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MINISTRY OF AGRICULTURE AND FORESTRY GENERAL
DIRECTORATE OF WATER MANAGEMENT

Water Efficiency Campaign

Water Efficiency
Guide Documents Series

MANUFACTURE OF OTHER TECHNICAL AND INDUSTRIAL TEXTILES

NACE CODE: 13.96

ANKARA 2023

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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 Techniques Available
NACE	Statistical Classification of Economic Activities
DGWM	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

1Introduction

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 of the Millennium Development Goals: *Ensuring Environmental Sustainability and* Goal 9: Industry, Innovation and Infrastructure *from the Sustainable Development Goals* and *Goal 12: Responsible Production and Consumption within* the scope of the goals of efficient , fair and sustainable use of resources, especially water, environmentally friendly production and consumption that is the concern of future generations such issues are included.

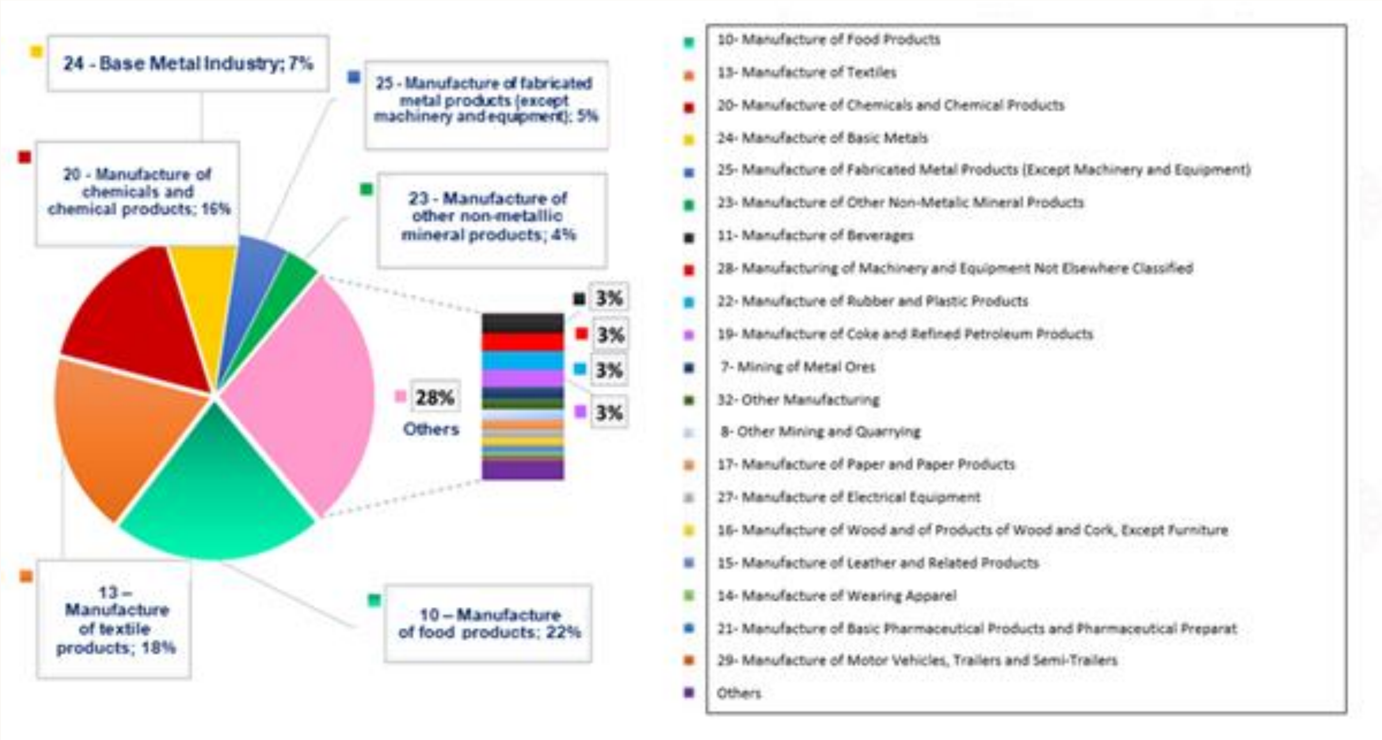
In the European Green Deal Action Plan prepared by our country within the scope of the European Green Deal, where member countries agree on goals such as implementing a clean, circular economy model with the goal of carbon neutrality, expanding the efficient use of resources and reducing environmental 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) 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. 2023/9Water 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 data on water supply, sectoral water use, wastewater generation, recycling were obtained and the best available techniques (BAT) published by the European Union and sectoral reference documents (BREF), water efficiency, clean 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);

(i) Good Management Practices were examined under 4 main groups: (ii) General Measures, (iii) Measures Related to Auxiliary Processes and (iv) Sector-Specific Measures.

Within the scope of the project carried out, at the stage of determining the BATs for each sector; environmental benefits, operational data, technical specifications-requirements and applicability criteria were taken into account. 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 created BAT lists for the local industrial infrastructure and capacity of our country, the BAT lists prepared specifically for each NACE code are prepared by the enterprises; water saving, economic savings, environmental benefits, applicability, cross-media impact were scored and prioritized on the criteria, 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 MoAFacco 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, eleROonic 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)
- EleROicity, 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)

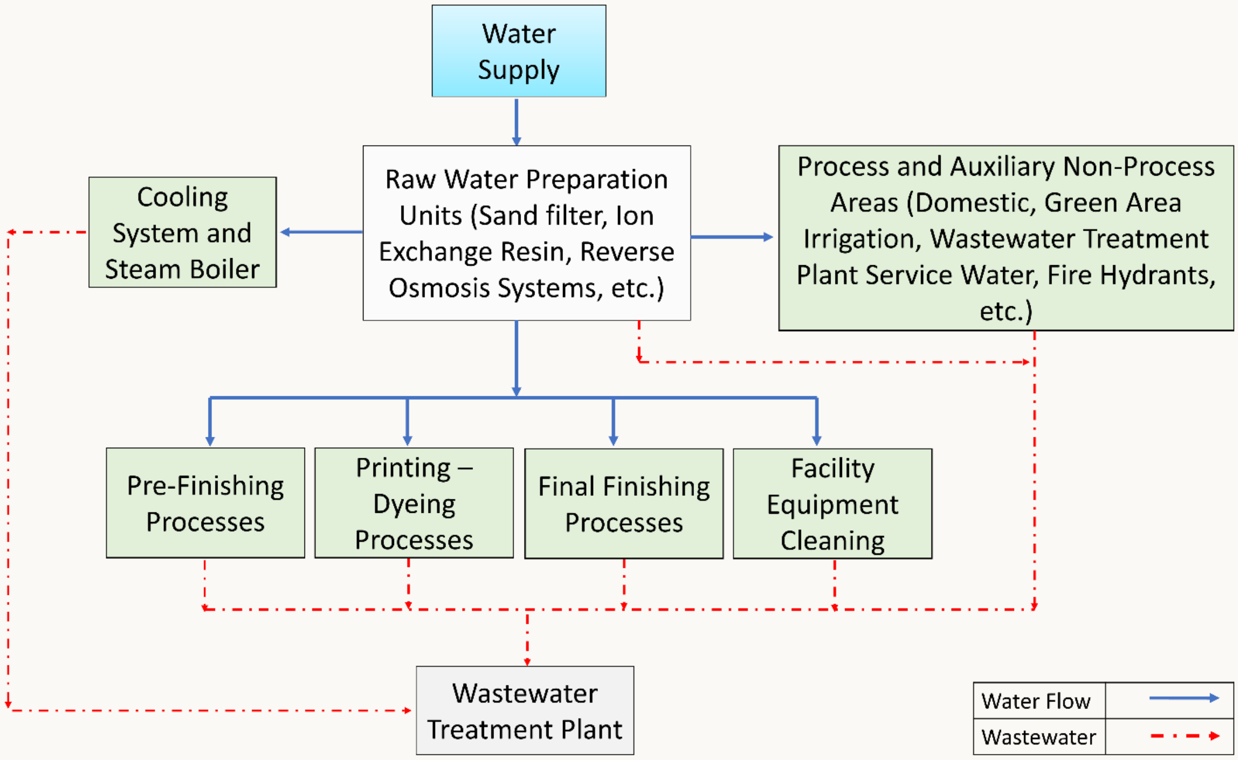
"Manufacture of Textile Products" and "Manufacture of Apparel"

Under the "Manufacture of Textile Products" and "Manufacture of Clothing" sectors, 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 of nonwovens, clothing Except for the item
13.96	Manufacture of other technical and industrial textiles
13.99	Manufacture of other textiles n.e.c.
14.13	Manufacture of other outerwear

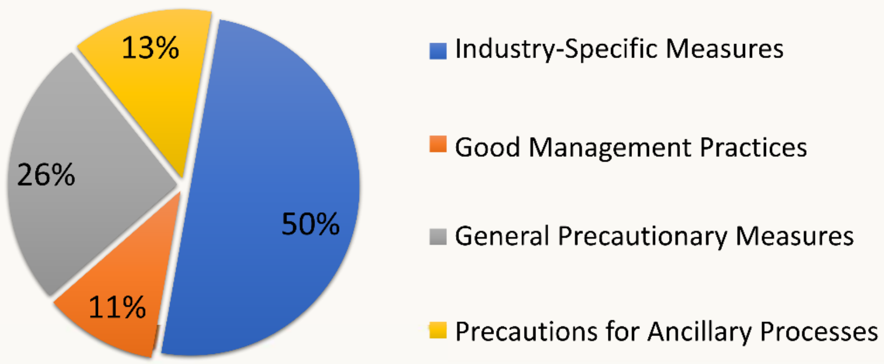
2.1Manufacture of Other Technical and Industrial Textiles (NACE 13.96)

Other Technical and Industrial Textiles Manufacturing Sector Water Flow Chart



	Minimum	Maximum
Specific Water Consumption of the Facilities Visited within the Scope of the Project (L/kg product)	0,01	110,7
Reference Specific Water Consumption (L/kg product)	0,5	250

Percentage Distribution of Water Efficiency Applications



Within the scope of the manufacture of other technical and industrial textiles, metallized yarn, woven fabric from metallized yarns, cords in pieces from textile materials; products such as narrow woven fabrics, woven labels, cord fabrics, etc. are manufactured. Although the production processes vary greatly depending on the raw materials used in the facilities, the techniques/technologies applied and the features expected from the product, the sector generally covers pre-treatment, dyeing-printing and finish-finishing (finishing) processes. In pre-treatment processes such as bleaching, bleaching, hydrophilizing, mercerization, textile materials are prepared for the dyeing-printing process. In addition, technical properties such as strength, dyestuff affinity, gloss are also added to the raw material to be used. Dyeing-printing processes, on the other hand, aim 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 line with the customer's demand.

Within the scope of the production of other technical and industrial textiles, water consumption is generally realized in pre-treatment, dyeing-printing and finishing-finishing (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 manufacturing sector of other technical and industrial textiles, the reference specific water consumption is in the range of 0.5 – 250 L/kg. The specific water consumption of the production branch analyzed within the scope of the study is 0.01 – 110.7 L/kg. It is possible to achieve 40-52% water recovery in the sector with the implementation of sector-specific techniques, good management practices, general precautionary measures and measures related to auxiliary processes.

13.96 Manufacture of Other Technical and Industrial Textiles 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 **Sector-Specific Measures**
9613.	Manufacturing Other technical and industrial textiles	1. Reducing the use of hydrogen peroxide stabilizers in the bleaching process
		2. The use of dyestuffs that can adhere to the fiber at a high rate and the auxiliary chemicals that provide this
		3. Treatment of dyeing wastewater by chemical precipitation
		4. Reuse of dyeing bath solution waste in dyeing
		5. Reuse of dyeing baths
		6. Use of equipment with automatic control mechanism and isolation system to reduce steam losses
		7. Reuse of rinse water in the next painting
		8. Application of fill-unload systems instead of overBAT washing method
		9. Preferring a low flotte ratio in the selection of new machines
		10. Use of solvents in cleaning and washing to remove knitting oils from the fabric
		11. Reduction of water and energy consumption by pad-batch dyeing with reactive dyes
		12. Dyeing according to the puller method with low-salt reactive dyestuffs that provide high fixation
		13. Removal of dirty water remaining in the fiber from the fiber before the next wash
		14. Use of advanced systems for dosing impregnation floats
		15. Using countercurrent flushing
		16. Use of washing/rinsing wastewater for cleaning purposes
		17. Use of highly efficient washing machines and energy recovery equipment in continuous processes
		18. Collecting cooling water that does not come into contact with fabric/yarn and reusing it in processes requiring hot water
		19. Reuse of finishing wastewater in other processes
		20. Reuse of coolants that do not come into contact with the product in the process
		21. Substitution of sodium hypochlorite and chlorite-containing compounds used in the bleaching process
		22. Wastewater from the last wash after dyeing, required for dyeing If it meets the process water criteria, it can be used in the preparation of the dyeing bath
		23. Recovery of washing wastewater after dyeing by adsorption
		24. Application of oxidation desizing process in cases where the source of raw materials cannot be controlled

NACE Code	NACE Code Description	Prioritized Sectoral Water Efficiency Techniques
9613.	Manufacturing Other technical and industrial textiles	25. Reuse of sizing agents by recovery by ultrafiltration
		26. Selection of raw materials with low additive application Stabilized pre-
		27. use of unreduced sulfur-free dyestuffs or pre-reduced liquid paint formulations with a sulfur content of less than 1%
		28. Using hydrogen peroxide as an oxidizer
		29. Using only the amount of reducing agent required for the reduction of the dyestuff
		30. Recovery of alkali in mercerized rinse water
		31. Removal of water-insoluble oils by washing with organic solvents
		32. Use of low-input processes and minimization of impregnation vat volume
		33. Use of polyfunctional reactive dyestuffs instead of conventional reactive dyes
		34. Reducing wastewater generation with application techniques such as foaming and spraying in finishing
		35. Using sodium chloride for flax and bast fibers that cannot be bleached with hydrogen peroxide alone
		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 BAT 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
		The water used in production processes and auxiliary processes and the formed
		8. Monitoring wastewater in terms of quantity and quality and adapting this information to the environmental management system
		General Precautionary Measures
		1. Minimization of spills and leaks
		2. Recovery of water from rinsing solutions and reuse of recovered water in processes appropriate to its quality
		It will save water at water usage points such as showers/toilets, etc.
		3. Use of automated hardware and equipment (sensors, smart handwashing systems, etc.)

NACE Code	NACE Code Description	Prioritized Sectoral Water Efficiency Techniques
9613.	Manufacturing Other technical and industrial textiles	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. Detection and reduction of water losses
		8. Use of automatic check-off valves to optimise water use
		9. Documentation of production procedures and use by employees to prevent waste of water and energy Transportation of toxic or hazardous chemicals for the aquatic environment
		10. Construction of closed storage and impermeable waste/scrap yard to prevent
		11. Substances that pose a risk in the aquatic environment (oils, emulsions, binders storage, storage and prevention of mixing with wastewater after use.
		12. Prevention of mixing of clean water streams with polluted water streams Wastewater quantities and qualities at all wastewater formation points
		13. Characterization and determination of wastewater streams that can be reused with or without treatment
		14. Use of closed-loop water cycles in appropriate processes
		15. Use of computer-aided control systems in production processes
		16. Untreated reuse of relatively clean wastewater from washing, rinsing and equipment cleaning in production processes Separate collection and treatment of grey water in the plant and high water quality
		17. Use in areas that do not require (green area irrigation, floor, floor washing, etc.)
		18. Implementation of time optimization in production and arrangement of all processes to be completed as soon as possible
		19. Collecting rainwater and evaluating it as an alternative water source in facility cleaning or in appropriate areas
		20. Avoiding the need for rinsing between activities by using compatible chemicals in successive processes
		21. Nanofiltration (NF) or reverse osmosis (RO) concentrates Reuse with or without purification depending on the characterization

NACE Code	NACE Code Description	Prioritized Sectoral Water Efficiency Techniques
9613.	Manufacturing Other technical and industrial textiles	**Precautions for Ancillary Processes**
		1. Saving water by reusing steam boiler condensate
		2. Water saving through isolation of steam and water lines (hot and cold) Prevention of water and steam losses in pipes, valves and connection points in the lines and monitoring with a computer system
		3. To the principle of reverse osmosis of old equipment in the ventilation system replacement by ion exchange resins (systems that produce demineralized water) and reuse of water
		4. Prevention of flash steam losses due to boiler draining
		5. Use of air cooling systems instead of water cooling in cooling systems
		6. Use of a closed-loop refrigeration system to reduce water use
		7. Collecting the water generated by surface runoff with a separate collection system and using it for cooling water, process water, etc.
		8. Reducing the amount of blowdown by using deaerators in steam boilers
		9. Minimizing boiler discharge water (blowdown) in steam boilers
		10. Reuse of energy generated from the steam condenser
A total of 74 techniques have been proposed in this sector.		

Other Technical and Industrial Textiles For NACE Code;

(i) Sector-Specific Methods,
(ii) Good Management Practices,
(iii) Measures in the nature of General Measures, and
(iv) Measures for Auxiliary Processes are given under separate headings.

2.1.1 Industry-Specific Measures

- ***Substitution of sodium hypochlorite and chlorite-containing compounds used in the bleaching process*** Sodium hypochlorite bleaching leads to secondary reactions that produce organic halogen compounds (trichlormethane makes up the majority of the compounds formed), usually measured as AOX. 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 $H_2 O_2$ - 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.

- ***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, $H_2 O_2$ /HOO-, H_2 O/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 ensured that the fibers are bleached with high efficiency without damage.

Textile Dyehouses

https://www.hursan.com.tr/up/galeri/baslik-1454924924-boyahane-2.jpg

- ***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).

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

  Washing and rinsing processes are among the most widely used processes in the textile industry. In intermittent processes, "overBAT washing" and "fill-empty systems" systems are used in washing and rinsing processes. In overBAT washing, clean water is fed to the machine and water is discharged from the overBAT weir. OverBAT 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 overBAT 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 overBAT at the lower level. It is especially effective when hot water is used for rinsing. By using fill-empty systems instead of overBATing, 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).

- ***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.

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

  Material paint in uninterrupted dyeing processes; It is impregnated with 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.

- ***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.

- ***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.

- ***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.

- ***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).

- ***Application of oxidation desizing process in cases where the source of raw materials cannot be controlled***

  In cases where the source of raw materials cannot be controlled within the scope of resource use efficiency in the textile sector, oxidation desizing process should be applied. The proposed technique provides significant environmental benefits in water and energy consumption. With the use of ozone as an oxidation agent, COD values in wastewater decrease and the recovery potential of wastewater increases.

- ***Reuse of sizing agents by recovery by ultrafiltration***

  During the weaving process, sizing is carried out to protect the warp yarns and the sizing materials must be removed during textile pre-treatment. This process causes a 40–70% increase in the total COD load in woven fabric finishing. Water-soluble synthetic sizing materials such as polyvinylalcohol, polyacrylates and carboxymethylcellulose can be recovered from washing flottes by ultrafiltration. In addition, it is possible to recover modified starches such as carboxymethylstarch. Sizing substances are removed by washing with hot water in a continuous washing machine in textile pre-treatment. The sizing material concentration of approx. 20–30 g/L in the washing flotte can be increased to 150–350 g/L in the ultrafiltration plant. This concentrate can be recovered and reused for sizing. The sizing permeate can also be reused in the washing machine (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.

- ***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.

- ***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).

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

  Machines with a high flotte ratio cause not only high water and energy consumption, but also the consumption of chemicals and auxiliaries dosed according to the volume of the flotte. 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 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.

- ***Using only the necessary amount of reducing agent for the reduction of the dyestuff***

  In order to use sulfur-free reducing substances instead of sodium sulfur, it is necessary to consume only the amount of reducing agent required for the reduction of the dyestuff. 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.

- ***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.

- ***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).

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

- ***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.

- ***Reducing wastewater generation with application techniques such as foaming and spraying in finishing Foam*** is a microheterogeneous colloid, short- or long-lived, metastable system separated from each other by a thin film layer, in which any liquid is inflated with a suitable gas, usually air, increasing the surface area by roughly 1,000 times, thus containing less liquid. 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) .

- ***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. The dock is slowly rotated until the desired chemical 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 provides low water and energy consumption (approximately 50-80% less than conventional systems).

- ***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.

- ***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.

- ***Removal of dirty water remaining in the fiber from the fiber before the next wash***
  In order to minimize the wastewater pollutant load, reduce the amount of wastewater and reduce water use, the dirty water remaining in the fiber in continuous dyeing processes must be removed from the fiber before the next washing step, using squeezing rollers and similar equipment.

- ***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.

- ***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.

- ***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 BAT 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.

- ***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.

- ***Use of polyfunctional reactive dyes 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). 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.

- ***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).

- ***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.

- ***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).

2.1.2Good 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 an 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, 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. Selection of suitable treatment technology for industrial wastewater; It depends on integrated factors such as land availability, desired purified 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).

- ***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).

- ***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, water needs should be determined throughout the facility and in production processes, quality requirements should be determined at water usage points, 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 BAT 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).

- ***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 BATs. For this reason, 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 reduce energy consumption by 6-10% and water consumption and wastewater by 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 (MoEUCC, 2020e).

2.1.3 General Precautionary Measures

- ***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 BAT 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).

- ***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).

- ***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 BAT 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 BAT 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).

- ***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).

- ***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). With the recovery of rinse water, 1-5% savings in raw water consumption can be achieved.

- ***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).

- ***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 for the transportation of toxic or hazardous chemicals for the aquatic environment to the receiving water environments. 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.

- ***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 (RO) concentrates are combined with other wastewater streams and given to the wastewater treatment plant channel. Concentrates formed in RO 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 RO concentrates by feeding them back into raw water reservoirs and mixing them (MOAF, 2021).

- ***Reuse of nanofiltration (NF) or reverse osmosis (RO) 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).

- ***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).

- ***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 as much as possible***

  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.

- ***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.

- ***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.

- ***By characterizing the amount and quality of wastewater at all wastewater formation points, determining the wastewater BATs that can be reused with or without treatment, It is*** possible to reuse various wastewater streams with or without treatment by determining and characterizing wastewater formation points in industrial facilities (Öztürk, 2014; TUBITAK MAM, 2016; MOAF, 2021). In this context, filter backwash water, RO 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 (RO) 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 RO 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 by treatment/untreated (Öztürk, 2014). In another textile mill engaged in textile finishing-dyeing, it has been determined that 46-50% reduction in water consumption, 48-56% reduction in wastewater amounts and 16-20% reduction in wastewater load can be achieved by reusing wastewater with or without treatment (Öztürk, 2014).

- ***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.

- ***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 BATs, 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).

- ***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).

- ***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).

2.1.4Precautions for Ancillary Processes

- ***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).

- **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).

- **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).

- ***Saving water with the insulation of steam and water lines (hot and cold) and preventing water and steam losses at pipes, valves and connection points in the lines and monitoring them with a computer system*** Steam in case of improper design of steam lines in facilities, failure to carry out routine maintenance and repairs of steam lines, mechanical problems occurring in the lines and improper operation of the lines, complete insulation of steam lines and hot surfaces There may be losses. 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, BAT 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, regular calibration of measuring equipment (thermometers, chemical scales, dispensing/dosing systems, etc.) and heat treatment units (including chimneys) 1-6% savings in water consumption can be achieved with routine inspection and cleaning, effective maintenance-repair, cleaning and loss control practices (Hasanbeigi, 2010; Ozturk, 2014; MOAF, 2021).

- ***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.

BATs for refrigeration systems

- ***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 loop 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).

- ***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.

- ***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).

BATs for ventilation and air conditioning systems

- ***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. For 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.).

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