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MINISTRY OF AGRICULTURE AND FORESTRY
GENERAL DIRECTORATE OF WATER MANAGEMENT

Water Efficiency Campaign

Water Efficiency Guidance Documents Series

FINISHING OF TEXTILE PRODUCTS

NACE CODE: 13.30

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Abbreviations

WWTP	Wastewater Treatment Plant
EU	European Union
SS	Suspended Solids
BREF	Best Available Techniques Reference Document
EMS	Environmental Management System
MoEUCC	Republic of Turkey Ministry of Environment, Urbanization and Climate Change
NOM	Natural Organic Matter
EMAS	Eco Management and Audit Program Directive
EPA	United States Environmental Protection Agency
IPPC	Industrial Pollution Prevention and Control
ISO	International Organization for Standardization
BAT	Best Available Techniques
NACE	Statistical Classification of Economic Activities
GDWM	General Directorate of Water Management
RO	Reverse Osmosis
MoAF	Ministry of Agriculture and Forestry of the Republic of Turkey
TURKSTAT	Turkish Statistical Institute
NF	Nanofiltration
MF	Microfiltration
UF	Ultrafiltration
GW	Groundwater
SW	Surface Water

1 Introduction

Our country is located in the Mediterranean basin, where the effects of global climate change are felt intensely, and is considered among the regions that will be most affected by the negative effects of climate change. Projections on how our water resources in our basins will be affected in the future due to climate change show that our water resources may decrease by up to 25 percent in the next hundred years.

For 2022, the annual amount of usable water per capita in our country is 1,313 m³, and it is expected that the annual amount of usable water per capita will fall below 1,000 cubic meters after 2030 due to human pressures and the effects of climate change. It is obvious that if the necessary measures are not taken, Turkey will become a country suffering from water scarcity in the very near future and will bring many negative social and economic consequences. As can be understood from the results of future projections, the risk of drought and water scarcity awaiting our country necessitates the efficient and sustainable use of our existing water resources.

The concept of water efficiency *can be defined as* "the use of the least amount of water in the production of a product or service". Water efficiency approach; It is based on the rational, sharing, equitable, efficient and effective use of water in all sectors, especially drinking water, agriculture, industry and household uses, taking into account the needs of not only people but also ecosystem sensitivity and all living things by protecting it in terms of quantity and quality.

With the increasing demand for water resources, the change in precipitation and temperature regimes as a result of climate change, the increase in population, urbanization and pollution, it is becoming more and more important to share the usable water resources among the users in a fair and balanced way. For this reason, it has become a necessity to create a roadmap based on efficiency and optimization in order to protect and use limited water resources with sustainable management practices.

In the sustainable development vision determined by the United Nations, Goal 7 from the Millennium Development Goals: *Ensuring Environmental Sustainability* and Goal 9 from the Sustainable Development Goals*: Industry, Innovation and Infrastructure* and *Goal 12: Responsible Production and Consumption goals* Issues such as efficient, fair and sustainable use of resources, especially water, environmentally friendly production and consumption that is the concern of future generations are included.

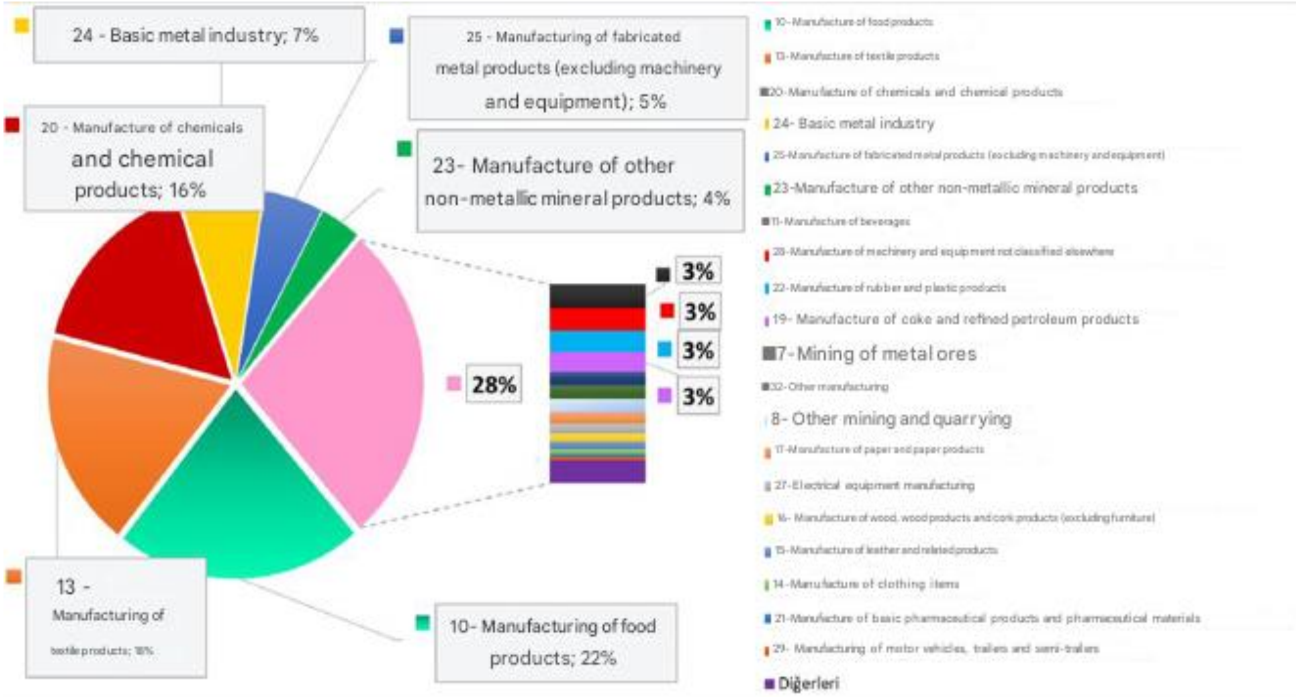
In the European Green Deal Action Plan prepared by our country within the scope of the European Green Deal, where member countries agree on goals such as implementing a clean, circular economy model with the goal of carbon neutrality, expanding the efficient use of resources and reducing environmental impacts, actions emphasizing water and resource efficiency in various fields, especially in industry, production and consumption have been determined.

The "Industrial Emissions Directive (EED)", which is one of the most important components of the European Union environmental legislation in terms of industry, includes the measures to be taken to control, prevent or reduce the discharges/emissions from industrial activities to the receiving environment, including air, water and soil, with an integrated approach. In the Directive, Best Available Techniques (BAT/ BAT) are presented in order to systematize the applicability of cleaner production processes and to eliminate the difficulties experienced in practice. Considering the costs and benefits, BATs are the most effective implementation techniques for a high level of environmental protection. In accordance with the Directive, Reference Documents (BAT-BREF) have been prepared for each sector, in which the BATs are explained in detail. In BREF documents, BATs are presented in a general framework such as good management practices, general precautionary techniques, chemical use and management, techniques for various production processes, wastewater management, emission management and waste management.

The Ministry of Agriculture and Forestry, General Directorate of Water Management carries out studies aimed at disseminating efficient practices in urban, agricultural, industrial and individual water use and increasing social awareness. "Water Efficiency Strategy Document and Action Plan within the Framework of Adaptation to the Changing Climate ***(2023-2033)" entered into force with the Presidential Circular No. 2023/9*** Water efficiency action plans addressing all sectors and stakeholders have been prepared. In the Industrial Water Efficiency Action Plan, a total of 12 actions have been determined for the period 2023-2033 and responsible and relevant institutions have been appointed for these actions. Within the scope of the said Action Plan; Carrying out studies to determine specific water usage ranges and quality requirements on the basis of sub-sectors in the industry, organizing technical training programs and workshops on a sectoral basis, and preparing water efficiency guidance documents are defined as the responsibility of the General Directorate of Water Management.

On the other hand, with the "Industrial Water Use Efficiency Project According to NACE Codes" ***carried out by the Ministry of Agriculture and Forestry, General Directorate of Water Management,*** the best sectoral techniques specific to our country have been determined within the scope of studies to improve water efficiency in the industry. As a result of the study, sectoral guidance documents and action plans classified with NACE codes, which include the measures recommended to improve water use efficiency in sectors with high water consumption operating in our country, have been prepared.

As in the world, the sectors with the highest share in water consumption in our country are food, textile, chemistry and basic metal sectors. Within the scope of the studies, field visits were carried out in enterprises representing 152 sub-sectors in 35 main sectors, especially food, textile, chemistry, basic metal industry, which will represent production areas of different capacities and diversity within the scope of NACE Codes, which operate in our country and have high water consumption, and provide data on water supply, sectoral water use, wastewater generation and recycling. and the best available techniques (BAT) and sectoral reference documents (BREF) published by the European Union, water efficiency, cleaner production, water footprint, etc.



Distribution of water use in industry on a sectoral basis in our country

As a result of the studies, specific water consumption and potential savings rates for the processes of the enterprises were determined for 152 different 4-digit NACE codes with high water consumption, and water efficiency guidance documents were prepared by taking into account the EU best available techniques (BAT) and other cleaner production techniques. The guidelines include 500 techniques for water efficiency (BAT);
It has been examined under 4 main groups: (i) Good Management Practices, (ii) General Measures, (iii) Measures Related to Auxiliary Processes and (iv) Sector-Specific Measures.

Within the scope of the project, environmental benefits, operational data, technical specifications-requirements and applicability criteria were taken into account during the determination of BATs for each sector. In the determination of BATs, BREF documents were not limited to the BATs, but also different data sources such as current literature data, real case studies, innovative practices, and reports of sector representatives on a global scale were examined in detail and sectoral BAT lists were created. In order to evaluate the suitability of the BAT lists created for the local industrial infrastructure and capacity of our country, the BAT lists prepared specifically for each NACE code were prioritized by the enterprises by scoring them on the criteria of water saving, economic saving, environmental benefit, applicability, cross-media impact, and the final BAT lists were determined using the scoring results. Sectoral water efficiency guidelines have been created on the basis of the NACE code based on the water and wastewater data of the facilities visited within the scope of the project and the final BAT lists highlighted by the sectoral stakeholders and determined by taking into account the local dynamics specific to our country.

2 Scope of the Study

The guidance documents prepared within the scope of water efficiency measures in the industry include the following main sectors:

- Crop and animal production, hunting and related service activities (including sub-production areas represented by 6 four-digit NACE Codes)
- Fisheries and aquaculture (including 1 sub-production area represented by a four-digit NACE Code)
- Extraction of coal and lignite (including 2 sub-production areas represented by a four-digit NACE Code)
- Service activities in support of mining (including 1 sub-production area represented by a four-digit NACE Code)
- Metal ore mining (including 2 sub-production areas represented by a four-digit NACE Code)
- Other mining and quarrying (including 2 sub-production areas represented by a four-digit NACE Code)
- Manufacture of food products (including 22 sub-production areas represented by a four-digit NACE Code)
- Manufacture of beverages (including 4 sub-production areas represented by a four-digit NACE Code)
- Manufacture of tobacco products (including 1 sub-production area represented by a four-digit NACE Code)
- Manufacture of textiles (including 9 sub-production areas represented by a four-digit NACE Code)
- Manufacture of apparel (including 1 sub-production area represented by a four-digit NACE Code)
- Manufacture of leather and related products (including 3 sub-production areas represented by a four-digit NACE Code)
- Manufacture of wood, wood products and cork products (except furniture); manufacture of articles made by knitting from reeds, straw and similar materials (including 5 sub-production areas represented by a four-digit NACE Code)
- Manufacture of paper and paper products (including 3 sub-production areas represented by a four-digit NACE Code)
- Manufacture of coke and refined petroleum products (including 1 sub-production area represented by a four-digit NACE Code)
- Manufacture of chemicals and chemical products (including 13 sub-production areas represented by a four-digit NACE Code)
- Manufacture of basic pharmaceutical products and pharmaceutical materials (including 1 sub-production area represented by a four-digit NACE Code)
- Manufacture of rubber and plastic products (including 6 sub-production areas represented by a four-digit NACE Code)
- Manufacture of other non-metallic mineral products (including 12 sub-production areas represented by a four-digit NACE Code)
- Base metal industry (including 11 sub-production areas represented by a four-digit NACE Code)
- Manufacture of fabricated metal products (excluding machinery and equipment) (including 12 sub-production areas represented by a four-digit NACE Code)
- Manufacture of computers, electronic and optical products (including sub-production area represented by 2 four-digit NACE Codes)
- Manufacture of electrical equipment (including 7 sub-production areas represented by a four-digit NACE Code)
- Manufacture of machinery and equipment, n.e.c. (including 8 sub-production areas represented by a four-digit NACE Code)
- Manufacture of motor vehicles, trailers and semi-trailers (including 3 sub-production areas represented by a four-digit NACE Code)

- Manufacture of other means of transport (including 2 sub-production areas represented by a four-digit NACE Code)
- Other productions (including 2 sub-production areas represented by a four-digit NACE Code)
- Installation and repair of machinery and equipment (including 2 sub-production areas represented by a four-digit NACE Code)
- Electricity, gas, steam and ventilation system production and distribution (including 2 sub-production areas represented by a four-digit NACE Code)
- Waste collection, remediation and disposal activities; recovery of materials (including 1 sub-production area represented by a four-digit NACE Code)
- Construction of non-building structures (including 1 sub-production area represented by a four-digit NACE Code)
- Storage and supporting activities for transportation (including 1 sub-production area represented by a four-digit NACE Code)
- Accommodation (including 1 sub-production area represented by a four-digit NACE Code)
- Educational Activities (Higher Education Campuses) (including 1 sub-production area represented by a four-digit NACE Code)
- Sports, entertainment and recreational activities (including 1 sub-production area represented by a four-digit NACE Code)

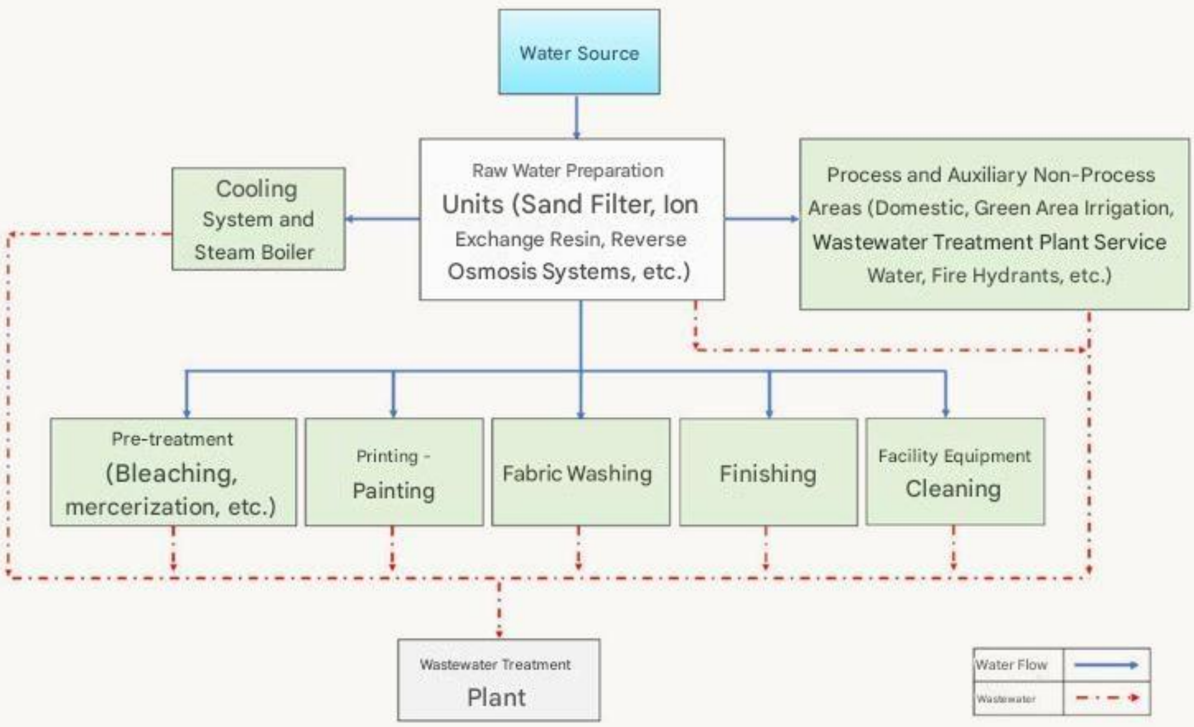
"Manufacture of Textile Products" and "Manufacture of Apparel"

Under the "Manufacture of Textile Products" and "Manufacture of Clothing" sector, the sub-production branches for which guide documents have been prepared are as follows:

13.10	Preparation and twisting of textile fiber
13.20	Woven
13.30	Finishing of textiles
13.91	Manufacture of knitted (knitwear) or crocheted (crochet) fabrics
13.92	Manufacture of finished textiles other than apparel
13.93	Manufacture of carpets and rugs
13.95	Manufacture of nonwovens and products made from nonwovens, excluding apparel
13.96	Manufacture of other technical and industrial textiles
13.99	Manufacture of other textiles n.e.c.
14.13	Manufacture of other outerwear

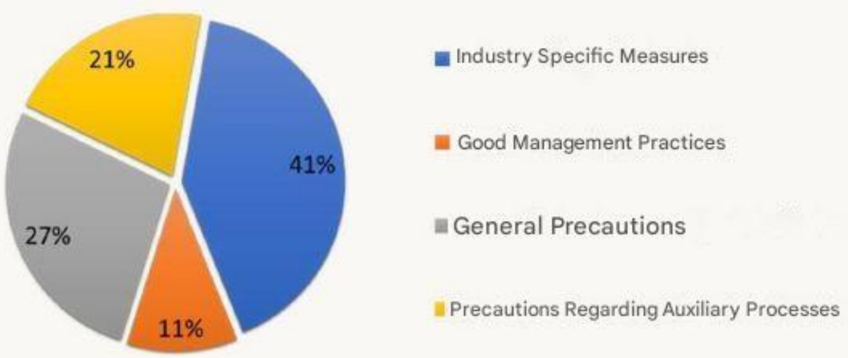
2.1 Finishing of Textile Products (NACE 13.30)

Textile Products Finishing Sector Water Flow Diagram



	Minimum	Maximum
Specific Water Consumption of Facilities Visited within the Scope of the Project (L/kg product)	0.06	402.6
Reference Specific Water Consumption (L/kg product)	50	250

Percentage Distribution of Water Efficiency Practices



The finishing of textile products sector covers the pre-treatment, dyeing-printing and finishing-finishing (finishing) processes of textile materials. Depending on the raw material used in the facilities, the techniques/technologies applied and the features expected from the product, one or more of these processes can be used in the production processes. Textile materials are prepared for dyeing-printing process in pre-treatment processes such as bleaching, bleaching, hydrophilizing, mercerization. In addition, technical properties such as strength, dyestuff affinity, and gloss are added to the raw material to be used. In dyeing-printing processes, it is aimed to color textile materials with various dyeing-printing methods and recipes. In the final finishing processes, technical properties such as non-flammability, water-oil repellency, wrinkle resistance are gained in accordance with the use of the final product.

In the finishing of textile products, water consumption is generally realized in fabric washing, printing/dyeing and finishing processes. Significant water consumption is also realized for filter washing, resin regeneration and membrane cleaning processes in raw water preparation units such as activated carbon filters, ion exchange resins, reverse osmosis, which are used to produce soft water for use in production processes in the sector. In addition, water consumption occurs in auxiliary units such as cooling towers and steam boilers.

In the textile finishing sector, the reference specific water consumption is in the range of 50 – 250 L/kg. The specific water consumption of the production branch analyzed within the scope of the study is 0.06 – 406.2 L/kg. With the implementation of sector-specific techniques, good management practices, measures in the nature of general measures and measures related to auxiliary processes, in the sector It is possible to achieve 29-50% water recovery.

13.30 Finishing of Textile Products The priority water efficiency implementation techniques recommended under the NACE code are presented in the table below.

NACE Code	NACE Code Description	Prioritized Sectoral Water Efficiency Techniques
13.30	Finishing of textiles	**Industry-Specific Measures**
		1. Increasing washing efficiency in textile processes
		2. Reducing the use of hydrogen peroxide stabilizers in the bleaching process
		3. Reduction of print paste losses on rotary printers
		4. Reduction of the number of dyes and use of automated dosing and dispensing systems in dosing and dispensing of dye formulations
		5. The use of dyestuffs that can adhere to the fiber at a high rate and the auxiliary chemicals that provide this
		6. Treatment of dyeing wastewater by chemical precipitation
		7. Reuse of dyeing bath solution waste in dyeing
		8. Reuse of dyeing baths
		9. Recovery of washing wastewater after dyeing by membrane filtration
		10. Reduction of sizing agent use by pre-wetting the warp yarns
		11. Use of equipment with automatic control mechanism and isolation system to reduce steam losses
		12. Reuse of rinse water in the next painting
		13. Selection of the most suitable machines for the lot sizes to be processed
		14. Application of fill-unload systems instead of overflow washing method
		15. Preferring a low flotte ratio in the selection of new machines
		16. Use of solvents in cleaning and washing to remove knitting oils from the fabric
		17. Use of biodegradable and water-soluble lubricants instead of conventional mineral oil-based lubricants
		18. Avoiding the use of dangerous carriers
		19. Boiling rinsing instead of using detergent in the final washing of cotton dyed with reactive dyes
		20. Reduction of water and energy consumption by pad-batch dyeing with reactive dyes
		21. Dyeing according to the puller method with low-salt reactive dyestuffs that provide high fixation
		22. Removal of dirty water remaining in the fiber from the fiber before the next wash
		23. Use of advanced systems for dosing impregnation floats
		24. On-line distribution of chemicals through separate lines
		25. Using countercurrent flushing
		26. Use of washing/rinsing wastewater for cleaning purposes

NACE Code	NACE Code Description	Prioritized Sectoral Water Efficiency Techniques
13.30	Finishing of textiles	27. Use of highly efficient washing machines and energy recovery equipment in continuous processes 28. Use of fill-and-dump wash or smart rinse techniques instead of overflow/rinse 29. Application of pH control methods in dyeing with acid and basic dyes 30. Use of reactive dyes instead of chromium-containing dyes 31. Minimizing the mixing of heavy metals into wastewater in the dyeing process with metal complex paints 32. Reuse of wash water from printing dyeing tape cleaning 33. Replacing traditional oils with water-soluble oils Collecting cooling water 34. that does not come into contact with fabric/yarn and reusing it in processes requiring hot water 35. Returning wastewater other than pre-treatment and finishing wastewater to the production process using membrane technologies 36. Reuse of finishing wastewater in other processes Reuse of cooling 37. water that does not come into contact with the product in the process 38. Substitution of mineral oils with low biodegradability in the process of synthetic fiber preparation 39. Substitution of sodium hypochlorite and chlorite-containing compounds used in the bleaching process 40. Separation of wastewater from hypochlorite bleaching from other wastewater streams and composite wastewater 41. Use of biodegradable/eliminable complexing agents in pre-treatment and dyeing processes Pigment printing pastes with optimized environmental 42. performance Use Wastewater from the last wash after dyeing, required for dyeing 43 To be used in the preparation of the dyeing bath if it meets the process water criteria 44. Recovery of washing wastewater after dyeing by adsorption 45. Combining dessizing/washing and bleaching in a single step 46. Selection of raw materials with low additive application Stabilized pre- 47. unreduced sulfur-free dyestuffs or sulfur content Use of pre-reduced liquid dye formulations of less than 1%

NACE Code	NACE Code Description	Prioritized Sectoral Water Efficiency Techniques
13.30	Finishing of textiles	48. Using hydrogen peroxide as an oxidizer
		49. Using only the amount of reducing agent required for the reduction of the dyestuff
		50. Recovery of alkali in mercerized rinse water
		51. Removal of water-insoluble oils by washing with organic solvents
		52. Performing the thermosetting process before washing
		53. Use of low-input processes and minimization of impregnation vat volume
		54. Reduction of concentrated flotte losses
		55. Use of fully closed-loop equipment in the use of halogenated organic solvents
		56. Use of polyfunctional reactive dyestuffs instead of conventional reactive dyes
		57. Reducing wastewater generation with application techniques such as foaming and spraying in finishing
		58. Using sodium chloride for flax and bast fibers that cannot be bleached with hydrogen peroxide alone
		59. Treatment and reuse of wastewater containing pigment printing paste
		60. In printing-dyeing processes; Reducing water consumption in cleaning processes
		61. Use of water flow control devices and automatic shut-off valves in continuously operating machines
		62. Evaluation of the possibilities of reuse of technically suitable wastewater streams without treatment
		Good Management Practices
		1. Using an integrated wastewater management and treatment strategy to reduce the amount of wastewater and the pollutant load
		2. Establishment of an environmental management system
		3. Preparation of water flow diagrams and mass balances for water
		4. Preparation of a water efficiency action plan to reduce water use and prevent water pollution
		5. Providing technical training to personnel for the reduction and optimization of water use
		6. Good production planning to optimize water consumption
		7. Setting water efficiency targets
		8. The water used in production processes and auxiliary processes and the formed Monitoring wastewater in terms of quantity and quality and using this information in environmental management Adaptation to the system

NACE Code	NACE Code Description	Prioritized Sectoral Water Efficiency Techniques
13.30	Finishing of textiles	**General Water Efficiency BATs** 1. Minimization of spills and leaks 2. Recovery of water from rinsing solutions and reuse of recovered water in processes appropriate to its quality 3. It will save water at water usage points such as showers/toilets, etc. automatic hardware and equipment (sensors, intelligent handwashing systems etc.) Use 4. Use of pressure washers for equipment cleaning, general cleaning, etc. 5. Reuse of filter washing water in filtration processes, production reuse of relatively clean cleaning water in processes and reduce water consumption through the use of clean-in-place systems (CIP) 6. Avoiding the use of drinking water in production lines 7. Use of cooling water as process water in other processes 8. Detection and reduction of water losses 9. Use of automatic check-off valves to optimise water use 10. Documentation of production procedures and use by employees to prevent waste of water and energy 11. Reuse of pressurized filtration backwash water prior to water softening at appropriate points 12. Optimising the frequency and duration of regeneration (including rinses) in water softening systems Transport of toxic or hazardous chemicals for the aquatic environment 13. Construction of closed storage and impermeable waste/scrap yard to prevent Storage, storage and post-use of substances that pose a risk in the aquatic environment (such as oils, emulsions, binders 14.) Blocking 15. Where technically feasible, suitable wastewater is treated and used as steam boiler feed water 16. Prevention of mixing of clean water streams with polluted water streams Wastewater quantities and qualities at all wastewater formation points 17. Characterization and determination of wastewater streams that can be reused with or without treatment 18. Use of closed-loop water cycles in appropriate processes 19. Computer-aided control systems in production processes Use

NACE Code	NACE Code Description	Prioritized Sectoral Water Efficiency Techniques
13.30	Finishing of textiles	20. Untreated reuse of relatively clean wastewater from washing, rinsing and equipment cleaning in production processes 21. Determination of the scope of reuse of washing and rinsing waters 22. Separate collection and treatment of gray water in the facility and use it in areas that do not require high water quality (green area irrigation, floor, floor washing, etc.) 23. Implementation of time optimization in production and arrangement of all processes to be completed as soon as possible 24. Collecting rainwater and evaluating it as an alternative water source in facility cleaning or in appropriate areas 25. Avoiding the need for rinsing between activities by using compatible chemicals in successive processes Nanofiltration (NF) or reverse osmosis (CTR) concentrates 26. Reuse with or without purification depending on characterization **Precautions for Auxiliary Processes** 1. Saving water by reusing steam boiler condensate 2. Water saving through isolation of steam and water lines (hot and cold) providing, preventing water and steam losses at pipes, valves and connection points in the lines and monitoring them with a computer system 3. Based on the principle of reverse osmosis of old equipment in the ventilation system replacement with ion exchange resins (systems that produce demineralized water) and reuse of water 4. Reuse of the liquid formed by condensation from the ventilation system 5. Avoiding unnecessary cooling processes by identifying processes that need wet cooling 6. Reduction of water consumption in closed-loop cooling systems by increasing the number of cycles and improving the quality of the catch-up water

NACE Code	BORN Code Description		Prioritized Sectoral Water Efficiency Techniques
13.30	Finishing of textiles	7.	Reduction of evaporation losses in closed-loop cooling water
		8.	Water recovery with tower cooling application in systems that do not have a closed loop
		9.	Increasing the number of cycles by using anti-corrosion and anti-scale inhibitors in systems with a closed water loop
		10.	Prevention of flash steam losses due to boiler draining
		11.	The use of hot water produced in the cogeneration system in heating processes
		12.	Use of cold water produced in the cogeneration system in cooling processes
		13.	Installation of water softening systems for the healthy operation of cooling water recovery systems
		14.	Use of a closed-loop refrigeration system to reduce water use
		15.	In some periods of the year, when the need for cooling is low, cooling with local dry air
		16.	Collecting the water generated by surface runoff with a separate collection system and using it for cooling water, process water, etc.
		17.	Reducing the amount of blowdown by using deaerators in steam boilers
		18.	Minimizing boiler discharge water (blowdown) in steam boilers
		19.	Reuse of energy generated from steam condenser A total of

115 techniques have been proposed in this sector.

2.1.1 Industry-Specific Measures

- ***Reuse of finishing wastewater in other processes***

  The reuse of finishing wastewater in other processes is one of the effective practices that reduce water use in the sector. With this application, water savings can be achieved at varying rates in various industrial facilities.

- ***Returning wastewater other than pre-treatment and finishing wastewater to the production process using membrane technologies***

  The burning, hydrophilizing, mercerization and bleaching processes carried out to remove the foreign substances on the fabric after the fabric comes out of the weaving machine or knitting machine are called pre-treatment. The purpose of the pre-treatment process; It is to make the raw fabric ready for dyeing or printing. All mechanical and chemical processes that textile materials undergo before leaving them to the finishing plant after pre-treatment and coloring processes are called finishing processes or finishing processes. With the exception of wastewater from pre-treatment (hydrophilization and bleaching) and finishing processes (impregnation flotter wastes), other wastewater can be combined and returned to the production process by ultrafiltration + nanofiltration + reverse osmosis (IPPC BREF, 2003).

- ***Reuse of coolants that do not come into contact with the product in the process***

  Water is used as the most suitable heat transfer fluid in the cooling process. In industrial applications, cooling water is used in single-pass cooling systems, closed-circuit cooling systems and open-type cooling circuits. Cooling water that does not come into contact with any product can be reused in the process by rotating it in a closed circuit or by maintaining it properly (IPPC BREF, 2003).

Washing Machines in the Textile Industry

- ***Collecting cooling water that does not come into contact with fabric/yarn and reusing it in processes requiring hot water***

  Cooling water that does not come into contact with fabric or yarn can be collected in a tank and reused in processes that require hot water such as dyeing, whitening and washing. With this method, condenser-cooling water, heat exchanger water, water from compressors can be recovered (IPPC BREF, 2003).

- ***Selection of raw materials with low additive application***

  The process of transferring chemicals to fabrics in aqueous environments is called application. "Impregnation" and "puller" methods are used for the application. A reduction in the rate of chemical pollution can be achieved by using raw materials with low additional material application. Thus, the wastewater pollution load is reduced and the recovery potential of wastewater increases.

- ***Reduction of sizing agent use by pre-wetting the warp yarns***

  Reducing the amount of sizing applied to the warp yarn during weaving preparation is one of the most effective pollution prevention methods to reduce the organic load caused by sizing materials. The pre-wetting application is based on passing the warp yarn through hot water before sizing. The warp yarn is immersed in hot water (an additional jet of hot water is possible) and then a pair of spin rollers removes excess water prior to the sizing step. In addition, systems with double dip and squeeze steps are also used. In addition to more homogeneous sizing, sizing adhesion is increased and yarn hairiness is reduced by pre-wetting application. With this method, a smaller amount of sizing material can be applied to the fibers without affecting the weaving efficiency. Reducing the use of sizing matter increases the potential for wastewater recovery by reducing the pollutant load in wastewater.

  Sizing agents are applied to the warp yarns to prevent yarn breakage during weaving. Pre-wetting can be applied to the warp yarn before the sizing agents are applied to the warp yarn. Pre-soaking; It is based on passing the warp yarn through hot water before sizing. The warp yarn is immersed in hot water (an additional jet of hot water is possible) and then a pair of spin rollers removes excess water prior to the sizing step. Pre-wetting provides more homogeneous sizing and minimizes the amount of sizing agent used (IPPC textile BREF, 2003). By pre-wetting the warp yarn, reductions of 20-50% in the amount of sizing material used can be achieved (IPPC textile BREF, 2003). Reducing the use of sizing material reduces the pollutant load in wastewater and increases the wastewater recovery potential.

- ***The use of dyestuffs that can adhere to the fiber at a high rate and the auxiliary chemicals that provide this***

  With the use of dyes that can adhere to the fiber at a high rate, the number of washing baths and water consumption in post-processing can be reduced. With the application of this technique, improvements can be achieved in water consumption, chemical use, wastewater quantity and pollution load of wastewater (IPPC BREF, 2003).

- ***Combining dessizing/washing and bleaching in a single step***

  Desizing is the most important source of pollution in textile processes. Especially in cases where natural sizing materials are removed, washing water from desizing can constitute 70% of the total COD in final wastewater. Within the scope of resource use efficiency in the textile industry, it is recommended to combine desizing/washing and bleaching in a single step.

  New excipient formulations, automatic dosing and new steamers: dessizing, hydrophilizing (alkaline cracking) and pad steam peroxide bleaching are carried out in one step. Combining the three processes in one step significantly reduces water and energy consumption.

  For example, when the production of white, undyed cotton covers is examined, there is no need to descale the fabric after weaving. The traditional process consists of five steps, which include soaking/hydrophilizing, basic peroxide bleaching, and three successive rinsing steps. The final rinse water is reused to create the first bath. This process can be further enhanced by combining the soaking/hydrophilizing and bleaching steps in one step, rinsing in two steps, and reusing the second rinse bath in the bleaching/hydrophilizing bath . In addition, the energy consumption of the process can be reduced by heat recovery. It is stated that with these improvements, a 50% reduction in the water requirement in the process will be achieved.

- ***Reduction of the number of dyes and use of automated dosing and dispensing systems in dosing and dispensing of dye formulations***

  In the textile industry, dyeing processes are one of the most water-consuming processes. Since the dyeing efficiency will increase with the reduction of the number of dyes and the use of an automation system, water consumption decreases with the application of the technique. The following methods can be applied to reduce water consumption in dosing and dispensing paint formulations:

  - Reducing the number of dyes through the use of trichromatic systems,
  - The use of manual systems for dosing and dispensing only dyes that are not used frequently, and automatic systems for dosing and dispensing other dyes,
  - Reduction of dead volume in the distribution line on long continuous lines by using decentralized automation stations where different chemicals are not mixed with the paint before processing and the system is cleaned fully automatically.

- ***Use of equipment with automatic control mechanism and isolation system to reduce steam losses***

  Automatic control mechanisms, such as doors that ensure full closure of the machines, reduce steam losses in batch dyeing. Steam leaks may occur if the steam lines and hot surfaces are not fully insulated due to the lack of proper design of the steam lines and routine maintenance and repairs in the facility . This increases both the water consumption and energy consumption of the facility. Steam insulation and continuous monitoring of steam consumption using automatic control systems can reduce water consumption.

- ***Preferring a low flotte ratio in the selection of new machines***

  Machines with a high float ratio cause not only high water and energy consumption, but also the consumption of chemicals and auxiliaries, which are dosed according to the volume of the float. Machines operating with low float ratio, on the other hand, achieve higher fixation efficiencies by saving chemicals as well as water and energy. However, the total water consumption is not only determined by the flotte ratio in the dyeing step, but is also affected by the rinsing and washing processes. "Ultra-low float ratio" is used to describe machines that can work with the minimum amount of water required to ensure complete wetting of the textile product and to prevent cavitation of the pumps. This term is used only for machines that are dyed in ropes. The fact that both the material and the float are circulated at the same time by preferring features such as low float ratio, separation of the process flottle and washing flottes, and separation of the float from the raw material during the process reduces water use (IPPC BREF, 2003).

- ***Use of low-input processes and minimization of impregnation vat volume***

  According to the impregnation method, the main emission sources in the dyeing processes are the discharge of waste paint flottes in boats, pumps and pipes while dyeing in a new color at the end of each batch. These losses can be reduced by placing a float in the upper space between the clamping rolls of the impregnation step or by minimizing the vessel volume (e.g. flexible-frame, U-shaped chassis). The capacities of conventional impregnation vats range from 30 to 100 liters. The use of U-shaped vessels (with a capacity of 12 litres) can reduce the amount of unused float by up to 60%-90% per batch compared to the conventional system. Instead, if painting between rollers with flotte application systems (5 liters), a reduction of up to 95% is achieved.

- ***On-line distribution of chemicals through separate lines***

  In pre-treatment, dyeing and finishing processes (continuous or semi-continuous processes) where concentrated impregnation flottes are used, preventing or minimizing flotte excesses provides environmental benefits. In the automatic systems used for the just-in-time preparation of the flottes, the required amount of flotte can be prepared and added by on-line measurement of the flotte purchases and the amount of processed fabric. Thus, flotte excesses and wastewater pollution are minimized. In addition, in modern dosing and distribution systems, the water used to wash the preparation vessel and supply pipes is also taken into account when calculating the amount of flotte to be prepared. Although the amount of wastewater is reduced with this application, the pre-mixing of chemicals is still taking place. In this case, automatic dosing systems can be used, in which the chemicals are not mixed with each other before they arrive at the applicator or dyeing machines. The use of a separate line for each product is important for continuous process lines. As a result, there is no need to clean tanks, pipes and pumps before the next step, saving chemicals, water and time. By preparing the flotte required for dyeing based on the on-line measurement of the amount of flotte taken by the fabric, the amount of residual dye flotte, which can be up to 150 liters in the feed tanks, can be reduced to 10-15 liters. Thus, excessive use of flotte is prevented and water consumption is reduced.

- ***Removal of dirty water remaining in the fiber from the fiber before the next wash***

  In continuous dyeing processes, wastewater pollutant load, amount and water use can be reduced by removing the dirty water remaining in the fiber from the fiber by using squeezing rollers and similar equipment before the next washing step.

- ***Avoiding the use of dangerous carriers***

  The following techniques can be applied to minimize the environmental effects of dyeing polyester and polyester mixtures with disperse dyes:

  - Avoiding the use of dangerous carriers,
  - Avoiding the use of sodium dithionite by applying the following methods:
    - Use of reducing agents based on sulfinic acid derivatives instead of sodium dithionite,
    - Instead of reduction, the use of disperse dyes, which can be cleaned by hydrolytic solubilization in an alkaline environment .
  - Use of optimized paint formulations containing highly biodegradable dispersators .

- ***Use of stabilized non-sulfur-free dyestuffs or pre-reduced liquid paint formulations with a sulphur content of less than 1% instead of conventional powder and liquid sulfur dyes***

  Sulfur dyestuffs used in the dyeing process can be reduced using only glucose (in one case) or combinations of glucose with dithionite, hydroxyacetone or formamide sulfiniic acid without using any sodium sulfide . By using low sulfur or sulfur-free paints, the sulfur content in the wastewater is reduced and the recovery potential of the wastewater is increased.

- ***Replacing conventional oils with water-soluble oils***

  Traditional knitting oils (conventional mineral oil-based lubricants) are emulsified and removed with the help of various chemicals. This process takes place under alkaline conditions with heavy water consumption, high temperature and long processing times. Water-soluble oils, on the other hand, can be easily removed from the fabric by washing at lower temperatures. In the production of knitted fabrics obtained from the mixture of cotton or cotton with synthetic fibers, water-soluble oils can be easily removed by washing at 40°C. This enables hydrophilization and bleaching of the fabric in a single step, saving water and energy.

  In the production of knitted fabrics made from synthetic fibers (such as polyester or polyamide), the fabric is often thermofixed before washing. If conventional oils are present on the fabric, an intense gas emission occurs and it becomes difficult to remove the remaining oil from the fabric, including subsequent washing. In this case, washing can often be done before thermosetting using water-soluble oils instead of conventional lubricants. Substituting traditional oils with water-soluble oils shortens the processing time and reduces the consumption of water, energy and chemicals. In addition, wastewater from these oils, which are known to be biodegradable, is more suitable for biological treatment plants.

- ***Using hydrogen peroxide as an oxidizer***

  Hydrogen peroxide is generally used for bleaching yarns and woven fabrics made of cellulosic, wool and their blends. With current technologies, a high degree of whiteness (Berger Whiteness Index of 75>) can be achieved by using hydrogen peroxide alone in bleaching knitted cotton & cotton blends. An exception is flax and other body fibers that cannot be bleached using peroxide alone. For flax, two-step bleaching with hydrogen peroxide-chlorine dioxide is carried out.

  The use of hydrogen peroxide prevents the formation of harmful adsorbable organic halogen compounds (AOX) such as trichlormethane and chloracetic acid in wastewater, increasing the recovery potential of wastewater.

- ***Dyeing according to the puller method with low-salt reactive dyestuffs that provide high fixation***

  In dyeing cellulosic fiber with reactive dyestuffs according to the classical shrinkage method, high amounts of salt are needed to increase the dyestuff intake. Most of the dyestuffs used at low salinity are polyfunctional dyestuffs and can be fixed at high levels. Reactive dyestuffs that require low amounts of salt have high solubility and remain dissolved even in solutions with a higher concentration than required for low flotte dyeing machines. Dyeing cellulosic fiber by puller method positively affects wastewater salinity and wastewater treatment processes by reducing salt consumption by 1/3 compared to what is needed in conventional reactive dyestuffs (IPPC BREF, 2003). In addition to these, it also provides low energy and water consumption advantages.

- ***Boiling rinsing instead of using detergent in the final washing of cotton dyed with reactive dyes***

  After reactive dyeing, detergent consumption and pollution load in wastewater can be reduced by rinsing boiling (at 95°C) instead of washing with detergent. After hot rinsing, the fastness values of the product are better after the first neutralization rinse, compared to conventional rinses with detergent and ion trap. The main benefit obtained by the application of the technique is to increase the recovery potential of wastewater by reducing detergent consumption and the pollution load given to wastewater.

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Textile Dyehouses

- ***Dyeing according to the puller method with low-salt reactive dyestuffs that provide high fixation***

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- ***Using countercurrent flushing***

  Especially in continuous processes, dyeing and post-printing washes consume more water than the dyeing and printing steps themselves. Water and energy savings can be achieved by increasing washing efficiency. For example; Many factors such as temperature, processing time, float / substance change affect the washing efficiency. The techniques applied in washing machines largely depend on the type of fabric to be washed. According to the reverse current principle , the washing efficiency can be increased by reducing the carry-over effect (e.g. vacuum suction) in the washing process. By increasing the washing efficiency, water and energy consumption for washing can be reduced.

- ***Reduction of water and energy consumption by dyeing with reactive dyes by pad-batch method The*** pad-batch method (semi-intermittent) includes the impregnation step in the fulard. After the fabric is squeezed, it is wrapped in a dock and kept at room temperature.
  Desired chemical
  The dock is rotated slowly until the reactions (e.g. fixation of the dyestuff, etc.) are completed. When the process is completed, the fabric is washed in an open-width washing machine. This method is often used for pre-treatment (e.g., desizing up) and dyeing (especially with reactive and direct dyes). The characteristic features of this method are that it is uniformly reproducible and has low water and energy consumption (approximately more than conventional systems).
  50-80% less).

- ***Reuse of dyeing baths***
  The turbidity formed in the dyeing bath is removed with toluene and similar extractions, and the dyes and chemicals that have been lost due to previous use are completed for reuse. Different healing methods may need to be developed for different bath solutions. With the application of this technique, more efficient dyeing can be achieved by reducing the frequency of staining bath emptying.

- ***Treatment of dyeing wastewater by chemical precipitation***
  High >(90%) decolorization and low COD removal (40-50%) can be achieved by using aluminum sulfate, cationic organic polyelectrolyte and very low dose anionic polyelectrolyte together in the technique of recycling dyeing wastewater from cotton textile manufacturing by chemical precipitation. It is possible to use the obtained water for different purposes. However, this method is adversely affected by high dissolved solids, temperature, detergent and COD content.

- ***Use of advanced systems for dosing impregnation floats***
  Impregnation flottes left over from dyeing and finishing processes are wastes that require control specific to the textile industry. By using advanced systems for dosing impregnation flattes in continuous dyeing processes, the use of chemicals and wastewater pollution load can be reduced.

Textile dyes

- ***Use of polyfunctional reactive dyestuffs instead of conventional reactive dyes The*** fixation of reactive dyes to cellulose fibers is expressed either as a percentage of the total amount of dye appliquéd (fixation rate) or as a percentage of the amount of dye extracted (shrinkage rate) Is. In monofunctional paints, the fixation rate is 60% and the shrinkage rate is around 70%. In other words, 40% of the appliquéd paint is lost in wastewater. In bifunctional reactive paints, shrinkage rates of over 90% can be achieved with fixation rates of approximately 80%. With the use of bifunctional reactive dyes, the amount of unused dyestuff given to wastewater is significantly reduced. This reduction is advantageous in cases where advanced oxidation techniques are used for the treatment of dyes in wastewater. Compared to conventional reactive dyes, the use of polyfunctional reactive dyestuffs provides high fixation efficiency and reduces the use of salt, energy and water.

- ***Use of highly efficient washing machines and energy recovery equipment in continuous processes***
  There are many variables that affect washing efficiency, such as temperature, processing time, float/substance change and so on. Washing methods largely depend on the type of fabric to be washed (e.g. light or heavy weight fabrics, etc.). The basic strategy in washing is to reduce the dirty water/flott in the fabric with the reverse current principle. The reverse flow principle means that the lightly contaminated water from the last wash basin is reused in the penultimate vessel and the movement of the water in this direction continues until it reaches the first vessel to be emptied. This method can be applied in washing after continuous dessizing, hydrophilizing, bleaching, dyeing or printing processes (EPA, 1995). This method reduces water use and increases washing efficiency. Since a smaller amount of water will be heated, energy use is also significantly reduced. Installing a heat recovery system in the continuous washing machine eliminates the need for simultaneous water inlets and outlets. These measures can be used to reduce total water and energy consumption.

- ***Recovery of alkali in mercerized rinse water***
  In the mercerization process, which uses a high amount of caustic as the base chemical, the fabric is first immersed in a concentrated caustic solution of 18-25% for a short time and then washed to remove excess caustic (Yang et al., 2007; Avdičevič et al., 2017). For this reason, very high volumes (200-300 L/min) of wastewater are generated in the mercerization process (Varol, 2008). This wastewater and caustic with alkaline characterization; It can be recovered by evaporation and membrane filtration systems. With the application of the evaporation system, the weak caustic solution is condensed and the concentrated caustic is recovered. With the four-stage evaporator, 70-80% caustic is recovered. In caustic recovery with membrane filtration system, the caustic in the filtrate water is reused by re-excavation (Balkan et al., 2021). More than 90% caustic recovery is possible with membrane processes (Varol 2008). With the recovery of caustic from the mercerization process, both the alkaline content of the wastewater and the chemical consumption required for the neutralization of the wastewater are reduced (Balkan et al., 2021).

- ***Use of washing/rinsing wastewater for cleaning purposes***

In the textile industry, process wastewater of different characteristics is generated in basic production processes such as finishing and dyeing and in auxiliary production processes such as raw water softening systems. The high pH, electrical conductivity, COD, SS and color content of some process wastewater prevent the reuse of untreated. However, wastewater of this character can be used in facility washing processes that do not require high water quality (Öztürk, 2014). The water used in the cleaning of facilities and equipment does not need to be of process water quality. By using not very polluted washing and rinsing water in cleaning processes, water consumption and wastewater generation in plant and equipment cleaning can be reduced.

- ***Substitution of sodium hypochlorite and chlorite-containing compounds used in the bleaching process*** Sodium hypochlorite bleaching is a secondary bleaching process that forms organic halogen compounds (trichlormethane makes up the majority of the compounds formed), usually measured as AOX

It causes reactions. In cases where hypochlorite (step 1) and hydrogen peroxide (step 2) were applied in combination, AOX values of 90-100 mg Cl/l were observed in the NaOCl – bleaching bath where the process took place. Due to the fact that it is carried by the textile material from the previous bath, concentrations of up to 6 mg Cl/l can also be found in the used H_2O_2- bleach bath. The amount of AOX formed during chlorite bleaching is much lower than that of sodium hypochlorite. Recent research has shown that the formation of AOX is not caused by sodium chloride itself, but by chlorine or hypochlorite, which is present in the form of impurities or used as an activating agent. The use and storage of sodium chloride requires special care due to its toxicity, corrosion and explosion risks. With the use of chloride-containing compounds in bleaching, less organic halogen compounds will be formed, which is beneficial in terms of environmental factors. Thus, the recovery potential of wastewater increases.

Washing Machines

- ***Reducing the use of hydrogen peroxide stabilizers in the bleaching process***

  In order to prevent catalytic damage to fibers caused by uncontrolled OH radicals, it is generally necessary to use ion scavengers, stabilizers and similar complex generators that will inactivate catalysts. Stabilizers used in hydrogen peroxide bleaching cause various environmental problems by forming strong complexes. Hydrogen peroxide consists of reactive oxygenated compounds (O_2, H_2O_2/HOO-, H_2O/OH-etc.) that damage the fibers during bleaching. Under optimum conditions (pH approx. 11.2, homogeneously dispersed catalyst and controlled peroxide concentration), the removal of OH radicals and the optimum utilization of hydrogen peroxide can be achieved. The addition of formic acid (formiate ion) as a removal agent from the environment is also useful for controlling the formation of OH radicals and reducing the damage to the fibers. By avoiding the use of harmful ion-scavenging substances, minimum peroxide consumption (50% <compared to uncontrolled conditions) and (pre-)oxidation of the removed substances, it can be achieved that the fibers are bleached with high efficiency without damage.

- ***Separation of wastewater from hypochlorite bleaching from other wastewater streams and composite wastewater***

  The use of hypochlorite causes side reactions that lead to the formation of a number of chlorinated hydrocarbon compounds, such as the carcinogenic trichlormethane. The majority of these by-products can be identified as absorbable organic halogens by means of the total AOX parameter. Chlorine, chlorine-releasing compounds and highly chlorinated acids (e.g. trichloracetic acid) can also result from additives similar to the formation of harmful AOX. Halogenated solvents also cause the AOX problem. Limiting the use of sodium hypochlorite to only those where high whiteness is desired and to fabrics that are sensitive and fragile to depolymerization may alleviate the problem. To reduce AOX formation, sodium hypochlorite bleaching should be followed by a two-step process in which peroxide is used in the first step and hypochlorite in the second step. In order to reduce AOX contamination and protect the recovery potential of wastewater, wastewater from hypochlorite bleaching should be kept separate from other wastewater.

- ***Reuse of dyeing bath solution waste in dyeing***

  In continuous dyeing processes, the material is impregnated with paint; reducing agent and wetting agent with single-bath or two-bath processes. In pad-steam, which is a single-bath method, reducing agent and paint are added at the same time. In pad-dry/pad-steam, which is a two-bath method, it is first impregnated with a flotte containing dye and wetting, and if necessary, after a period of drying, the reducing agent is applied in the second step. The material is then treated with fully saturated steam. Finally, rinsing, oxidation and re-rinsing processes are applied. Due to the fact that the withdrawal of the dyestuff from the flottle is not very high in uninterrupted methods, the dyeing bath can be reused. Reuse and recovery of dyeing bath wastewater can be achieved by collecting dyeing bath wastewater separately from washing wastewater after dyeing. A significant reduction in wastewater, BOD and COD loads can be achieved by reusing the staining bath.

- ***Use of biodegradable/eliminable complexing agents in pre-treatment and dyeing processes***

  Complexing agents are used to prevent the harmful effects of hardness-forming alkaline earth-alkaline cations and transition-metal ions in aqueous solutions (e.g. catalytic degradation of hydrogen peroxide), especially during pretreatment and dyeing processes. Polycarboxylates or substituted polycarboxylic acids (e.g., polyacrylates and polyacrylate-maleic acid copolymerizates), hydroxycarboxylic acids (e.g., gluconates, citrates) and some sugar-acrylic acid copolymers are alternatives to conventional complexing agents when complexing agents must be used. There is no N or P in the molecular structure of these products. In addition, hydroxycarboxylic acids and sugar-acrylic acid copolymers are readily biodegradable.

  The main benefits from using these products are:

  - Reduction of eutrophication in receiving environments (waters) where treated wastewater is given,
  - Increased biodegradability of final wastewater,
  - Reduced risk of reactivation of heavy metals in sediments.

  Due to the increase in the biodegradability of wastewater and the decrease in pollution load, the potential for recovery of wastewater by treatment increases.

- ***Using sodium chloride for flax and bast fibers that cannot be bleached with hydrogen peroxide alone***

  In cases where the desired high degree of whiteness cannot be achieved with one-step processes using hydrogen peroxide alone, a two-step process with hydrogen peroxide (first step) and sodium hypochlorite (second step) can be applied to reduce the amount of AOX. In this method, impurities on the fiber – which is the precursor of the haloform reaction – are removed in step one, thus reducing the amount of AOX in the wastewater. Sodium chloride is a highly efficient bleaching agent for flax, jute and some synthetic fibers. Since less organic halogen compounds will be formed by the use of chloride-containing compounds in bleaching, the recovery potential of wastewater increases as well as environmental benefits (IPPC BREF, 2003).

- ***Selection of the most suitable machines for the lot sizes to be processed***

  The flotte ratio is one of the parameters that affect the environmental performance of the dyeing processes according to the puller method . Machines that are best suited to the lot sizes to be processed should be selected to ensure that the machines operate within the designed range of nominal float ratios. Since water consumption will increase depending on the flotte ratio, the use of higher flotte ratios and water consumption can be prevented by choosing appropriate machines (IPPC BREF, 2003).

- ***Use of pigment printing pastes with optimized environmental performance***

  The final steps in pigment printing consist of hot air drying and fixation of the printed fabric . In both steps, emissions of volatile organic compounds into the air can reach significant amounts.

  Ammonia emissions can be reduced to less than 0.6 g NH3/kg of textile by using printing pastes optimized for properties such as high biodegradability and low ammonia content. The application of the technique does not directly save water, but provides an environmental benefit to reduce air pollution emissions

- ***Reduction of print paste losses on rotary printers***

  In order to ensure water efficiency in printing and dyeing processes, it is necessary to reduce the printing paste losses in rotary printing by minimizing the volume of printing paste supply systems in rotary printing machines, recovery of the printing paste, two-step reactive printing method, etc. Printing paste losses are also reduced by optimizing the size of feeding equipment/tanks and reusing printing pastes (black ink production, etc.). Thus, the wastewater pollution load is reduced and the recovery potential of wastewater increases.

- ***Use of wastewater from the final washing after dyeing in the preparation of the dyeing bath if it meets the necessary process water criteria for dyeing***

  In fabric finishing and dyeing, especially in the finishing processes after dyeing (final finishing processes), intensive water consumption occurs. Wastewater generated in final finishing processes (washing/rinsing and softening wastewater) can be recovered and reused (Öztürk, 2014). The wastewater generated especially in the last steps of these processes has the character of process water. For this reason, a large part of the wastewater generated in washing/rinsing processes can be reused in other finishing processes, preparation of dye baths and other in-house processes. Since these wastewater streams have the character of process water, they often do not need to be treated. After dyeing, the amount of wastewater and water use can be reduced by using wastewater from the last wash with low pollution load in the preparation of the dyeing bath.

- ***Reduction of concentrated flotte losses***

  The following techniques can be applied to reduce concentrated flotte losses:

  - Using methods that require little material application and minimizing the volume of the impregnation vessel when impregnating dyeing techniques are used
  - Dispensing chemicals on-line via separate lines and mixing them just before feeding into the applicator
  - Dosing of impregnation flottes based on the quantities of the supplied floats.

  With the application of the above techniques, dyeing efficiency increases, water consumption can be reduced in dyehouse processes by reducing flotte ratios. Modern dyeing systems that work with the lowest possible rinsing water flow allow an additional water saving of 25%.

- ***Recovery of washing wastewater after dyeing by adsorption***

  It is possible to effectively remove organic components by treating dyeing wastewater, especially the first washing wastewater, with activated carbon. While the salt content (approximately 80 g/l) of the wastewater passed through the activated carbon columns does not change, the wastewater turns into a shiny and colorless form and becomes suitable for bath solution preparation.

- ***Recovery of washing wastewater after dyeing by membrane filtration***

  Reusable filtrate water of the order of 65-70% can be produced by treating dyeing bath wastewater by nanofiltration/reverse osmosis by applying a pressure of approximately 7-10 bar. Hot filtrates from hot staining bath wastewater can be reused in washing after staining (IPPC BREF, 2003).

- ***Reuse of rinse water in the next painting***

  By using techniques to minimize the effect of regurgitation in the rinsing process, the rinse bath can be used for the next dye bath. This removes all residues from the rinse float and reduces total water consumption by 50% (IPPC BREF, 2003).

- ***Application of fill-unload systems instead of overflow washing method***

  Washing and rinsing processes are among the most widely used processes in the textile industry. In intermittent processes, "overflow washing" and "fill-empty systems" systems are used in washing and rinsing processes. In overflow washing, clean water is fed to the machine and water is discharged from the overflow weir. Overflow washing causes inefficient water consumption in machines operating at high float rates. Fill-empty systems, on the other hand, have more efficient water consumption. In these systems, rinsing consists of successive filling, working and emptying steps. Machines in modern fill-and-dump systems (IPPC BREF, 2003);

  - It is equipped with powerful filling and emptying, combined cooling and rinsing, heated tanks of full volume. These systems provide shorter working times compared to conventional stone washing.
  - Thermal shock in the first rinse step is prevented by the use of a combined cooling and rinsing system (IPPC BREF, 2003).

In the smart rinsing technique, clean water is taken into the machine and discharged through an overflow weir located close to the bottom of the machine. In addition, the inlet of clean water into the machine is adjusted in proportion to the amount of float discharged by the overflow at the lower level. It is especially effective when hot water is used for rinsing. By using fill-empty systems instead of overflowing, 50-75% savings can be achieved in the water consumption of the machine. Smart rinsing and fill-and-dump systems ensure efficient use of water and energy, while reducing total production costs by shortening processing time (IPPC BREF, 2003).

- ***The use of solvent in cleaning and washing to remove knitting oils from the fabric The*** washing process with solvent is carried out in the tumbler with cuts (usually for knitted fabrics) or without cuts in open-width fabrics (for woven and knitted fabrics). Pollution

  By removing the elements with a solvent that is continuously purified and recycled in a closed loop, the wastewater pollution load is reduced and the recovery potential of wastewater is increased.

- ***Use of biodegradable and water-soluble lubricants instead of conventional mineral oil-based lubricants***

  Knitting machine needles need to be lubricated using knitting machine oil. Due to the losses in the machine, approximately 4-8% of the fiber weight remains on the knitted fabric. This situation requires the addition of surfactant to the wash baths in order for mineral oil-based formulations to be emulsified. In order to prevent this , water-soluble lubricants with a high biodegradation rate should be preferred instead of conventional mineral oil-based lubricants. Water-soluble oils can be easily removed from the fabric by washing at lower temperatures compared to conventional mineral oils. For knitted fabrics made of synthetic fibers, the washing process must be carried out before thermosetting in order to remove oils and prevent their emission into the air. Thus, the use of surfactants in washing baths can also be prevented. Unlike conventional mineral oil-based lubricants, water-soluble oils can be easily removed from the fabric by washing. The use of water-soluble oils also reduces the consumption of water, energy and chemicals along with the processing time.

- ***Removal of water-insoluble oils by washing with organic solvents***

  Organic solvents used to remove water-insoluble oils enable the breakdown of stubborn impurities by means of an in-circuit system (e.g. advanced oxidation methods). The advantage of this technique is that persistent contaminants are degraded during the process (e.g., by advanced oxidation processes). The method facilitates the removal of water-insoluble oils, the treatment and recovery of wastewater .

- ***Use of the necessary amount of reducing agent only for the reduction of the*** dyestuff In order to replace sodium sulfide primarily with sulfur-free reducing agents, only the amount of reducing agent required for the reduction of the dyestuff

  It is necessary to be consumed. The reaction of the oxygen and the reducing agent in the machine should be prevented. Nitrogen is used to remove oxygen from the float and air in the machine. By using sulfur-free reducing agents, the sulfur content in the wastewater is minimized and the recovery potential of the wastewater is increased.

- ***Performing the thermosetting process before washing***

  Performing the thermosetting step prior to washing and treating the air emissions from the stenter with dry electrofiltration systems that allow the oils to be collected separately and energy recovery allows for energy recovery and separate collection of the oil. Thus, the pollution load to wastewater is reduced and the recovery potential of wastewater increases.

- ***Use of fully closed-loop equipment in the use of halogenated organic solvents***

  In cases where the use of halogenated organic solvents cannot be avoided (e.g. in fabrics that are highly loaded with preparation agents such as silicone oils that are difficult to remove with water), completely closed circuit devices are used to prevent possible contamination. Thus, the necessary conditions are provided for the degradation of persistent pollutants in the circuit. By using closed-loop systems in solvent washing processes, the heat required for the evaporation of the solvent is lower, resulting in a reduction in both water and energy consumption. Organic matter pollution in wastewater is also reduced.

- ***Use of fill-and-dump wash or smart rinse techniques instead of overflow/rinse***

  Filling and emptying and smart rinsing methods are more efficient in terms of water consumption than conventional overflow rinses. Considering the filling and emptying method, a 50-75% reduction in water consumption can be achieved by rinsing 2-4 times in the form of "filling and emptying" instead of each overflow rinse.

  In hot and warm rinsing processes, energy consumption can be reduced as well as water consumption. Compared to the conventional overflow method, another advantage of both the "smart rinsing" and the filling and emptying methods is that it is possible to store the rinse waters separately with the concentrated dye flottes used.

- ***Minimizing the mixing of heavy metals into wastewater in the dyeing process with metal complex paints***

  In dyeing wool with metal complex dyes, it is ensured that the loading of wastewater with heavy metals is minimized. When working at a ratio of 1:10 in the wool dyeing process, a chromium emission value of 10-20 mg is obtained for one kg of treated wool, which is equal to 1-2 mg/l chromium concentration in the used chromium bath. These values can be achieved by using auxiliary chemicals that increase dye uptake and using pH-controlled methods to maximize final float uptake in other wool products. With this method, the recovery potential of wastewater can be increased by reducing the heavy metal pollution load of wastewater.

- ***Treatment and reuse of wastewater containing pigment printing paste***

  Pigment printing paste wastewater containing organic paint pigments, organic thickeners, organic binders, fixants, catalysts and softeners can be reused after treatment with appropriate membrane techniques. Process steps generally include microfiltration/ultrafiltration application after the pre-treatment stage such as coagulation and precipitation. Then, the suspended solids in the concentrated waste are removed by adding flocculant. The resulting sludge is separated from the system for physicochemical treatment. It is stated that with the application of this technique, 90% of the wastewater generated in the process can be recovered and reused in washing (IPPC BREF, 2003).

- ***In printing-dyeing processes; Reduction of water consumption in cleaning processes***

  Water consumption in printing-dyeing processes; Start/stop control of the cleaning of the printing belt, mechanical removal of print paste and ink residues can be reduced by reusing the rinse water used during the cleaning of printing-dyeing equipment. The mentioned techniques are explained below in order (IPPC Textile BREF, 2003).

  - In many cases, the water flow in the cleaning of the printing conveyor belt continues when the fabric and the printing conveyor belt are stopped for any reason. The start/stop control of the water flow can be automatically connected to the start/stop control of the printing conveyor belt.
  - Significant amounts of water are used to clean rackets, stencils and buckets in print-paint offices. Removing the pressure paste residues before washing the equipment by spraying water reduces the amount of water used. Physical methods (for example, spatulas) can be used to remove paint from buckets.
  - Typically, the first half of the water from the washing equipment contains a lot of pressure paste and it is essential to discharge it as wastewater. The water used in this first step does not have to be of high quality, so reclaimed water can be used in this step. In the second half of the washing process, it is necessary to use clean water. The water used in the second half, which is not very contaminated, can be reused as the first rinse water in the next step.

  With the application of these techniques in printing-dyeing enterprises, water use can be reduced by up to 55%. (IPPC BREF, 2003).

- ***Evaluation of the possibilities of treatment of technically suitable wastewater streams*** Water streams that do not need treatment (e.g. uncontaminated cooling water or uncontaminated process water) are separated from the wastewater that needs to be treated, thus ensuring that the uncontaminated water is recycled. Thanks to this process, a reduction in energy and water use is achieved.

- ***Reducing wastewater generation with application techniques such as foaming and spraying in finishing***

  Foam is a suitable gas, usually inflated with air, to roughly reduce the surface area of any liquid It is a microheterogeneous colloid, short- or long-lived, metastable system, separated from each other by a thin film layer, which has been increased by a factor of 1,000 and therefore contains less fluid. In the foams used in the textile industry, aqueous floats used in normal application methods are used as liquids, and air is used as gas. Foam is obtained by distributing air as fine particles in water with the help of surfactants (tensides). By using the foam and spraying method, less water consumption can be achieved in the final processes.

  In intermittent processes, softeners are applied directly in the dyeing machine after the dyeing process, which is usually done using the puller method. In this application, harmful softening agents are used and 10-20% of the warm softening float by volume is lost. As an alternative to this situation, it is recommended to impregnate softeners in fulard or to use spraying and foaming application systems. With the application of alternative techniques, there is no need to use cationic softener and the loss of chemicals is reduced. In addition, dyeing and rinsing flottes can be reused by making the softener application on a separate equipment after the intermittent dyeing process. Because there are no cationic softener wastes to prevent dye adsorption in subsequent dyeing processes. With the application of this technique, the use of water, energy and chemicals decreases (IPPC BREF, 2003).

- ***Substitution of mineral oils with low biodegradability in the process of synthetic fiber preparation There*** are products that can be used as a substitute for mineral oils for many applications, and fatty acid esters are one of them. Thanks to this technique, 20% in waste generation and 20% in water useEnvironmental improvement is achieved with a reduction of 30-40%.

- ***Use of water flow control devices and automatic shut-off valves in continuously operating machines***

  Monitoring and control equipment is widely used in production processes where water consumption is intense in industrial enterprises . Thus, inefficiencies in processes and water consumption can be minimized. In this context, continuously operating machines can be equipped with flow meters, meters and automatic shut-off valves. This practice facilitates the implementation of managerial BATs such as the preparation of annual inventory reports based on mass balances, monitoring of production inputs and outputs in terms of their quantities , and loss control. The main investment in the implementation of this BAT proposal is flowmeter-meters, automatic shut-off valves and installation costs (Öztürk, 2014).

- ***Reuse of wash water from printing dyeing tape cleaning***

  There is no need for high-quality process water in printing blanket washing. Wastewater with appropriate characterization can be reused in printing blanket washing. In addition, printing blanket washing wastewater can be reused 2-3 times for the same purpose (Öztürk, 2022). It is possible to collect lightly colored and fiber-containing printing dyeing tape wastewater in a tank after mechanical filtration and reuse it in the same process. With this application, water savings of 70% can be achieved in cases where the addition of fresh water is insufficient (IPPC BREF, 2003).

- ***Use of reactive dyes instead of chromium-containing dyes***

  Chromium pollution is reduced by using reactive dyes instead of chrome dyes or, where this is not possible, by using ultra-low chroming methods, and the recovery potential of wastewater increases.

- ***Increasing washing efficiency in textile processes***

  Significant water and energy savings can be achieved by optimizing the washing efficiency in washing and rinsing processes, which are among the most widely used processes in the textile industry (IPPC BREF, 2003). It is recommended to apply the techniques listed below to increase washing efficiency.

  - Using one of the "fill and drain" or "smart rinse" systems instead of overflow rinsing systems that cause inefficient water consumption in machines operating at high float rates
  - Saving water and energy by reducing the dirty water/flotte in the fabric with the reverse current principle in continuous (uninterrupted) washing and rinsing systems
  - With the use of fully closed-loop systems in fabric washing systems with organic solvents , both caustic recovery and reuse of filtrate water in the process if it meets the process water criteria
  - Enzymatic post-soaping in reactive dyeing is the application of the enzymatic process to remove unfixed dyestuff molecules not only from the fibers, but also from the puller bath. With the application of enzymatic post-treatment, there is no need for a hot washing step . With this application, water and energy savings are achieved and the processing time is shortened.

2.1.2 Good Management Practices

- ***Establishment of an environmental management system***

Environmental Management Systems (EMS) include the organizational structure, responsibilities, procedures and resources required to develop, implement and monitor the environmental policies of industrial organizations. The establishment of the environmental management system improves the decision-making processes of institutions between raw materials, water-wastewater infrastructure, planned production process, and different treatment techniques. Environmental management organizes how to manage resource procurement and waste discharge demands with the highest economic efficiency, without compromising product quality and with the least possible impact on the environment.

The most widely used Environmental Management Standard is ISO 14001. Alternatives include the Eco Management and Audit Programme Directive (EMAS) (761/2001). It has been developed for the evaluation, improvement and reporting of the environmental performance of enterprises. It is one of the leading practices within the scope of eco-efficiency (cleaner production) in EU legislation and participation is provided voluntarily (TUBITAK MAM, 2016; MoAF, 2021). The benefits of establishing and implementing an Environmental Management System are as follows:

- Economic benefits can be achieved by improving business performance (Christopher, 1998).
- International Organization for Standardization (ISO) standards are adopted, resulting in greater compliance with global legal and regulatory requirements (Christopher, 1998).
- While the penalty risks related to environmental responsibilities are minimized, the amount of waste, resource consumption and operating costs are reduced (Delmas, 2009).
- The use of internationally accepted environmental standards eliminates the need for multiple registrations and certifications for businesses operating in different locations around the world (Hutchens Jr., 2017).
- Especially in recent years, the improvement of the internal control processes of companies is also important to consumers. The implementation of environmental management systems provides a competitive advantage over companies that do not adopt the standard. It also contributes to the better position of institutions in international areas/markets (Potoski & Prakash, 2005).

The benefits listed above depend on numerous factors such as the production process, management practices, resource use, and potential environmental impacts (MoAF, 2021). Savings of 3-5% in water consumption can be achieved with applications such as the preparation of annual inventory reports with similar content to the environmental management system and monitoring of inputs and outputs in production processes in terms of quantity and quality (Öztürk, 2014). The total duration of the EMS development and implementation phases is estimated to be 8-12 months (ISO 14001 User Manual, 2015).

Industrial organizations also carry out studies within the scope of the ISO 14046 Water Footprint Standard, which is an international standard that defines the requirements and guidelines for assessing and reporting their water footprint. With the implementation of the relevant standard, it is aimed to reduce the use of fresh water and environmental impacts required for production. In addition, the ISO 46001 Water Efficiency Management Systems Standard, which helps industrial organizations to save water and reduce operating costs, helps organizations to improve their water efficiency policies by monitoring, benchmarking and reviewing.

- ***Using an integrated wastewater management and treatment strategy to reduce the amount of wastewater and the pollutant load***

  Wastewater management should be based on a holistic approach from wastewater production to final disposal and includes functional elements such as composition, collection, treatment including sludge disposal and reuse. The selection of appropriate treatment technology for industrial wastewater depends on integrated factors such as land availability, desired treated water quality, and compliance with national and local regulations (Abbassi & Al Baz, 2008).

  The reuse of treated wastewater at the plant not only improves the quality of water bodies, but also reduces the demand for fresh water. Therefore, it is very important to determine the appropriate treatment strategies for different reuse targets.

  In integrated industrial wastewater treatment, different aspects such as wastewater collection system, treatment process, and reuse target are evaluated together (Naghedi et al., 2020). For industrial wastewater recovery, an integrated wastewater management framework can be determined by combining methods such as SWOT method (strengths, weaknesses, opportunities and threats), PESTEL method (political, economic, social, technological, environmental and legal factors), decision tree with expert opinions (Naghedi et al., 2020). Integrating the Analytical Hierarchy Process (AHP) and Unified Consensus Solution (CoCoSo) techniques can be used to set priorities for industrial wastewater management processes based on a multitude of criteria (Adar et al., 2021).

  With the implementation of integrated wastewater management strategies, an average reduction of up to 25% in water consumption, wastewater quantity and pollution loads of wastewater can be achieved. The potential payback period of the application ranges from 1-10 years (MoAF, 2021).

Industrial Wastewater Treatment Plant

- ***Providing technical training to personnel for the reduction and optimization of water use***
  With this measure, water saving and water recovery can be achieved by increasing the training and awareness of the personnel, and water efficiency can be achieved by reducing water consumption and costs. Due to the fact that the personnel do not have the necessary technical knowledge in industrial facilities, problems may arise with the use of high amounts of water and wastewater formation. For example, it is important that cooling tower operators, who represent a significant proportion of water consumption in industrial operations, are properly trained and have technical knowledge. In applications such as determining water quality requirements in production processes, measuring water and wastewater amounts, etc., it is necessary for the relevant personnel to have sufficient technical knowledge (MoAF, 2021). For this reason, it is important to provide training to staff on water use reduction, optimization and water saving policies. Practices such as involving personnel in water conservation studies, creating regular reports on water usage amounts before and after water efficiency initiatives, and sharing these reports with personnel support participation and motivation in the process. The technical, economic and environmental benefits to be obtained through personnel training give results in the medium or long term (TUBITAK MAM, 2016; MoAF, 2021).

- ***Monitoring the amount and quality of the water used in production processes and auxiliary processes and the wastewater generated and adapting this information to the environmental management system*** There are resource uses in industrial facilities, and inefficiency and environmental problems that occur as a result of resource use can be caused by input-output flows. Therefore
  It is necessary to monitor the water and wastewater used in production processes and auxiliary processes in terms of their quantity and quality (TUBITAK MAM, 2016; MoAF, 2021). Process-based quantity and quality monitoring, together with other good management practices (personnel training, establishment of an environmental management system, etc.), can be used to reduce energy consumption by 6-10%, water consumption and wastewater amounts.
  It can provide a reduction of up to 25% (Öztürk, 2014).

  The main stages for monitoring water and wastewater in terms of quantity and quality are:
  - Use of monitoring equipment (such as meters) to monitor consumption of water, energy, etc. on the basis of processes,
  - Establishment of monitoring procedures,
  - Determining the use/exit points of all inputs and outputs (raw materials, chemicals, water, products, wastewater, sludge, solid waste, hazardous waste and by-products) related to the production process, monitoring, documenting, comparatively evaluating and reporting in terms of their quantity and quality,
  - Monitoring raw material losses in production processes where raw materials are transformed into products and taking measures against raw material losses (MoEUB, 2020e).

- ***Good production planning to optimize water consumption***

  In industrial production processes, planning a raw material until it turns into a product by using the least process is an effective practice to reduce labor costs, resource use costs and environmental impacts and to ensure efficiency (TUBITAK MAM, 2016; MoAF, 2021). Production planning in industrial facilities by considering the water efficiency factor reduces water consumption and wastewater. Modifying production processes or combining some processes in industrial facilities provides significant benefits in terms of water efficiency and time planning (MoAF, 2021).

- ***Preparation of a water efficiency action plan to reduce water use and prevent water pollution***

  It is important for water efficiency to prepare an action plan that includes what to do in the short, medium and long term in order to reduce the amount of water-wastewater in industrial facilities and to prevent water pollution. At this point, determining the water needs throughout the facility and in the production processes, water

  quality requirements should be determined at the points of use, wastewater formation points and wastewater characterization should be done (MoAF, 2021). At the same time, it is necessary to determine the measures to be implemented to reduce water consumption, wastewater generation and pollution loads, to make feasibility and to prepare action plans for the short-medium-long term. In this way, water efficiency and sustainable water use are ensured in facilities (MoAF, 2021).

- ***Setting water efficiency targets***

  The first step in achieving water efficiency in industrial facilities is to set targets (MoAF, 2021). For this, first of all, a detailed water efficiency analysis should be carried out on the basis of processes. Thus, unnecessary water use, water losses, wrong practices affecting water efficiency, process losses, reusable water-wastewater resources with or without treatment can be determined. It is also extremely important to set water saving potential and water efficiency targets for each production process and the plant as a whole (MoAF, 2021).

- ***Preparation of water flow diagrams and mass balances for water***

  Determination of water use and wastewater generation points in industrial facilities, creation of water-wastewater balances in production processes and auxiliary processes other than production processes are the basis of many good management practices in general. Creation of process profiles throughout the plant and on the basis of production processes; It facilitates the identification of unnecessary water usage points and high water use points, the evaluation of water recovery opportunities, process modifications and the determination of water losses (MoAF, 2021).

2.1.3 General Water Efficiency BATs

- ***Detection and reduction of water losses***

  In industrial production processes, water losses occur in equipment, pumps and pipelines. First of all, water losses should be detected and leaks should be prevented by keeping equipment, pumps and pipelines in good condition by performing regular maintenance (IPPC BREF, 2003). Regular maintenance procedures should be established and particular attention should be paid to the following:

  - Adding pumps, valves, level switches, pressure and flow regulators to the maintenance checklist ,
  - Carrying out inspections not only in the water system, but also especially for heat transfer and chemical distribution systems, broken and leaking pipes, barrels, pumps and valves,
  - regular cleaning of filters and pipelines,
  - Calibrating, routinely checking and monitoring measuring equipment such as chemical measuring and dispensing instruments, thermometers, etc. (IPPC BREF, 2003).

  With effective maintenance-repair, cleaning and loss control practices, savings ranging from 1-6% in water consumption can be achieved (Öztürk, 2014).

- ***Minimization of spills and leaks***

  Both raw material and water losses can be experienced due to spills and leaks in enterprises. In addition, if wet cleaning methods are used to clean the spilled areas, there may be increases in water consumption, wastewater amounts and pollution loads of wastewater (MoAF, 2021). In order to reduce raw material and product losses, spillage and splash losses are reduced by using anti-splashes, fins, drip trays, sieves (IPPC BREF, 2019).

- ***Untreated reuse of relatively clean wastewater from washing, rinsing and equipment cleaning in production processes***

  In industrial facilities, relatively clean wastewater, especially washing-final rinsing wastewater and filter backwash wastewater, can be recycled without treatment in floor washing and garden irrigation processes that do not require high water quality, saving between 1-5% in raw water consumption . The initial investment costs required for the application consist of the establishment of new pipelines and reserved tanks (Öztürk, 2014).

- ***Prevention of mixing of clean water streams with dirty water streams***

  By determining the wastewater formation points and characterizing the wastewater in industrial facilities, wastewater with high pollution load and relatively clean wastewater can be collected in separate lines (TUBITAK MAM, 2016; MoAF, 2021). In this way, wastewater streams of appropriate quality can be reused with or without treatment. By separating wastewater streams, water pollution is reduced, treatment performances are increased, energy consumption can be reduced in relation to reducing treatment needs, and emissions are reduced by ensuring wastewater recovery and recovery of valuable materials . In addition, heat recovery from separated hot wastewater streams is also possible (TUBITAK MAM, 2016; MoAF, 2021) Separation of wastewater streams often requires high investment costs, and costs can be reduced when it is possible to recover large amounts of wastewater and energy (IPPC BREF, 2006).

• ***Where technically feasible, suitable wastewater is treated and used as steam boiler feed water*** Although it is difficult to apply in industrial facilities, it is possible to treat suitable wastewater to process water quality and reuse it in production processes, including steam boilers. In this way, savings ranging from 20-50% in total water consumption and wastewater generation can be achieved (Öztürk, 2014; TUBITAK MAM, 2016). The initial investment cost required for the application is the treatment system to be used. Considering the amount of water to be recycled, the amount of economic savings, the applied unit water-wastewater costs, and the operation and maintenance costs of the treatment system, the payback periods vary (MoAF, 2021). Membrane systems (a combination of ultrafiltration (UF), nanofiltration (NF) and reverse osmosis (CTR) systems can be used for recovery. For example, in some industrial facilities, it is possible to treat the cooling system blowdown water and reuse it as process water (MoAF, 2021).

• ***Determination of wastewater flows that can be reused with or without treatment by characterizing the amount and quality of wastewater at all wastewater formation points By determining*** and characterizing wastewater formation points in industrial facilities, it is possible to reuse various wastewater streams with or without treatment (Öztürk, 2014; TUBITAK MAM, 2016; MoAF, 2021). In this context, filter backwash water, CTR concentrates, blowdown water, condensate water, relatively clean washing and rinsing water can be reused without treatment in the same/different processes and in areas that do not require high water quality (such as plant and equipment cleaning). Apart from this, it is possible to reuse wastewater streams that cannot be reused directly in production processes after they are treated using appropriate treatment technologies.

Membrane filtration processes are an integral part of many wastewater reuse systems. Nanofiltration (NF) and Reverse osmosis (CTR) filtration systems are used for industrial wastewater recovery. Microfiltration (MF) and ultrafiltration (UF) are often used for the pretreatment of water before it goes to the NF or CTR process (Singh et al., 2014).

In the textile industry, water savings of 30-70% can be achieved by reusing washing and rinsing water without treatment (USEPA, 2008; LCPC, 2010; MoAF, 2021). In addition, in a clean production study carried out in the textile industry, it has been reported that a reduction in total water consumption in the range of 29-55% and in the pollution loads of composite wastewater in the range of 42-53% will be achieved with the recovery applications of appropriate wastewater streams (Öztürk, 2014). In another textile enterprise engaged in textile finishing-dyeing, by reusing wastewater with or without treatment, 46-50% in water consumption, wastewater amounts

It has been determined that 48-56% and 16-20% reduction in the COD load of wastewater can be achieved (Öztürk, 2014).

- ***Use of cooling water as process water in other processes***

  Water cooling systems are widely used in processes where thermal energy is used intensively and cooling is required . It is possible to save water and energy by using heat exchangers in cooling water return, preventing contamination of cooling water and increasing cooling water return rates (TUBITAK MAM, 2016; MoAF, 2021). In addition, if the cooling water is collected separately, it is often possible to use the collected water for cooling purposes or to reuse it in appropriate processes (EC, 2009). With the reuse of cooling water , 2-9% of total water consumption can be saved (Greer et al., 2013). Savings of up to 10% can be achieved in energy consumption (Öztürk, 2014; MoAF, 2021).

- ***Determination of the scope of reuse of washing and rinsing waters***

  In industrial facilities, relatively clean wastewater such as washing-final rinsing wastewater and filter backwash wastewater can be reused without treatment in floor washing and garden irrigation processes that do not require high water quality (Öztürk, 2014). Thus, it is possible to save between 1-5% in raw water consumption (MoAF, 2021).

- ***Use of pressure washers for equipment cleaning, general cleaning, etc.***

  Water nozzles are widely used in equipment plant cleaning. Effective results can be obtained by using correctly placed, appropriate nozzles to reduce water consumption and wastewater pollution loads. The use of active sensors and nozzles where high water consumption occurs and where possible is very important for the efficient use of water. Thanks to the replacement of mechanical equipment with pressurized nozzles, it is possible to achieve significant water savings (TUBITAK MAM, 2016). Reducing water consumption, wastewater generation and wastewater pollution load through the use of water pressure-optimised nozzles in technically feasible processes are the main environmental benefits of the application.

- ***Use of automatic check-off valves to optimise water use***

  Monitoring and controlling water consumption using flow control devices, meters and computer-aided monitoring systems provides significant technical, environmental and economic advantages (Öztürk, 2014). Monitoring the amount of water consumed within the facility and in various processes prevents water losses (TUBITAK MAM, 2016). It is necessary to use flow meters and meters in the facility and production processes, to use automatic shut-off valves and valves in continuously operating machines, to develop monitoring-control mechanisms according to water consumption and some determined quality parameters using computer-aided systems (TUBITAK MAM, 2016). With this application, it is possible to save up to 20-30% in water consumption on a process basis (DEPA, 2002; LCPC, 2010; IPPC BREF, 2003). By monitoring and controlling water consumption on a process basis , 3-5% savings can be achieved in process water consumption (Öztürk, 2014).

- ***Avoiding the use of drinking water in production lines***

  In different sub-sectors of the manufacturing industry, water with different water quality can be used in accordance with production purposes. In industrial facilities, raw water obtained from underground water sources is used in production processes after being treated. However, in some cases, although it is costly in production processes, drinking water can be used directly or raw water is disinfected with chlorinated compounds and evaluated in production processes. These waters, which contain residual chlorine, can react with organic compounds (natural organic substances (NOM) in the water in the production processes and form disinfectant by-products harmful to living metabolisms (Özdemir & Toröz, 2010; Oğur et al.; MoAF, 2021). The use of drinking water containing residual chlorine compounds or raw water disinfected with chlorinated compounds should be avoided as much as possible. In the disinfection of raw water, disinfection methods with high oxidation ability such as ultraviolet (UV), ultrasound (US) or ozone can be used instead of chlorine disinfection. In order to increase the technical, economic and environmental benefits to be provided by the application, determining and using the water quality parameters required in each production process helps to reduce unnecessary water supply and treatment costs. With this application, it is possible to reduce water, energy and chemical costs (TUBITAK MAM, 2016).

- ***Collecting rainwater and evaluating it as an alternative water source in facility cleaning or in appropriate areas***

  In today's world where water resources are decreasing, rainwater harvesting is frequently preferred especially in regions with low rainfall. There are different technologies and systems for rainwater collection and distribution systems. Cistern systems, infiltration into the ground, collection from the surface and filter systems are used. Rainwater collected by special drainage systems can be used for production processes, garden irrigation, tank and equipment cleaning, surface cleaning, etc., if it meets the required quality requirements (Witness et al., 2015).

  In various examples, 50% water savings were achieved in landscape irrigation by using roof rainwater collected in industrial facilities and using it in buildings and landscaping areas after storing it (Yaman, 2009). Perforated stones and green areas can be preferred in order to increase the permeability of the ground and to ensure that rainwater passes and is absorbed into the soil in the field (Yaman, 2009). Rainwater collected on the roofs of buildings can be used for car washing and garden irrigation. It is possible to reuse the collected water by recovering 95% of it with biological treatment after use (Şahin, 2010).

- ***Recovery of water from rinsing solutions and reuse of recovered water in processes appropriate to its quality***

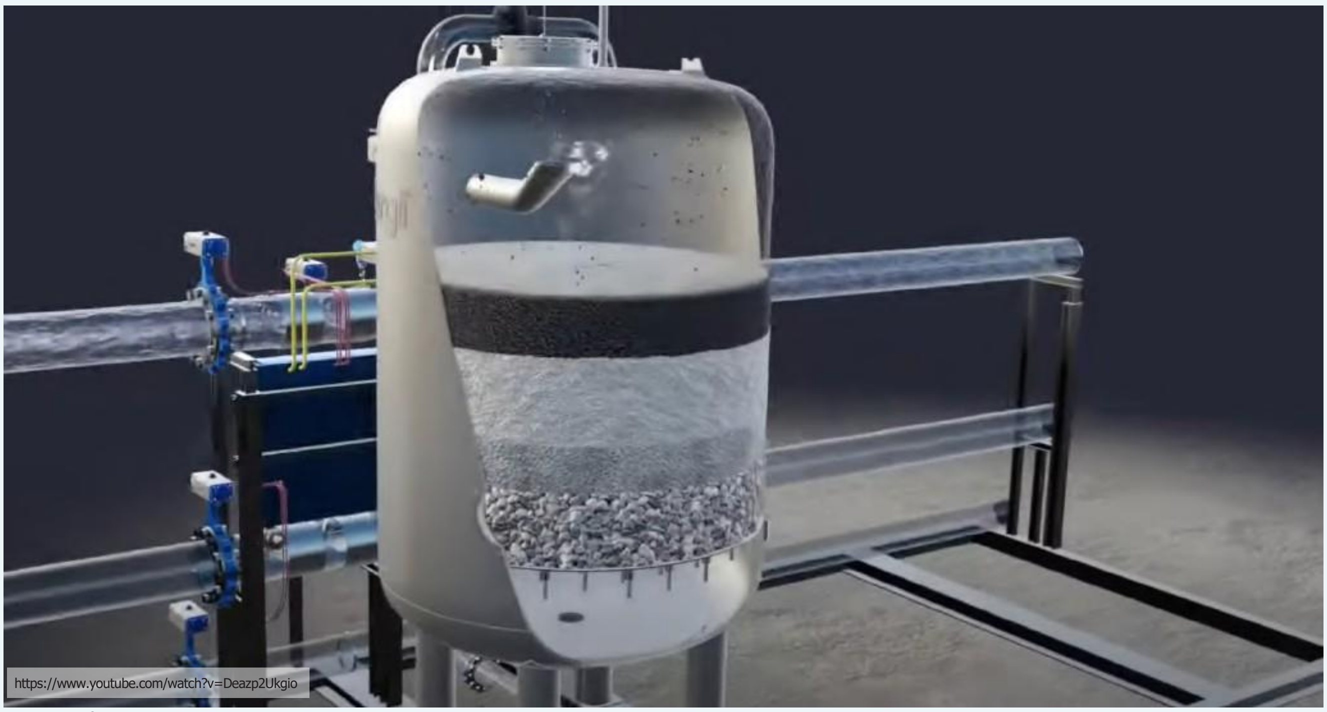
  Rinsing wastewater in industrial facilities can be reused without treatment in relatively clean wastewater, floor washing and garden irrigation processes that do not require high water quality (Öztürk, 2014). In raw water consumption with the recovery of rinse water
  Savings of 1-5% can be achieved.

- ***Optimising the frequency and duration of regeneration (including rinses) in water softening systems***

Cationic ion exchange resins, which are one of the most commonly used methods for softening raw water in industrial facilities, are routinely regenerated. In regeneration, pre-washing, brine regeneration and final rinsing processes are carried out using raw water, respectively. Regeneration periods are determined depending on the hardness of the water. If the hardness is high, more frequent regeneration should be done in water softening systems.

In regeneration processes, washing, regeneration and rinsing wastewater are usually removed directly . However, if the washing and final rinsing water is of raw water quality, it can be sent to the raw water tank or reused in processes that do not require high water quality, such as facility cleaning and green area irrigation (MoAF, 2021).

It is very important to determine the optimum regeneration frequency in regeneration systems. Although regeneration in water softening systems is adjusted according to the frequency recommended by the supplier or depending on the flow rate and time entering the softening system, this frequency also varies depending on the calcium concentration in the raw water. For this reason, online hardness measurement is applied when determining the frequency of regeneration. Thus, regeneration frequencies can be optimized, as well as excessive washing, rinsing or backwashing with salt water can be prevented by using online hardness sensors.



Water Softening Systems

- ***Use of closed-loop water cycles in appropriate processes***

  In general, refrigerants are chemical compounds with certain thermodynamic properties that affect the performance of the cooling process, taking heat from the substances to be cooled and cooling them (Kuprasertwong et al., 2021).

  Water is used as a refrigerant in manufacturing industry processes and in many processes led by product cooling. While this cooling process is carried out, the water can be reused through the cooling tower or central cooling systems. If unwanted microbial growth occurs in the cooling water, it can be controlled by adding chemicals to the recirculation water (TUBITAK MAM, 2016).

  By reusing cooling water in processes such as cleaning, water consumption and the amount of wastewater generated are reduced. However, the need for energy for cooling and recirculation of cooling water emerges as a side interaction.

  Heat recovery is also provided by the use of heat exchangers in cooling waters. Generally , closed loop systems are used in facilities where water cooling systems are used. However, the cooling system blowdowns are removed by giving them directly into the wastewater treatment plant channel. These removed blowdown waters can be reused in suitable production processes.

- ***Storage, storage and prevention of substances that pose a risk in the aquatic environment (such as oils, emulsions, binders) and mixing with wastewater after use***

  In industrial facilities, water recovery is achieved by using dry cleaning techniques and preventing leaks in order to prevent chemicals that pose a risk to the aquatic environment such as oils, emulsions and binders from mixing with wastewater streams (TUBITAK MAM, 2016).

- ***Construction of closed storage and impermeable waste/scrap yard to prevent the transportation of toxic or hazardous chemicals for the aquatic environment***

  In industrial facilities, closed and impermeable waste/scrap storage areas can be built to prevent the transport of toxic or dangerous chemicals to the receiving environments for the aquatic environment. This practice is already being implemented within the scope of the current environmental regulations in our country. Within the scope of the field studies carried out, a separate collection channel can be built in the toxic or hazardous substance storage areas in industrial facilities to prevent the separate collection of the leachate in question and its mixing with the natural water environments.

- ***Avoiding the need for rinsing between activities by using compatible chemicals in successive processes***

  Chemical compatibility is a measure of how stable a substance is when mixed with another substance. If two substances mix with each other and undergo a chemical reaction, they are considered incompatible.

  Various chemicals are used in industrial facilities to increase washing and rinsing efficiency. The fact that these chemicals are compatible and act as solvents shows a positive course in increasing efficiency. Therefore, dirt on the material can be removed in a shorter time and more effectively, and the amount of water used in washing processes can be significantly reduced. In this case, even if the amount of wastewater can be reduced, there may be an increase in the chemical loads carried by the wastewater. These negative effects can be minimized by ensuring that the washing water containing solvents used in the washing and rinsing processes is reused.

  It is possible to save 25-50% of water by reusing washing water. Reserved tanks and new pipelines may be needed for the application. In alternative cases, the washing solution is kept directly in the system and can be used many times until it loses its properties.

- ***Use of computer-aided control systems in production processes***

  Since inefficient resource use and environmental problems in industrial facilities are directly related to input-output flows, process inputs-outputs should be defined in the best way specific to production processes (TUBITAK MAM, 2016). Thus, it becomes possible to develop measures to increase resource efficiency, economic and environmental performance. Organizing input-output inventories is considered a prerequisite for continuous improvement. While such management practices require the participation of technical staff and senior management , they pay for themselves in a short time with the work of various experts (IPPC BREF, 2003). It is necessary to use measurement equipment on the basis of application processes and to perform some routine analyzes/measurements specific to the processes. In order to obtain the highest level of efficiency from the application, using computerized monitoring systems as much as possible ensures that the technical, economic and environmental benefits to be obtained are increased (TUBITAK MAM, 2016).

Computer Aided Control System

- ***Reuse of filter wash water in filtration processes, reuse of relatively clean cleaning water in production processes, and reduction of water consumption by using clean-in-place systems (CIP)***

  Wastewater from backwashes of activated carbon filters and softening devices often contains only a high percentage of suspended solids (SS). Backwash water, which is one of the easiest wastewater types to recycle, can be recovered by filtering with ultrafiltration plants. In this way, water savings of up to 15% are achieved (URL - 1, 2021).

  Regeneration wastewater formed after the regeneration process is soft water with high salt content and constitutes approximately 5-10% of total water consumption. It is ensured that regeneration wastewater is collected in a separate tank and evaluated in processes with high salt requirements, facility cleaning and domestic use. For this, a reserved tank, plumbing and pump are needed. With the reuse of regeneration wastewater, water consumption, energy consumption, wastewater amounts and salt content of wastewater are reduced by approximately 5-10% (Öztürk, 2014). The payback period varies according to the consumption of regeneration water in production processes, facility cleaning and domestic use. It is estimated that if regeneration water is reused in production processes that require high salt (since both water and salt will be recovered), the potential payback period will be less than one year. It is estimated that the payback period will be over one year for facility and equipment cleaning and domestic uses (MoAF, 2021).

  In our country, reverse osmosis (CTR) concentrates are combined with other wastewater streams and given to the wastewater treatment plant channel. The concentrates formed in the CTR systems used for additional hardness removal can be used in garden irrigation, in-plant and tank-equipment cleaning (TUBITAK MAM, 2016; MoAF, 2021). In addition, with the structuring of raw water quality monitoring, it is possible to re-evaluate CTR concentrates by feeding them back into raw water reservoirs and mixing them (MoAF, 2021).

- ***Reuse of pressurized filtration backwash water prior to water softening at appropriate points***

  Softened waters with low calcium and magnesium concentrations are needed for many industrial processes. With water softening systems, calcium, magnesium and some other metal cations in hard water are removed from the water and soft water is obtained.

  Savings are achieved by reusing pressurized filtration backwash water at appropriate points before water softening. This measure is similar in content to applications such as "Reuse of filter backwash water in filtration processes, relatively cleaning water in production processes, and reducing water consumption by using in-situ cleaning systems".

- ***Documentation of production procedures and use by employees to prevent waste of water and energy***

  In order to make efficient production in an enterprise, effective procedures should be applied in order to identify and evaluate potential problems and their sources and to control the production stages (Ayan, 2010). Determining and implementing appropriate procedures in production processes ensures more efficient use of resources (such as raw materials, water, energy, chemicals, personnel and time) and assurance of reliability and quality in production processes (Ayan, 2010). The presence of documented production procedures in production processes contributes to the development of the ability to develop sudden reflexes for the evaluation of operational performance and the solution of problems (TUBITAK MAM, 2016; MoAF, 2021). Effective implementation and monitoring of procedures created specifically for production processes is one of the most effective ways to ensure product quality, to receive feedback and to develop solution proposals (Ayan, 2010). Documenting, effectively implementing and monitoring production procedures is a good management practice and is an effective tool in structuring and ensuring the continuity of the cleaner production approach and environmental management system. In addition to the potential benefits, there may be changes in the cost and economic gains of the application depending on the sector or facility structure (TUBITAK MAM, 2016; MoAF, 2021). Although the establishment and monitoring of production procedures is not costly, the payback period may be short considering the savings and benefits it will provide (TUBITAK MAM, 2016; MoAF, 2021).

- ***Implementation of time optimization in production and arrangement of all processes to be completed as soon as possible***

  In industrial production processes, planning the process from raw material to product transformation using the least process is an effective practice to reduce labor costs, resource use costs and environmental impacts and to ensure efficiency. In this context, it may be necessary to review the production processes and revise them to use the least number of process steps (TUBITAK MAM, 2016). In cases where the desired product quality cannot be achieved due to some inadequacies, inefficiency and design errors in basic production processes, production processes may need to be renewed. Therefore, in this case, the use of resources required in the manufacture of the unit amount of product and the amount of waste, emissions and solid waste generated increase. Time optimization in production processes is an effective practice (TUBITAK MAM, 2016).

- ***Separate collection and treatment of gray water in the facility and use it in areas that do not require high water quality (green area irrigation, floor, floor washing, etc.)***

  Wastewater generated in industrial facilities is not only industrial wastewater originating from production processes, but also includes wastewater originating from showers, sinks, kitchens, etc. Wastewater consisting of showers, sinks, kitchens, etc. is called gray water. Water savings can be achieved by treating these gray waters with various treatment processes and using them in areas that do not require high water quality .

- ***Reuse of nanofiltration (NF) or reverse osmosis (CTR) concentrates with or without purification depending on characterization***

  According to wastewater characterization and appropriate points of use, the reuse potentials of other wastewater resulting from membrane processes (backwash without or with the use of chemicals, CIP cleaning, module cleaning, cleaning of chemical tanks, etc.) should be evaluated.

  Nanofiltration is a membrane-based liquid separation technique with low energy consumption and low operating pressures, which is suitable for the treatment of well water and surface water Reverse osmosis is also a membrane-based liquid separation technique that can separate smaller substances than nanofiltration (Akgül, 2016).

  Depending on the characterization of nanofiltration or reverse osmosis concentrates, savings are achieved by reusing them with or without treatment. Measures should be taken to reuse clean water in the production processes of filter backwash water in filtration processes and to reduce water consumption by using cleaning systems (MoAF, 2021).

- ***Use of automatic equipment and equipment (sensors, smart hand washing systems, etc.) that will save water at water usage points such as showers/toilets, etc.***

  Water is very important in many sectors of the manufacturing industry, both for production processes and for personnel to provide the necessary hygiene standards. Water consumption can be achieved in various ways in the production processes of industrial facilities, as well as savings in water consumption by using equipment such as sensor taps and smart hand washing systems in the water usage areas of the personnel. Smart hand washing systems adjust the water, soap and air mixture in the right proportion and provide resource efficiency in addition to water savings.

Reverse Osmosis System

2.1.4 Precautions for Auxiliary Processes

BATs for steam generation

- ***Saving water by insulating steam and water lines (hot and cold) and preventing water and steam losses in pipes, valves and connection points in the lines and monitoring them with a computer system***

Steam losses may occur if the steam lines are not properly designed in the facilities, routine maintenance and repairs of the steam lines are not carried out, mechanical problems that occur in the lines and the lines are not operated properly, and full insulation of the steam lines and hot surfaces is not made. This affects both the water consumption and energy consumption of the facility. It is necessary to use control systems with automatic control mechanisms in order to make steam insulations and to monitor steam consumption continuously. Due to the reduction of steam losses, similar savings can be achieved in fuel consumption and additional soft water consumption in boilers. Since fuel consumption in steam boilers will decrease, waste gas emissions are expected to decrease at the same rate. Since the use of additional soft water used in steam boilers will be reduced with the application, the amount of regeneration water, the amount of salt used in regeneration and reverse osmosis concentrates are also reduced. Automatic control mechanisms for full vapor insulation application and minimization of steam losses are used in many facilities with heavy steam consumption. With the configuration of the application, 2-4% fuel savings are achieved in steam boilers.

In order to prevent losses in production processes, adding the most important parts of equipment such as pumps, valves, adjustment knobs, pressure, flow regulators to the maintenance checklist, inspecting not only water systems but also heating and chemical distribution systems, drums, pumps and valves, regular cleaning of filters and pipelines, 1-6% savings in water consumption can be achieved with regular calibration of measuring equipment (thermometers, chemical scales, dispensing/dosing systems, etc.) and routine inspection and cleaning of heat treatment units (including chimneys) at specified periods, effective maintenance-repair, cleaning and loss control practices (Hasanbeigi, 2010; Ozturk, 2014; MoAF, 2021).

Industrial Steam Boilers

• ***Saving water by reusing steam boiler condensate***

When steam indirect heating techniques are used to transmit thermal energy in production processes, the recovery of condensed steam (condensate) is an effective practice in terms of reducing water consumption (IPPC BREF, 2009). By recovering condensate water, an average of 5% reduction in water consumption can be achieved (Greer et al., 2013). In addition, the potential payback period varies between 4-18 months (taking into account energy savings) (Öztürk, 2014; TUBITAK MAM, 2016).

• ***Prevention of flash steam losses due to boiler draining***

Steam boiler condensate is generally discharged from the system at atmospheric pressure from the equipment outlets and steam traps outlet. In condensate systems, as the pressure decreases, some of the condensate evaporates again and cools down to the boiling point of water at atmospheric pressure. The re-evaporated condensate, called flash steam, is thrown into the atmosphere and disappears. In the case of condensate return lines, which are usually quite long, cooling and therefore evaporation are inevitable. In order to prevent the condensate from evaporating again, savings can be achieved by keeping it in a flash tank under pressure until it returns to the boiler feed tank. As the pressure decreases in the condensate taken into the tank, the steam formed is collected on the tank and feeds the low pressure steam system from there. The remaining hot condensate is taken into the boiler from the bottom of the tank.

• ***Minimizing boiler discharge water (blowdown) in steam boilers***

Boiler blowdown refers to the water consumed from a boiler to prevent the condensation of pollutants during the continuous evaporation of steam . Boiler blowdown can be reduced by 50% with condensate recovery (IPPC BREF, 2009).

In automatic systems, the blowdowns in the boilers are constantly monitored and the system is re-analyzed together with the water taken after the blowdown. In the analysis, data such as dissolved and undissolved particles in the water and water density are processed. If the density for the boiler is above the system limits, the blowdown process is repeated. The system should be automated and the optimum blowdown frequency should be determined. When the frequency of blowdowns is reduced, the amount of wastewater decreases. This saves energy and cooling water used to cool wastewater (IPPC BREF, 2009). By optimizing the steam boiler blowdown process, operating costs are reduced by saving boiler water consumption, waste costs, conditioning and heating.

• ***Reuse of energy generated from the steam condenser***

By applying a simple modification to the piping system, the water that feeds the water resting/decarbonization unit can be obtained from the outlet of the turbine condenser unit. This water has sufficient temperature for the resting/decarbonization unit. Therefore, this water does not need to be heated by means of steam generated by the heat exchanger system. Thanks to this work, significant steam gain can be achieved. In addition, cooling water consumption can be reduced (CPRAC, 2021).

- ***Reducing the amount of blowdown by using deaerators in steam boilers***

  Free oxygen dissolved in steam boilers, feed water and hot water boilers, and carbon dioxide formed by the breakdown of carbonates in boilers can cause corrosion in the form of pores and rusting and melting in steam boilers, devices using steam and especially in installations. The effects of these gases increase as the proportion of fresh feed water and the operating pressure of the system increases. If these dissolved gases are not removed from the boiler feed water, the useful life of these systems is shortened, corrosion and various deformations may occur. These gases also cause excessive corrosion in carbon dioxide coils, steam appliances and condensate pipes. Boiler feed water must be purified from dissolved gases such as oxygen and carbon dioxide by passing through the deaerator. Deaeration systems are mechanical systems that allow dissolved gases to be evaporated from the water by giving air to the water with a fan. Dissolved deaeration can be increased by increasing the water and air contact surface in the deaerator system. In this way, corrosion formation is reduced and boiler efficiency is increased (TUBITAK MAM, 2016; MoAF, 2021).

BATs for refrigeration systems

- ***Use of a closed-loop refrigeration system to reduce water use***

  Closed-loop cooling systems significantly reduce water consumption compared to open-loop systems with more water-intensive use. In closed-loop systems, when the same water is recirculated in the system, cooling water is usually required to be added as much as the amount of evaporated water. Evaporation losses can also be reduced by optimizing cooling systems.


https://www.chiller.com.tr/wp-content/uploads/2018/04/chiller-sogutma-kapasitesi-hesabi.jpg

Cooling Systems (Chiller)

- ***Increasing the number of cycles by using anti-corrosion and anti-scale inhibitors in systems with closed water cycles*** Cooling towers and evaporative condensers are efficient and cost-effective systems that remove heat from air conditioning and industrial process cooling systems (IPPC BREF, 2001b; MoAF, 2021).

  More than 95% of the circulating water in these systems can be recovered (TUBITAK MAM, 2016). In cooling systems, impurities remain in the recirculation water due to the fact that some of the recirculation water is worked on the basis of evaporation, and the impurity concentrations gradually increase in each cycle. Impurities that can be included in the cooling system together with the air can cause contamination in the recirculation water (TUBITAK MAM, 2016). If impurities and contaminants are not effectively controlled, they can cause the formation of boilerstone and corrosion, unwanted biological growth and sludge accumulation. This can become a chronic problem that leads to a decrease in the efficiency of heat transfer surfaces and an increase in operating costs. In this case, it is necessary to implement a water treatment program specially designed in terms of the quality of the feed water supplied to the cooling system, the cooling water system building material and operating conditions. In this context; blowdown control, biological growth control, corrosion control, avoiding the use of hard water, using sludge control chemicals, using filtration and sieve systems may be appropriate (TUBITAK MAM, 2016). In addition, the establishment and periodic implementation of an effective cleaning procedure and program is a good management practice in terms of protecting cooling systems. Corrosion is one of the most important problems in cooling systems. In the tower recirculation water, as the degree of hardness increases, dissolved solids (sulfate, chloride, carbonate, etc.) that cause corrosion as a result of the formation of limestone and deposits on the walls will cause abrasion on the surface over time. In addition, the formation of deposits negatively affects heat transfer and reduces energy efficiency. In order to prevent these negativities, it is necessary to implement a lime and corrosion preventive chemical conditioning program, to disinfect with biocide that prevents biological activation, to clean the sediments by subjecting the cooling towers in use to chemical and mechanical cleaning at least twice a year, and to keep the hardness and conductivity values of the reinforcement water as low as possible (IPPC BREF, 2001; Kayabek et al., 2005). In order to improve the quality of the supplementary water, it may be necessary to treat (condition) it using an appropriate treatment system. In addition, unwanted microbial growth needs to be kept under control (IPPC BREF, 2001b; MoAF, 2021). Due to micro-residues and deposits in the cooling water, blowdown occurs in cooling systems as well as in steam boilers. Deliberate draining of the cooling system to bring the increased density of solids in the cooling system to balance is called cooling blowdown. It is possible to reduce the use of biocides and blowdown amounts by pre-treating cooling water with appropriate methods and continuous monitoring of cooling water quality (TUBITAK MAM, 2016). Although the investment cost depends on the scale of the application, the payback period in expected investment expenses varies between 3 and 4 years (IPPC BREF, 2001).

- ***Water recovery with tower cooling application in systems that do not have a closed loop***
  Cooling towers are divided into two as counter-flow and cross-flow according to their working principles. In counter-flow cooling towers, the airflow moves upwards as the water flows downwards, and in cross-flow cooling towers, the airflow moves horizontally as the water flows downwards.
  The water, which is exposed to fresh air, cools down until it descends into the cold water pool, where it is collected and sent to the facility. During these processes, some of the water evaporates. The air, whose humidity increases as a result of the evaporation of water, is thrown into the atmosphere from the fan chimney at the top of the tower . Evaporation losses in cooling towers must be managed effectively.

  Various chemicals are used in cooling towers to prevent the formation of bacteria and parasites and to control lime residues. These chemicals condense with the evaporation of water and cause unwanted sediment and deposits within the tower. A blowdown system is used to keep this concentration at a certain level. Blowdown water can be recovered by treatment with the use of membrane filtration systems or ion exchange resins. Recycling of blowdown wastewater is important in terms of water efficiency.

- ***The use of air cooling systems instead of water cooling in cooling systems*** Industrial cooling systems are used to cool heated products, processes and equipment. Closed and open circuit cooling systems can be used for this purpose, as well as industrial cooling systems where a fluid (gas or liquid) or dry air is used
  (IPPC BREF, 2001b; MoAF, 2021). Air cooling systems consist of finned tube elements, condensers and air fans (IPPC BREF, 2001b; MoAF, 2021). Air cooling systems can have different operating principles. In industrial air cooling systems, heated water is air-cooled in closed-loop refrigerant condensers and heat exchangers (IPPC BREF, 2001b; MoAF, 2021). In water cooling systems, the heated water is taken to a cooling tower and the water is cooled in drip systems. However, although water-cooled systems operate in a closed circuit, a significant amount of evaporation occurs. In addition, since some water is blown down in cooling systems , water is lost in this way (IPPC BREF, 2001b; MoAF, 2021). The use of air cooling systems instead of water in cooling systems is effective in reducing evaporation losses and also reducing the risk of contamination of cooling water (IPPC BREF, 2001b; MoAF, 2021).

- ***Reducing water consumption by increasing the number of cycles in closed-loop cooling systems and improving the quality of the make-up water***
  Water is used as a refrigerant in many processes such as the production processes of the manufacturing industry and the cooling of products. Water is recirculated through a cooling tower or central cooling systems and the cooling process is carried out. If an undesirable microbial growth occurs in the cooling water, it can be controlled by adding chemicals to the recirculation water (TUBITAK MAM, 2016). In the recirculation process, the number of cycles can be increased by good chemical conditioning. In this way, water can be saved by reducing the amount of fresh water fed into the system. In addition, good conditioning of the cooling completion water can also increase the number of cycles (MoAF, 2021).

- ***Avoiding unnecessary cooling processes by identifying processes that need wet cooling*** : The boundaries of the plant site affect design parameters such as cooling tower height. In cases where it is necessary to reduce the tower height, a hybrid cooling system can be applied. Hybrid refrigeration systems with and without evaporation (wet and dry) is a combination of cooling systems. Depending on the ambient temperature, the hybrid cooling tower can be operated as a completely wet cooling tower or as a combined wet/dry cooling tower (TUBITAK MAM, 2016). In regions where there is not enough cooling water or in cases where water costs are high, the evaluation of dry cooling systems or hybrid cooling systems can be an effective solution to reduce the amount of cooling supplement water (TUBITAK MAM, 2016).

- ***Reduction of evaporation losses in closed-loop cooling water***

  Some water evaporates during the cooling of the heated water in the cooling systems. Therefore, in closed-loop cooling systems, cooling water is added as much as the amount of evaporated water. Evaporation losses can be avoided by optimizing cooling systems. In addition, a reduction in the amount of blowdown can be achieved with applications such as the treatment of completion water added to cooling systems and the prevention of biological growth in cooling systems. Within the scope of the field studies carried out, the blowdown water formed in the cooling system is generally removed by giving it directly to the wastewater channel. By reusing the cooling system blowdown water, up to 50% of the water consumption of the cooling systems can be saved. To implement this measure, it may be necessary to install new pipelines and reserved tanks. (MoAF, 2021).

- ***In some periods of the year, when the need for cooling is low, cooling with local dry air***

  In cases where the need for cooling is low, it is possible to save water by cooling with dry air.

- ***Collecting the water generated by surface runoff with a separate collection system and using it for cooling water, process water, etc.***

  In most industrial facilities, wastewater is generated from process-sourced or non-process-based areas. The resulting wastewater can be treated and reused in appropriate places. By reusing the wastewater generated in the facility after treatment, savings can be achieved at varying rates in various industrial facilities. Water generated by surface runoff can be collected with a separate collection system and used as cooling water (MoAF, 2021).

• ***Installation of water softening systems for the healthy operation of cooling water recovery systems***

Cooling water is collected separately and used for cooling purposes or reused in appropriate processes (EC, 2009). In order for this system to work properly, a water softening system is required. It has suitable water quality in terms of cooling water, cleaning and reuse as irrigation water. However, due to the fact that it contains some hardness in its use as cooling water, an additional softening is required in order to prevent corrosion problems that will occur over time. Cooling water or before it can be reused in the process, these waters must be properly disinfected. In addition, it is possible to reuse the water in question not only in cooling processes but also in all production processes by treating it with appropriate treatment techniques (membrane filtration, advanced oxidation, chemical precipitation, granular activated carbon adsorption, etc.) (TUBITAK MAM, 2016). As the hardness of the cooling water increases, limestone and debris formation occurs on the walls. Deposit formation negatively affects heat transfer, reducing energy efficiency and increasing energy costs. With the increase in evaporation in the system, the ion concentration and conductivity value in the water increases. In order to prevent these negativities, it is necessary to apply lime and anti-corrosion chemical conditioning to the cooling water, to disinfect with a biocide that prevents biological activation, to subject the cooling towers to chemical and mechanical cleaning at least twice a year, to clean the sediments, and to keep the hardness and conductivity values as low as possible (TUBITAK MAM, 2016).

BATs for ventilation and air conditioning systems

• ***Reuse of the liquid formed by condensation from the ventilation system During the*** ventilation cycle, condensate with good water quality can be produced in the system. For example, in a facility in Spain, condensate water with a conductivity of about 200 µS in the ventilation system is collected in a tank and the automatic galvanizing line is flushed
(MedClean, n.d.).

• ***Replacing the old equipment in the ventilation system with ion exchange resins (systems that produce demineralized water) based on the principle of reverse osmosis and reusing the water***

By using ion exchange resins in the ventilation system, the conductivity of the final effluent is brought to a conductivity level suitable for use for equipment cleaning. Example

In a facility in Spain, effluent with a conductivity value of approximately 1000 µS is obtained by replacing the equipment in the ventilation system with ion exchange resins and reused in the system (MedClean, n.d.).

BATs related to the cogeneration system

- ***The use of hot water produced in the cogeneration system in heating processes***
  With the inclusion of cooling systems in cogeneration systems (trigeneration)
  It is possible to convert yield losses of 10-30% into hot water, water vapor, cold air, hot air and water (for this, it is necessary to use absorption heat exchangers). Thus, it is possible to meet some of the energy required in processes such as cooling and drying in the facility from the waste heat in the cogeneration systems. Energy costs can be reduced by up to 40% in facilities where cogeneration systems are used (TUBITAK MAM, 2016).

- ***The use of cold water produced in the cogeneration system in cooling processes*** It is possible to save water by evaluating the cold water produced in the cogeneration system in cooling processes (TUBITAK MAM, 2016).

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