amount of treated water after filtration. Designing backup filter tanks is recommended so that the filtration operation can take place continuously without interruption during the filtration process.

Ultrafiltration membrane (UF):

Treated water from the pressure filter tank continues to run into UF filtration system. UF filtration is designed to remove pollutant components such as particles or bacteria larger than 0.01µm (UF cannot remove ions and smaller molecules).

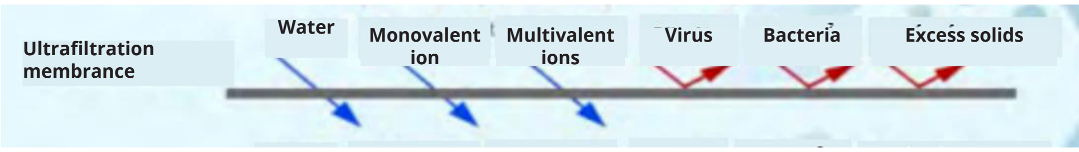


Figure 27. *UF membrane's ability to remove pollutants [10]*

To ensure stable filtration, UF station must be cleaned periodically using following cleaning procedures:

• Backwash: Use treated water for backwashing in combination with automatic cyclic aeration.

• Chemical backwashing (CEB): using treated water along with NaOCl chemical in combination with aeration. The CEB cycle depends on the difference gap between the UF operating parameter value and those of the original one.

Figure 28. *UF membrane system*

Reverse osmosis membrane (RO): Clean water filtered by the UF system is gathered in the UF tank. Here, some of the water is stored for backwashing of pressure and UF filter tanks. The rest is pumped by high-pressure pumps into the Reverse Osmosis (RO) membrane system, in which water flow at a higher pressure than that of the osmosis pressure is filtered and all pollutants (including suspended solids, bacteria, viruses, monovalent and polyvalent ions) is retained on the surface of the membrane.

Water coming out of the RO membrane is divided into 2 flows: filtered flow and reject flow.

- The filtered water flow is transferred to RO water tank.
- The reject flow is transferred to the wastewater treatment area.

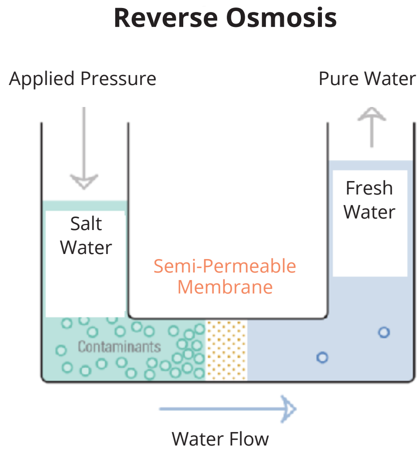


Figure 29. *Operating mechanism of RO membrane [11]*

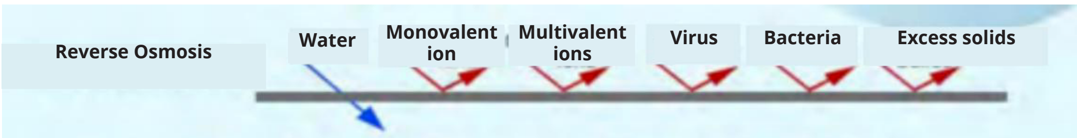


Figure 30. *RO membrane's ability to remove pollutants*

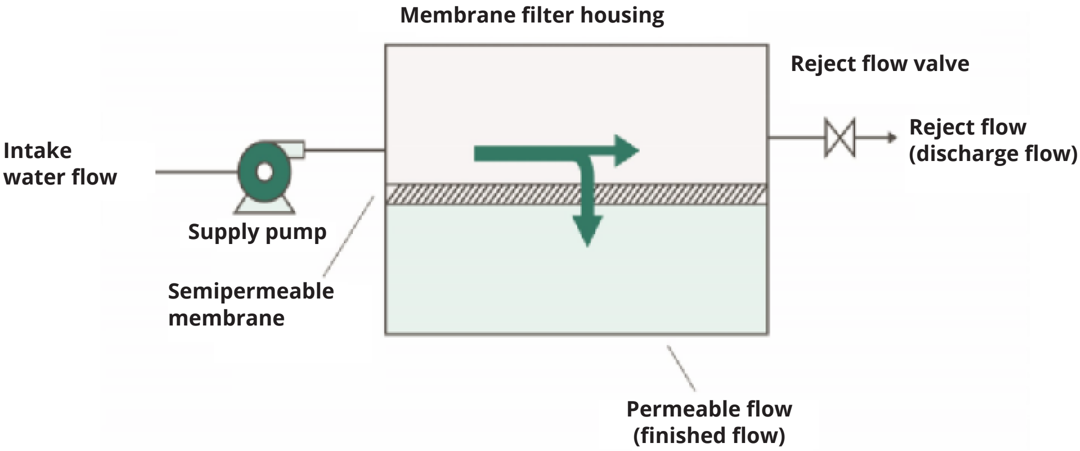


Figure 31. *RO membrane water flows diagram*

The quality of RO filtered water meets QCVN 01-1:2018/BYT standard on the quality of clean water for domestic purpose.

Table 19. *Comparison of water quality*

Parameter	Unit	Water quality	
		Inlet wastewater QCVN 40:2011/BT-NMT, Cột A	Standards on reused water quality (QCVN-01-1:2018/BYT) [12]
pH	-	≤ 6 - 8	6.0 – 8,5
Color	Pt-Co	≤ 120	≤ 1
Hardness	mg/L	≤ 200	≤ 25
Cl^-	mg/L	≤ 500	≤ 300
Fe	mg/L	≤ 1	≤ 0,05
COD	mg/L	≤ 80	≤ 0,05
BOD	mg/L	≤ 25	
SS	mg/L	≤ 50	
$N\text{-}NH_{4+}$	mg/L	≤ 5	

Similar to UF membrane, membrane cleaning in place (CIP) is carried out after a period of filtration based on the analysis of RO membrane operating parameters.

Benefits/impacts

• Save cost of input water, wastewater treatment and discharge fee;

• Supplement or replace virgin groundwater withdrawal, which has been limited in some areas, especially in Ho Chi Minh City.

• Satisfy the requirement on water reuse rate of some customers/brands and sustainable environment standards such as GRS, ZDHC, Higg FEM, etc.

Scope of application

If the effluent water quality from the wastewater biological and physiochemical treatment system is equivalent to or higher than QCVN 40:2011/BTNMT Column A, the wastewater recycle investment is more economically and technically feasible. Applicable for many textile wet processing factories with fairly large total water consumption.

Data to be measured/collected to calculate economic benefit

Calculation of economic benefits for calculating the environmental and economic benefits for the solution of Reusing wastewater using RO system.

Table 20. *Calculation of economic benefits for the solution of Recycling wastewater using RO system*

No.	Parameter	Unit	Source
1	Inlet wastewater flow for the recycling system	m^3/day	Factory data
2	RO recovery rate	50% - 60%	Supplier
3	Amount of RO filtered water	m^3/day	(3) = (1)*(2)
4	System operating time	hours/day	Factory data
5	Number of working days in a year	day	Factory data
6	Total amount of reusable wastewater	m^3/year	(6) = (5)*(3)
7	Water savings	m^3/year	(7) = (6)
8	Estimation of system operating costs	VND/m^3	Supplier
9	Water costs (tap water/clean water cost and discharge cost)	VND/m^3	Factory data
10	Total cost savings	million VND/ year	(10) = ((9)-(8))*(7)/10^6
11	Total investment costs	million VND	Supplier
12	Payback period	year	(12) = (11)/(10)

Case study:

A textile dyeing factory reuses 60% of treated wastewater by installing a RO filtration system of 1,200m^3/day. Although its wastewater effluent meets the industrial park standard, some pollution parameters still exceed the QCVN 40: 2011 for Column A. Hence, the wastewater is pretreated by suitable materials before passing through the RO filtration system. The factory benefits saving values as follows:

- Recycled water: 63.92%, equivalent to 212,100 m^3/year
- Savings amount: 4,560 million VND/year
- Investment cost: 14,408 million VND
- Operating cost: 8,103 VND/m^3
- Payback period: 5 years

Note: In case the factory wastewater quality does not meet the requirements of QCVN 40:2011/BTNMT Column A, it may increase the investment cost for renovating the wastewater treatment system to increase wastewater output quality or the cost for other treatment processes/technologies.

Application restrictions

Potential project risks can come from a variety of factors, including:

- The total dissolved solids (TDS) of inlet wastewater to pass the membrane must not exceed 1,000 ppm because high TDS will overload the membrane and increase operation, cleaning, membrane replacement costs. Factories are encouraged to adopt salt reduction technologies in the production process;
- Inlet wastewater quality of the recycling system is constantly changing. Therefore, the factory needs to control the operation process regularly to ensure the water quality meets the requirements;
- The amount of inlet water to the recycling system may vary due to changes in the production process;
- The system efficiency depends on operator experience and skill;
- Unsuitable membrane cleaning process or unreasonable chemicals dosing for membrane cleaning will waste water for cleaning as well as expose the membrane to damage risk;

• Periodic cleaning/maintenance activities of the system need to be developed into a specific process for monitoring and implementation;
• Factory needs to plan the reject water from the membrane system such as returning the water to the wastewater system, or applying evaporation technology to separate salt from water.

References – Appendix

• QCVN 40:2011/BTNMT, National technical regulation on industrial wastewater. QCVN 01-1:2018/BYT, National technical regulation on the quality of clean water used for domestic purposes.
• Puretech industrial water, What is reverse osmosis, URL: <https://puretecwater.com/reverse-osmosis/what-is-reverse-osmosis>
• United Chemical & Environment Technonogy Co., LTD, What is UF membrane? Comparison of UF membrane and Nano membrane, URL: <https://uce.com.vn/vi/mang-uf-la-gi-so-sanh-mang-uf-va-mang-nano/>

4.2. Rainwater harvesting

Technical description

Rainwater is collected from roofs to rainwater tanks/tubs and directed to the rainwater treatment system to meet the process water standard. Rainwater can be pre-treated together with utility feed water if the premise layout is suitable for mixing these two water sources.

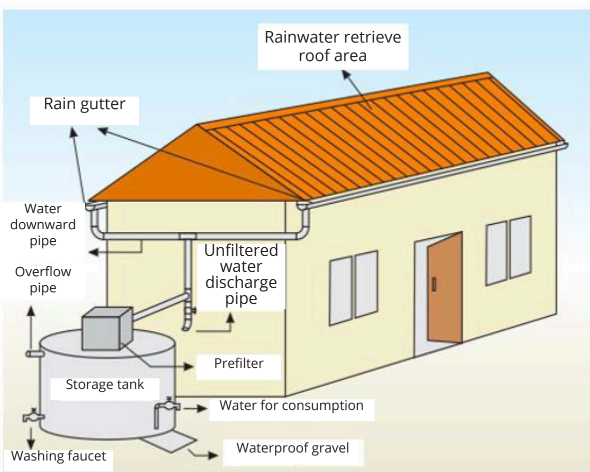


Figure 32. *Different components of a typical rainwater recovery system*

The rainwater collection and treatment system include the following components:
• Rainwater collection system:

• Rainwater collection area: Rainwater collection area is a surface that receives precipitation water, usually including paved areas in terraces, building ground, lawn, vacant ground, concrete roof, corrugated iron, etc.

• Water recovery gutter: The gutter will direct rainwater from the roof ramp to rainwater storage tank. Gutters come in many shapes: semicircles, rectangles, and usually made of PVC or metal materials.

Figure 33. *Rainwater pipeline system connected to drainage ditch*

• Water pipe: Drain water from roof area to storage tank. Pipe can be made of PVC plastic, galvanized iron, etc.

• Rainwater storage tanks: can be built above-ground or underground, made of reinforced cement materials, stainless steel, composite or plastic tanks.

Figure 34. *Typical factory rainwater filtration system*

Processing system:

Rainwater has a certain floating solids. In addition, if being stored in tank for a long time, biologic organisms might develop that need to be treated by chemicals before use. Depending on the plant layout, rainwater can be mixed with utility feed water for treatment or be treated separately.

Conventional rainwater treatment system often utilize reinforced concrete tanks to recover water, then rainwater is filtered by sand and activated carbon to remove floating particles such as mud, clay and dirt. Otherwise, fine filters with an intertwined structure can be used to remove sediment, metals and some microorganisms when there is a significant amount of sediment in the water or higher concentration of iron and manganese. To remove certain types of bacteria, a membrane filter with hole size of 0.5 microns is needed. To get rid of parasites, membrane size should be 1 micron. Some filters are impregnated with carbon to remove low concentration of organic compounds that cause color in the water. Finally, disinfectant chemicals can be used if necessary.

Figure 35. *Typical factory rainwater filtration system*

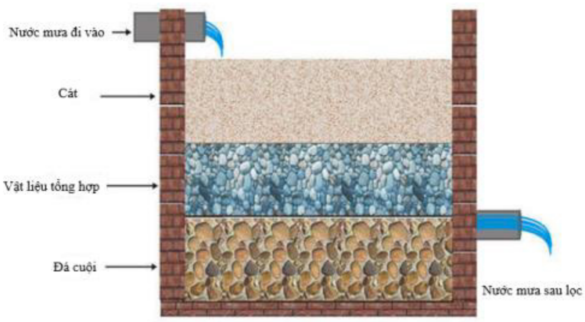


Figure 36. *Structure of a sand filter*

Figure 37. *Fine filter*

Rainwater treatment technologies vary according to the quality of rainwater and use purposes of the plant. They include sand filtration, coal filtration, fine filtration... The quality of rainwater after treatment depends on use purposes such as for production, domestic, watering plants or flushing toilets. Some water quality standards can be refered as follows:

• QCVN 01-1:2018/BYT National technical regulation on clean water for domestic purpose.

• QCVN 08-MT:2015/BTNMT National technical regulation on surface water quality.

Benefits/impacts

Rainwater recovery offers the following benefits:

• Reduce the cost of utility water;

• Contribute to reducing load on the industrial park drainage system, avoiding inundation at times of heavy rains;

• Satisfy sustainability requirement of international customers;

• Prepare for local authority ban on groundwater exploitation.

Scope of application

Some of the following criteria should be considered before applying:

• Average annual rainfall in the area. Look up the following website: Viet Nam Travel Weather Averages (Weatherbase), https://en.climate-data.org/asia/vietnam-60/

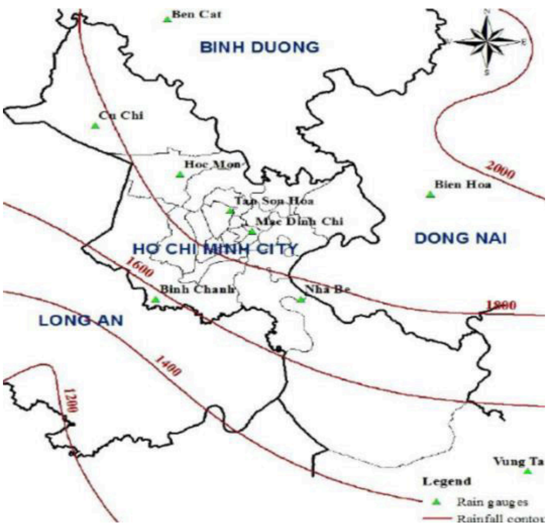


Figure 38. *Rainfall data in Ho Chi Minh City [13]*

• Roof area is large enough to recover rainwater.

• Premises and space for installation of storage tanks and treatment system. Normally, rainwater recovery system area is about 500 - 1,000 m^2 for about 600 - 1,200 m^3 of recovered water (with an average annual rainfall of 1,700 mm/year).

Data to be measured/collected to

calculate economic benefit

Calculation of economic benefits for for the solution of rainwater havesting.

Table 21. *Calculation of economic benefits for the solution of rainwater havesting*

No.	Parameter	Unit	Source
1	Total roof area	m^2	Google Map
2	Average annual rainfall	mm/year	Regional data
3	Percentage of collectable rainwater	%	Audit experience
4	Estimated volumn of collected rainwater	m^3/year	(4)=(1)*(2)*(3)/1000
5	Water savings in a year	m^3/year	(5)=(4)
6	Water costs (tap water cost)	VND/m^3	Factory data
7	Total cost savings	million VND/ year	(7)=(5)*(6)
8	Investment costs	million VND	Supplier
9	Payback period	year	(9)=(8)/(7)

Case study:

At a factory, the average annual rainfall is estimated at 1,868 mm/year along with the proposed roof area of 5,200 m^2. Following savings are realized:

- Water savings: 1.8%, equivalent to 6,800 m^3 of water/year
- Savings amount: 90 million VND/year
- Investment cost: 554 million VND
- Annual operating cost: 18 million VND/year
- Payback period: 6.1 years

Application restrictions

- Rainwater recovery surface/roof materials are not too old or appear rusty.
- Collection pipeline should separate rainwater flow from the general drainage system;
- Air environment around the factory is not polluted with too much fine dust or of a highly acidic environment.

• Sufficient space for constructing rainwater collection tanks and treatment zone.

• Take into account of premise layout, collection pipe length, storage tanks and rainwater handling areas.

• Routine check of rainwater quality is required before use as stored rainwater may develop foul odor due to microbiological contamination.

• Purpose of using rainwater is key factor of the treatment system.

References – Appendix

Dao Nguyen Khoi and Hoang Thi Trang (2016), "Analysis of Changes in Precipitation and Extremes Events," Sustainable Development of Civil, Urban and Transportation Engineering Conference. URL: <https://scholar.google.com/citations?view_op=view_citation&hl=vi&user=pAkyP00AAAAJ&citation_for_view=pAkyP00AAAAJ:cFHS6HbyZ2cC>

4.3. Optimizing printing mold cleaning water

Technical description

After printing the fabric, printing mold is often stained with many chemicals and ink. Therefore, before printing a new batch, they must be cleaned off. Currently, many factories often wash printed molds under direct running water with large flow and furthermore, do not have a separate guidance process for this activity. This practice wastes a large amount of water, which incurs the cost of purchasing water supply as well as wastewater treatment. Therefore, to optimize the water used for printing mold washing, suitable printing mold washing process should be developed and communicated to employees in this unit.

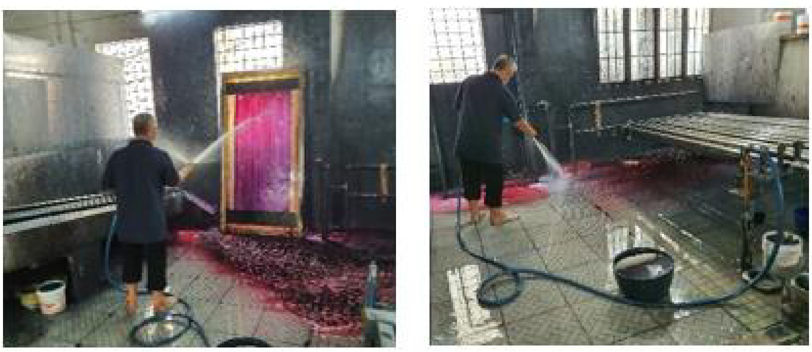


Figure 39. *Cleaning molds by continuous water flow*

The optimal printing mold cleaning process consists of following steps:

Step 1: Workers take molds from printing area to cleaning zone and immerse them in the sink for a specific amount of time for convenient cleaning.

Figure 40. *Water pressure nozzle*

Figure 41. *Cleaning tools*

Step 2: Next, workers to use the appropriate pressure spray to clean off chemicals and inks from the mold surface

Step 3: Finally, workers put molds on shelves to dry them up completely for the next printing.

At the printing mold cleaning area, it is recommended to prepare specialized items such as brooms for cleaning in addition to using water to increase work efficiency.

Benefits/impacts

The optimization of printing mold cleaning water offers the following benefits:

• Reduce the cost of input water for the printing mold cleaning process. In addition, saving wastewater treatment costs and discharge costs (if any) of the factory and the cost of discharging waste into the industrial park.

• Save labor and time for cleaning printed mold cleaning area.

• Production area is always kept clean and dry, which helps avoid affecting main production areas.

Scope of application

• Factories that use high-flow faucets to clean printing mold directly.

• Factories yet to have a specific printing mold cleaning process.

• Ineffective mold cleaning process, with too many steps.

• Economically feasible for factories that consume large amount of water for mold cleaning.

Data to be measured/collected to calculate economic benefit

Calculation of economic benefits for the solution of Optimizing printing mold cleaning water.

Application restrictions

Table 22. *Calculation of economic benefits for the solution of Optimizing printing mold cleaning water*

No.	Parameter	Unit	Source
1	Average number of molds being cleaned during a day	mold/day	Factory data
2	Number of operating days in a year	day	Factory data
3	Average cleaning time	min/mold	Survey/Measurement
4	Current water flow used when cleaning	liter/minute	Measurement
5	Amount of water used for printing mold cleaning	m^3	(5) = (1)*(2)*(3)*(4) /1000
6	Water flow used after installing pressure nozzle	liter/minute	Supplier
7	Water savings	m^3/year	(7) = ((4)-(6)*(1)*(2)*(3) /1000
8	Water costs	VND/m^3	Factory data
9	Total cost savings	million VND/year	(9) = (7)*(8)/10^6
10	Investment costs	million VND	Supplier
11	Payback period	year	(11) = (10)/(9)

Case study:

A textile dyeing factory has applied a procedure of cleaning the printing mold (when there is a change in printing color, printed pattern or there is a request from production). On average, the factory cleans about 10 printed molds daily and the cleaning time for each mold is about 9 minutes. Initially the factory used direct faucet cleaning with a large flow of 15 liters/minute. After switching to pressure cleaning using a water pressure nozzle with a lower flow of about 7 liters/minute, the savings were as follows:

- Water savings: 0.11%, equivalent to 216 m³/year
- Savings amount: 4.3 million VND/year
- Investment cost: 0.5 million VND
- Payback period: 0.1 years

• Soaking the mold too long affects its quality. The soaking time ranges from 10 to 15 minutes before cleaning.

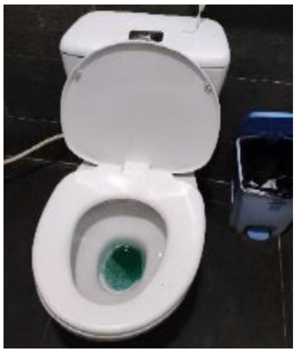
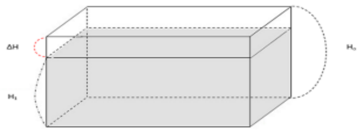
• A cleaning process information sheet is required to remind workers to follow the correct cleaning process and time.

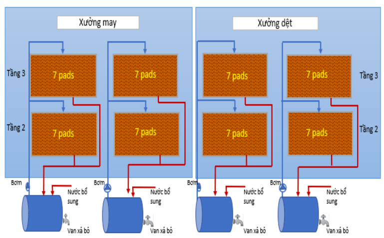
• Cleaning area need to be convenient between each printing line, isolated and avoid affecting other production areas.

• Water pressure of a cleaning nozzle may sometimes require attention, especially when a printing mesh mold has torn holes. Any water pressure, in that case, can cause further damage to the print mold.

4.4. Other solutions

Solution group	Solution	Description	Image
Domestic water	Installing low-flow aerator for faucet	- Applicable for faucets with high water flow. - Installing aerators to reduce water flow of faucets according to LEED version 4 standard, requiring water flow be as low as 1.9 liters/ minute.	
	Replacing high-flow with low-flow faucets	- Many factories still using hand-swipe faucets, hand-valve faucets, or high-flow faucets without an aerator installation position - Replacing these faucets with low-flow faucets to meet LEED standard requirements.	

Solution group	Solution	Description	Image
	Replacing single flush toilets with dual flush toilets	- Dual flush toilets can be used for different purposes. - Modification from single flush to dual flush scheme does not require high investment cost, but investment of new dual flush toilet is more cost-effective.	
Water maintenance/ management	Control leakage	- Leakage points often occur at the junction points of pipes, faucets or water-use equipment. - Set up management and maintenance routine of water distribution system. Instal water meters and record consumption.	 
	Install a central water data management system	- Manual recording of water consumption data on meters and make daily reports is time and labor extensive. - Gradually change to electronic meters once mechanical meters get broken.	
Reusing water	Recovering reject water from filter tanks before backwashing	- Utility water supplied by industrial park need to be softened by a filtration system before feeding to the production process and boiler. After a certain operation period, it is necessary to regenerate plastic beads to increase ion exchange of the filtration system. - Reject water of the filtration sytem is often discharged to wastewater treatment system. This source of water can be recovered, preliminarily treated and resupplied to the workshop for different purposes.	

Solution group	Solution	Description	Image
	Reusing wastewater for boiler dust stamping	- Steam and thermal oil boiler supply heat for factory operation. Boiler exhaust gas need to be treated before being released into the environment. - Wastewater after treatment is at least Column B standard according to QCVN 40:2011/BTNMT, reusing this water for dust stamping instead of using new clean water.	
Technology/ Process	Optimizing cooling tower blow down	- Depending on water quality and equipment to be cooled down, the cooling tower blow down time will be different. - According to the US Environmental Protection Agency (EPA), maximum allowable conductivity of water in cooling towers is 2,000 µS/cm. Considering extending the blow down time of the cooling towers to reduce water consumption. - When the TDS index of water in the cooling tower reaches about 1,800 µS/cm, implementing blow down and mark that number of days as the tower's blow down cycle. (See the TDS tracking table of cooling tower blow down water for reference)	
	Optimizing cooling pad blow down	- Cooling pad system (ventilation system combined with water membrane) helps ventilate the workshop. - According to consultant experience, blow down of cooling pad water tanks will be done after 05 to 10 days of operation or when the TDS index of cooling pad water reaches 1,500 ppm.	

BẢNG THEO DÕI TDS CỦA NƯỚC XẢ ĐÁY THÁP

	TDS (µS/cm)
Ngày 1	
Ngày 2	
Ngày 3	
Ngày 4	
Ngày 5	
Ngày 6	
Ngày 7	
Ngày 8	
Ngày 9	
Ngày 10	
...	
...	1,800

Solution group	Solution	Description	Image
	Reducing overflow washing	- After dyeing, it is necessary to do overflow washing to lower the temperature as required for finished product. Overflow washing method consumes a lot of water due to the need of continuous water supply and discharge. - Replacing overflow washing with discontinuous washing (loading, running, and discharging)	

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