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MINISTRY OF AGRICULTURE AND FORESTRY   
GENERAL DIRECTORATE OF WATER MANAGEMENT 



Water Efficiency  
Campaign

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WATER EFFICIENCY GUIDANCE  
DOCUMENTS SERIES

MAN-MADE OR SYNTHETIC FIBER  
MANUFACTURING

NACE KODU: 20.60

ANKARA 2023

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## Abbreviations

WWTP Wastewater Treatment Plant

EU European Union

SUS Suspended Solids

BREF Best Available Techniques Reference Document

EMS Environmental Management System

CSIDB Republic of Turkey Ministry of Environment, Urbanization and Climate Change

DOM 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

MET Best Available Techniques

NACE Statistical Classification of Economic Activities

SYGM General Directorate of Water Management

RO Reverse Osmosis

TOB Republic of Turkey Ministry of Agriculture and Forestry

TÜİK Turkish Statistical Institute

NF Nanofiltration

MF Microfiltration

UF Ultrafiltration

GW Groundwater

SW Surface Water

# 1 Introduction

Our country is located in the Mediterranean basin, where the effects of global climate change are felt intensely, and is considered to be 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 the year 2022, the annual amount of water available per capita in Turkey is 1,313 m<sup>3</sup>, and it is expected that the annual amount of water available per capita will fall below 1,000 cubic meters after 2030 due to human pressures and the effects of climate change. If the necessary measures are not taken, it is obvious that Turkey will become a water scarce country in the very near future and will bring many negative social and economic consequences. As it 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 *"using the least amount of water in the production of a product or service"*. The water efficiency approach is based on the rational, sharing, equitable, efficient and effective use of water in all sectors, especially in drinking water, agriculture, industry and household use, in a way that protects water in terms of quantity and quality and takes into account not only the needs of humans but also the needs of all living things with ecosystem sensitivity.

With the increasing demand for water resources, changes in precipitation and temperature regimes as a result of climate change, increasing population, urbanization and pollution, the fair and balanced distribution of usable water resources among users is becoming more and more important every day. Therefore, it has become imperative to create a road map based on efficiency and optimization in order to conserve and use limited water resources through sustainable management practices.

In the vision of sustainable development set by the United Nations, *Goal 7: Ensuring Environmental Sustainability* from the Millennium Development Goals, *Goal 9: Industry, Innovation and Infrastructure* from the Sustainable Development Goals and *Goal 12: Responsible Production and Consumption* from the Sustainable Development Goals include issues such as efficient, fair and sustainable use of resources, especially water, environmentally friendly production and consumption with concern for future generations.

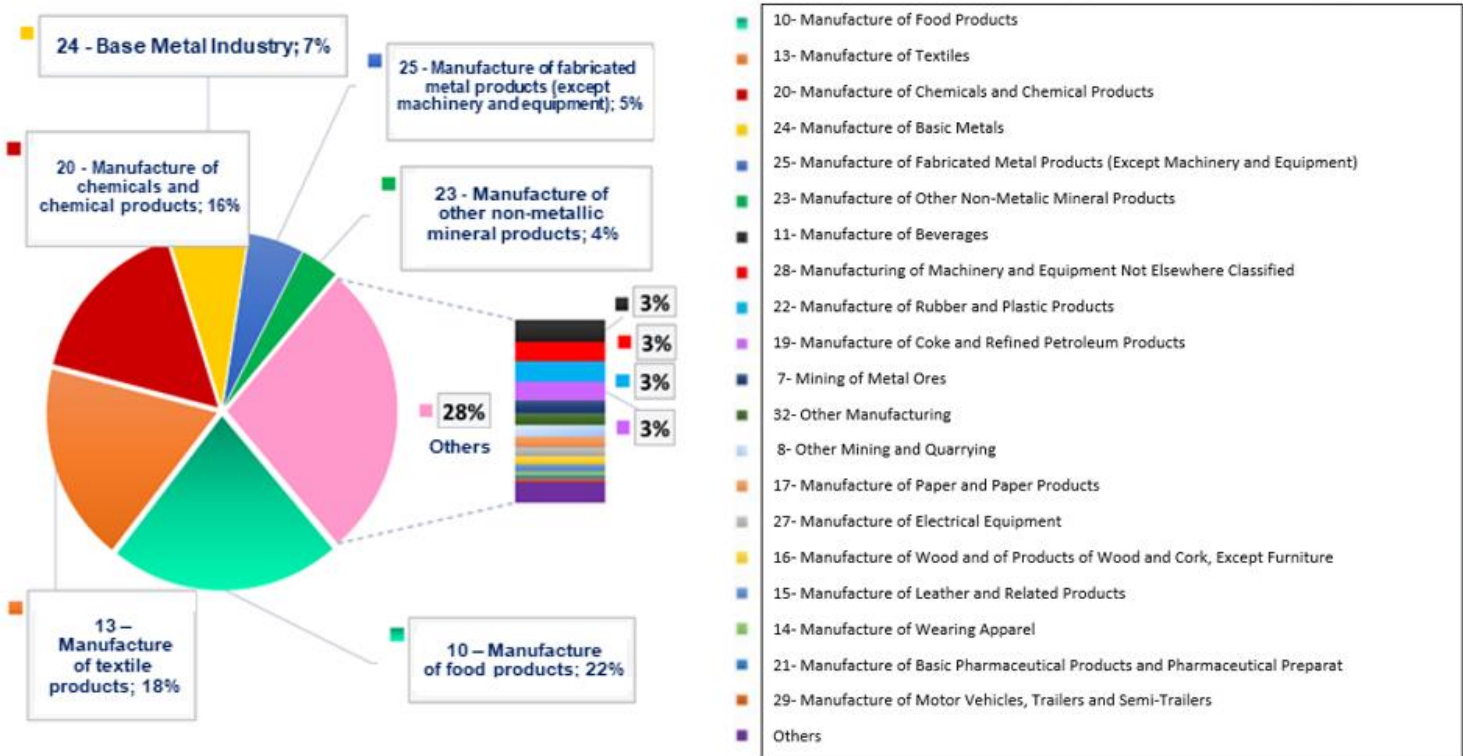
Within the scope of the European Green Deal, where member countries have agreed on goals such as implementing a clean, circular economy model with a carbon neutral target, expanding the efficient use of resources and reducing environmental impacts, actions emphasizing water and resource efficiency in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

The "Industrial Emissions Directive (EED)", which is one of the most important components of the European Union environmental legislation in terms of industry, includes measures to be taken for the control, prevention or reduction of 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 difficulties in implementation. BATs are the most effective implementation techniques for a high level of environmental protection, taking into account their costs and benefits. In accordance with the Directive, Reference Documents (BAT-BREF) have been prepared for each sector detailing BATs. In the BREF documents, BATs are presented in a general framework such as good management practices, techniques as general measures, 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 activities aimed at disseminating efficient practices in urban, agricultural, industrial and individual water use and raising social awareness. Water efficiency action plans addressing all sectors and stakeholders were prepared within the scope of **the "Water Efficiency Strategy Document and Action Plan (2023-2033) within the Framework of Adaptation to a Changing Climate"**, which entered into force with the Presidential Circular No. 2023/9. In the Industrial Water Efficiency Action Plan, a total of 12 actions have been determined for the 2023-2033 period and responsible and relevant institutions have been assigned for these actions. Within the scope of the Action Plan, the General Directorate of Water Management has been assigned the responsibility of conducting studies to determine specific water use ranges and quality requirements on the basis of sub-sectors in industry, organizing technical training programs and workshops on sectoral basis and preparing water efficiency guidance documents.

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

As in the world, the sectors with the highest share in water consumption in our country are food, textile, chemical 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, mainly food, textile, chemical and basic metal industries, representing production areas with different capacities and diversity within the scope of NACE Codes operating in our country and with high water consumption, and data on water supply, sectoral water use, wastewater generation, recycling were obtained and information was provided on best available techniques (BAT) and sectoral reference documents (BREF) published by the European Union, water efficiency, clean production, water footprint, etc.



Sectoral distribution of water use in industry in Turkey

As a result of the studies, specific water consumption and potential savings rates for the processes of enterprises for 152 different 4-digit NACE codes with high water consumption were determined, 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 (BATs) for water efficiency;

(i) Good Management Practices, (ii) General Measures, (iii) Measures Related to Auxiliary Processes and (iv) Sector Specific Measures.

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

## 2 Scope of the Study

Guidance documents prepared within the scope of water efficiency measures in industry cover the following main sectors:

- Crop and animal production and hunting and related service activities (including sub-production area represented by 6 four-digit NACE codes)
- Fisheries and aquaculture (including sub-production area represented by 1 four-digit NACE Code)
- Coal and lignite extraction (including sub-production represented by 2 four-digit NACE codes)
- Service activities in support of mining (including sub-production area represented by 1 four-digit NACE Code)
- Metal ores mining (including the sub-production area represented by 2 four-digit NACE codes)
- Other mining and quarrying (including sub-production represented by 2 four-digit NACE codes)
- Manufacture of food products (including 22 sub-production areas represented by four-digit NACE codes)
- Manufacture of beverages (including sub-production represented by 4 four-digit NACE codes)
- Manufacture of tobacco products (including sub-production area represented by 1 four-digit NACE Code)
- Manufacture of textile products (including 9 sub-production areas represented by four-digit NACE codes)
- Manufacture of apparel (including sub-production area represented by 1 four-digit NACE Code)
- Manufacture of leather and related products (including sub-production area represented by 3 four-digit NACE codes)
- Manufacture of wood, wood products and cork products (except furniture); manufacture of articles made of thatch, straw and similar materials (including sub-production area represented by 5 four-digit NACE Codes)
- Manufacture of paper and paper products (including sub-production area represented by 3 four-digit NACE codes)
- Manufacture of coke and refined petroleum products (including sub-production area represented by 1 four-digit NACE Code)
- Manufacture of chemicals and chemical products (including 13 sub-production areas represented by four-digit NACE codes)
- Manufacture of basic pharmaceutical products and pharmaceutical ingredients (including sub-production area represented by 1 four-digit NACE Code)
- Manufacture of rubber and plastic products (including sub-production area represented by 6 four-digit NACE codes)
- Manufacture of other non-metallic mineral products (including 12 sub-production areas represented by four-digit NACE codes)
- Basic metal industry (including 11 sub-production areas represented by four-digit NACE codes)
- Manufacture of fabricated metal products (except machinery and equipment) (including 12 sub-production areas represented by four-digit NACE codes)
- Manufacture of computers, electronic and optical products (including sub-production area represented by 2 four-digit NACE codes)
- Electrical equipment manufacturing (including sub-production area represented by 7 four-digit NACE codes)
- Manufacture of machinery and equipment not elsewhere classified (including sub-production area represented by 8 four-digit NACE codes)
- Manufacture of motor vehicles, trailers (semi-trailers) and semi-trailers (semi-trailers) (including sub-production area represented by 3 four-digit NACE codes)
- Manufacture of other means of transportation (including the sub-production area represented by 2 four-digit NACE codes)
- Other manufacturing (including sub-production represented by 2 four-digit NACE codes)
- Installation and repair of machinery and equipment (including sub-production represented by 2 four-digit NACE codes)
- Electricity, gas, steam and ventilation system production and distribution (including sub-production area represented by 2 four-digit NACE codes)
- Waste collection, reclamation and disposal activities; recovery of materials (including sub-production represented by 1 four-digit NACE Code)



- Construction of non-building structures (including sub-production area represented by 1 four-digit NACE Code)
- Warehousing and supporting activities for transportation (including sub-production area represented by 1 four-digit NACE Code)
- Accommodation (including sub-production area represented by 1 four-digit NACE Code)
- Educational Activities (Higher Education Campuses) (including sub-production area represented by 1 four-digit NACE Code)
- Sports, leisure and recreation activities (including sub-production area represented by 1 four-digit NACE Code)

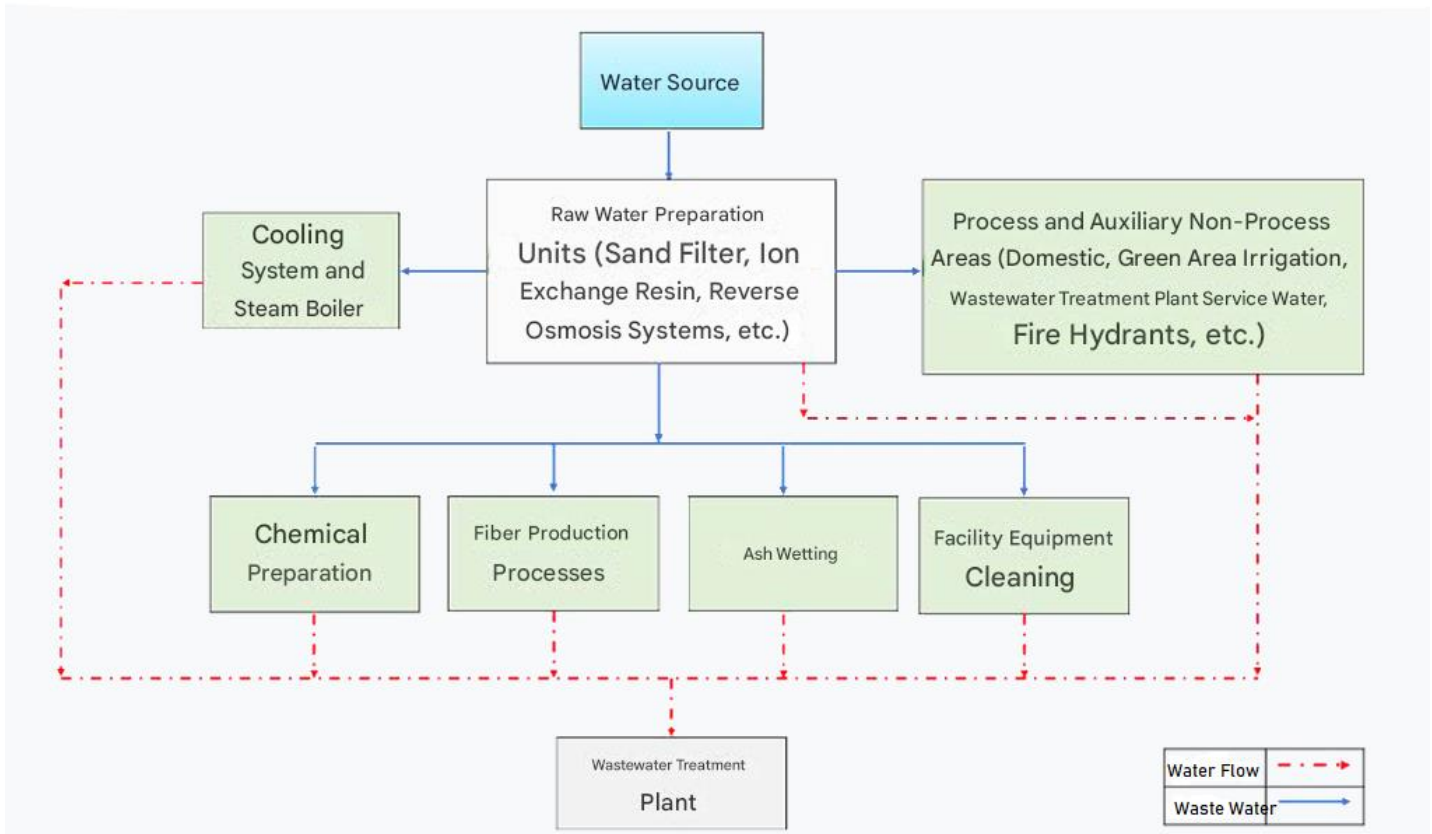
## Manufacture of chemicals and chemical products

Under the chemicals and chemical products manufacturing sector, the sub-production branches for which guidance documents were prepared are as follows

20.11	Manufacture of industrial gases
20.12	Manufacture of dyestuffs and pigments
20.13	Manufacture of other inorganic basic chemicals
20.14	Manufacture of other organic basic chemicals
20.15	Manufacture of chemical fertilizers and nitrogen compounds
20.16	Manufacture of plastic raw materials in primary form
20.17	Manufacture of synthetic rubber in primary form
20.20	Manufacture of pesticides and other agrochemical products
20.30	Manufacture of paints, varnishes and similar coatings, printing inks and pastes
20.41	Manufacture of soaps and detergents, cleaning and polishing agents
20.42	Manufacture of perfumes, cosmetics and personal care products
20.59	Manufacture of other chemical products not elsewhere classified
20.60	Manufacture of man-made or synthetic fibers

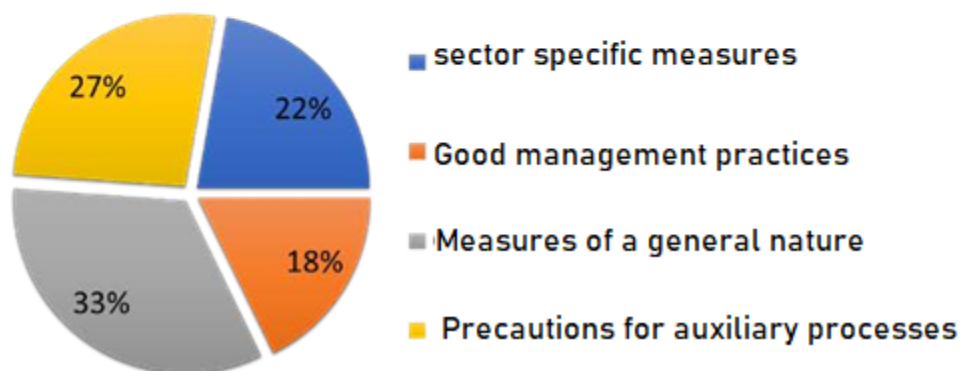
# 2.1 Manufacture of Man-made or Synthetic Fibers (NACE 20.60)

Artificial or synthetic fiber manufacturing sector water flow chart



	Minimum	Maksimum
Specific water consumption of facilities visited within the scope of the project (L/kg ürün)	2,2	10,1
Reference specific water consumption (L/kg ürün)	5	53

Percentage distribution of water efficiency practices



Man-made fiber production basically consists of extrusion, dyeing in the melt (if necessary), filtration, filament extraction and spinnerets, coagulation (solidification), stretching - drawing, lubrication, matting, crimping, fixing, tailoring, winding and twisting processes. In the extruder process, the primary polymer chips and additives are melted to reach a viscosity that can pass through the spinnerets. If necessary, the extruder process is followed by the melt dyeing process. The main reason for this is that some polymers can only be dyed in the melt. In the filtration process, it is aimed to separate the foreign substances that may be present in the molten polymer before it reaches the levels. The molten polymer material that has passed through the extruder process is sent to the filament production heads at a certain temperature and pressure. The liquid mass (molten polymer) flowing through the spinnerets at very high temperature solidifies in the coagulation process and becomes filament. The filament is then subjected to a stretching-drawing process to provide the filament with certain required properties. The stretch-draw process increases the gloss, tensile strength and flexibility properties of the fiber. After the stretching-drawing process, a lubrication process is applied to prevent fiber abrasion by reducing friction. Dulling is the process of reducing the natural luster of chemical fibers according to demand. In the crimping process applied after lubrication and dulling, the yarn is given the necessary volume and flexibility. In the fixing process; it is aimed to gain dimensional stability with moist or dry heat. After the fiber is given the desired properties, a bulk yarn structure is obtained with the tailoring process. The yarn is now ready to be wound. If the yarn coming out of the yarn production machine as a bobbin is to be used as carpet yarn, twisting process is also applied. The final product obtained after the winding and twisting processes is packaged and made ready for sale.

In addition to chemical preparation and fiber production processes in man-made fiber manufacturing, water is also consumed for ash wetting. In the raw water preparation units such as activated carbon filter, ion exchange resin, reverse osmosis, which are used to produce soft water to be used in production processes in the sector, significant water consumption is realized for filter washing, resin regeneration and membrane cleaning processes. Water is also consumed in auxiliary units such as cooling towers and steam boilers.

The reference specific water consumption in the man-made fiber manufacturing sector is in the range of 5 - 53 L/kg. The specific water consumption of the production line analyzed in the study is in the range of 2.2 - 10.1 L/kg. With the implementation of good management practices, general measures and measures related to auxiliary processes, it is possible to achieve water savings of 10 - 56% in the sector.

20.60 Manufacture of Man-made or Synthetic Fibers Priority water efficiency implementation techniques recommended under the NACE code are presented in the table below.

NACE Code	NACE Code Description	Sectoral Prioritized Best Available Techniques
20.60	Manufacture of man-made or synthetic fibers	<b>Sector Specific Measures</b>
		1. Preference for dry solvents or reuse of aqueous solvents with closed loop systems
		2. Separate collection of wastewater from processes processing aromatic hydrocarbons from other wastewater to facilitate raw material and product recovery
		3. Use of mechanical pumps in closed-loop processes in the production of aromatic chemicals, reduction of blowdown and/or use of dry running pumps
		4. Separation of organic phases and aqueous phases to prevent undissolved organic matter from mixing with wastewater
		5. Recovery of hydrocarbons by stripping
		6. Optimal catalyst selection to increase resource efficiency
		7. Recovering and reusing organic solvents to improve resource efficiency
		8. Utilization of stripping wastewater as process water or boiler feed water using advanced treatment techniques
		9. Recycling organic material back into the process for recovery and water reuse
		10. Using aqueous type ring vacuum pumps
		11. Use of separate collection systems for potential wastewater
		<b>Good Management Practices</b>
		1. Use integrated wastewater management and treatment strategy to reduce wastewater quantity and pollutant load
		2. Establishment of an environmental management system
		3. Preparation of water flow diagrams and mass balances for water
		4. Preparing a water efficiency action plan to reduce water use and prevent water pollution
		5. Providing technical trainings to staff for the reduction and optimization of water use
		6. Good production planning to optimize water consumption
		7. Setting water efficiency targets
		8. Monitoring the quantity and quality of water used in production processes and auxiliary processes and the wastewater generated and adapting this information to the environmental management system
		<b>Measures in the nature of General Measures</b>
		1. Minimization of spills and leaks
		2. Recovery of water from rinsing solutions and reuse of recovered water in processes appropriate to its quality
		3. Use of automatic hardware and equipment (sensors, smart hand washing systems, etc.) to save water at water usage points such as showers/toilets etc.
		4. Use of pressure washing systems for equipment cleaning, general cleaning, etc.
		5. Avoiding the use of drinking water in production lines
		6. Identification and reduction of water losses
7. Use of automatic control-close valves to optimize water use		

NACE  
CodeNACE  
CodeSectoral Prioritized Best Available  
Techniques

20.60

Manufacture of man-made or

8. Production procedures are documented and used by employees to prevent water and energy waste
  9. Optimizing the frequency and duration of regeneration (including rinses) in water softening systems
  10. Construction of closed storage and impermeable waste/scrap sites to prevent the transportation of toxic or hazardous chemicals for the aquatic environment
  11. Prevention of mixing of clean water flows with polluted water flows
  - Characterization of wastewater quantities and qualities at all wastewater generation points
  12. determination of wastewater streams that can be reused with or without treatment
  13. Use of closed loop water cycles in appropriate processes
  14. Use of computer-aided control systems in production processes
  15. Separate collection and treatment of gray water in the facility and its use in areas that do not require high water quality (green area irrigation, floor washing, etc.)
  16. Implementing time optimization in production and organizing all processes to be completed as soon as possible
  17. Avoiding the need to rinse between activities by using compatible chemicals in sequential processes
  18. Reuse of nanofiltration (NF) or reverse osmosis (RO) concentrates with or without treatment depending on their characterization
- Precautions for Auxiliary Processes**
1. Saving water by reusing steam boiler condensate Saving water by insulating steam and water lines (hot and cold),
  2. Prevention of water and steam losses in pipes, valves and connection points in the lines and monitoring with computer system
  3. Avoiding unnecessary cooling processes by identifying processes that need wet cooling
  4. Reducing water consumption by increasing the number of cycles in closed loop cooling systems and improving the quality of make-up water
  5. Prevention of flash steam losses due to boiler unloading
  6. Use of air cooling systems instead of water cooling in cooling systems
  7. Installation of water softening systems for the healthy operation of cooling water recovery systems
  8. Cooling with local dry air in some periods of the year when the cooling need is low
  9. Reducing the amount of blowdown by using degassers in steam boilers
  10. Minimizing boiler drain water (blowdown) in steam boilers

A total of 47 techniques have been proposed in this sector.

Manufacture of Man-made or Synthetic Fibers NACE Code;

- (i) Sector Specific Measures,
- (ii) Good Management Practices,
- (iii) General Precautions and
- (iv) Measures for auxiliary processes are given under separate headings.

## 2.1.1 Sector Specific Measures

- ***Preference for dry solvents or reuse of aqueous solvents with closed loop systems***

It is possible to reduce the amount of aromatic compounds and wastewater generated in aromatic extraction units by using dry solvents. On the other hand, it is also possible to reduce the amount of aromatic compounds and wastewater in aromatic extraction units and the amount of aromatic compounds contained in the wastewater by reusing aqueous solvents using closed loop systems. Dry or wet solvents can be used for aromatic extraction. By using dry solvents, the amount of wastewater can be zero or a very low amount of wastewater is generated. If wet solvents are preferred, water can be recovered and reused by using a closed loop recovery system (IPPC BREF, 2017b).

- ***Separate collection of wastewater from processes processing aromatic hydrocarbons from other wastewater to facilitate raw material and product recovery***

Separate collection of aqueous effluents from aromatic plants from wastewater from other sources facilitates the recovery of raw materials and products. For existing facilities, applicability may be limited to site-specific drainage systems (IPPC BREF, 2017b).

- ***Use of mechanical pumps in closed-loop processes in the production of aromatic chemicals, reduction of blowdown and/or use of dry running pumps***

In the production of aromatic hydrocarbons, the use of mechanical pumping systems in closed-loop processes, keeping blowdown water low or using dry-running pumps can reduce the amount of wastewater and organic load (IPPC BREF, 2017b).

- ***Separation of organic phases and aqueous phases to prevent undissolved organic matter from mixing with wastewater***

Separation of organic phases and aqueous phases under appropriate design and proper operating conditions (adequate retention time, phase boundary detection and control) to prevent undissolved organic matter from entering the wastewater increases the recovery of hydrocarbons and enables the reuse of the quench water. Hydrocarbons recovered from the quench water from the primary separation stage can be recovered or used as feedstock in other chemical processes. In the recovery of organics, efficiency can be increased through the use of steam, gas stripping or re-boiling. The treated quench water is reused in the dilution steam production system. To prevent salt accumulation in the system, a quench water discharge stream can be provided downstream of the final wastewater treatment system (IPPC BREF, 2017b).

- ***Recovery of hydrocarbons by stripping***

With stripping, volatile compounds are removed from the aqueous phase by a gas phase (e.g. steam, nitrogen or air) passed through the liquid. The resulting concentrate is recovered for reuse (e.g. by condensation) or disposed of. Removal efficiency can also be improved by increasing temperature or reducing pressure (IPPC BREF, 2017b).

- ***Optimal catalyst selection to increase resource efficiency***

The selection of catalysts should consider the optimum balance between the following factors to increase resource efficiency and wastewater recovery potential:

- Catalyst activity
- Selectivity of the catalyst
- Catalyst lifetime
- Use of less toxic metals

The potential for wastewater recovery increases with the use of less toxic metals.

- ***Recovering and reusing organic solvents to improve resource efficiency***

In the production of all organic basic chemicals, organic solvents used in the processes are recovered using appropriate techniques such as distillation, liquid phase separation. When necessary for recovery, purification is carried out using distillation, adsorption, stripping or filtration processes and the organic solvent is returned to the process (IPPC BREF, 2017b).

- ***Utilization of stripping wastewater as process water or boiler feed water using advanced treatment techniques***

Stripping wastewater can be reused as process water or boiler feed water by advanced treatment techniques. In this way, the amount of wastewater and water consumption can be reduced (IPPC BREF, 2017b).

- ***Use of separate collection systems for potential wastewater***

As a measure of high general applicability in all polymer plants, it is recommended that separate waste collection systems be used for potentially contaminated water released from leaks and other sources, including cooling water and surface runoff from process plant areas (MoEU<sup>1</sup>DB, 2006).

- ***Recycling organic material back into the process for recovery and water reuse***

Water recovery can be achieved by recycling aqueous streams from aqueous-type ring vacuum pumps or steam injectors back into the process to recover organic material and reuse water (IPPC BREF, 2017b).

- ***Using aqueous type ring vacuum pumps***

The amount of wastewater can be reduced by using aqueous type ring vacuum pumps and circulating the sealing fluid of the pump. Wastewater generation can be reduced by recirculating the water used as the pump's sealing fluid back into the pump casing through a closed loop with small drains. The technique is used to prevent or reduce emissions of organic compounds from vacuum systems to air and water (IPPC BREF, 2017b).

## 2.1.1 Good Management Practices

### ***Establishment of an environmental management system***

Environmental Management Systems (EMS) include the organizational structure, responsibilities, procedures and resources necessary to develop, implement and monitor the environmental policies of industrial organizations. The establishment of an environmental management system improves the decision-making processes of organizations between raw materials, water and wastewater infrastructure, planned production process and different treatment techniques. Environmental management organizes how resource supply and waste discharge demands can be managed 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 Scheme Directive (EMAS) (761/2001). It was developed to assess, improve and report on the environmental performance of businesses. It is one of the leading practices within the scope of eco-efficiency (cleaner production) in EU legislation and voluntary participation is provided (TUBITAK MAM, 2016; TOB, 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, ensuring greater compliance with global legal and regulatory requirements (Christopher, 1998).
- While minimizing the risks of penalties associated with environmental responsibilities, the amount of waste, resource consumption and operating costs are reduced (Delmas, 2009).
- The use of internationally recognized 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 companies' internal control processes has also been emphasized by consumers. The implementation of environmental management systems provides a competitive advantage against companies that do not adopt the standard. It also contributes to the better position of organizations in international areas / markets (Potoski & Prakash, 2005).
- The above-mentioned benefits depend on many factors such as the production process, management practices, resource utilization and potential environmental impacts (TOB, 2021). Practices such as preparing annual inventory reports with similar content to an environmental management system and monitoring the quantity and quality of inputs and outputs in production processes can save 3-5% of water consumption (Öztürk, 2014). The total duration of the development and implementation phases of an EMS takes an estimated 8-12 months (ISO 14001 User Manual, 2015).
- Industrial organizations also carry out studies within the scope of ISO 14046 Water Footprint Standard, an international standard that defines the requirements and guidelines for assessing and reporting water footprint. The



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the use of fresh water required for production and environmental impacts. In addition, the I 46001 Water Efficiency Management Systems Standard, which helps industrial organizations save water and reduce operating costs, helps organizations develop water efficiency policies by conducting monitoring, benchmarking and review studies.

- ***Use integrated wastewater management and treatment strategy to reduce wastewater quantity and pollutant load***

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

On-site reuse of treated wastewater not only improves the quality of water bodies, but also reduces the demand for freshwater. It is therefore crucial to identify appropriate treatment strategies for different reuse objectives.

In integrated industrial wastewater treatment, different aspects such as wastewater collection system, treatment process and reuse target are considered together (Naghedi et al., 2020). For industrial wastewater recovery, methods such as SWOT method (strengths, weaknesses, opportunities and threats), PESTEL method (political, economic, social, technological, environmental and legal factors), decision tree can be combined with expert opinions to determine the integrated wastewater management framework (Naghedi et al., 2020). The integration of Analytic Hierarchy Process (AHP) and CoCoSo techniques can be used to set priorities for industrial wastewater management processes based on multiple criteria (Adar et al., 2021).

The implementation of integrated wastewater management strategies can reduce water consumption, wastewater quantity and pollution loads of wastewater by up to 25% on average. The potential payback period of implementation varies between 1-10 years (MoAF, 2021).



### **education and optimization of water use**

Industrial Water Use Efficiency Project According to NAEE Codes

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. In industrial facilities, problems related to high water use and wastewater generation may arise due to the lack of necessary technical knowledge of the personnel. 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. It is also necessary for the relevant personnel to have sufficient technical knowledge in applications such as determining water quality requirements in production processes, measuring water and wastewater quantities, etc. (TOB, 2021). Therefore, it is important to train staff on water use reduction, optimization and water saving policies. Practices such as involving staff in water conservation efforts, creating regular reports on water use before and after water efficiency initiatives, and sharing these reports with staff support participation and motivation in the process. The technical, economic and environmental benefits of staff training are realized in the medium to long term (TUBITAK MAM, 2016; TOB, 2021).

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- **Monitoring the water used in production processes and auxiliary processes and the wastewater generated in terms of quantity and quality and adapting this information to the environmental management system.**

inefficiency and environmental problems can arise from input-output flows. For this reason

The quantity and quality of water and wastewater used in production processes and auxiliary processes should be monitored (TUBITAK MAM, 2016; TOB, 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%, water consumption and wastewater quantities by

It can provide up to 25% reduction (Öztürk, 2014).

The main stages for monitoring water and wastewater in terms of quantity and quality are as follows:

- Use of monitoring equipment (such as meters) to monitor water, energy, etc. consumption on a process-by-process basis,
- Establish monitoring procedures,
- Identifying 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, comparative evaluation and reporting in terms of quantity and quality,
- Monitoring raw material losses in production processes where raw materials are transformed into products and taking measures against raw material losses (MoEU, 2020e).

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In industrial production processes, planning by using the least amount of process from raw material to product is an effective practice to reduce labor costs, resource utilization costs and environmental impacts and to ensure efficiency (TUBITAK MAM, 2016; TOB, 2021). Production planning in industrial plants, taking into account the water efficiency factor, reduces water consumption and wastewater amount. Modifying production processes or combining some processes in industrial plants provides significant benefits in terms of water efficiency and time planning (TOB, 2021).

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• ***Preparing 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 short, medium and long term actions to be taken in order to reduce water-wastewater quantities and prevent water pollution in industrial facilities. At this point, determination of water needs throughout the facility and in production processes, determination of quality requirements at water use points, wastewater generation points and wastewater characterization should be carried out (TOB, 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 their feasibility and to prepare action plans for the short-medium-long term. In this way, water efficiency and sustainable water use in facilities are ensured (MoAF, 2021).

• ***Determination of water efficiency targets***

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

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

Determining the points of water use and wastewater generation in industrial plants, establishing water-wastewater balances in production processes and auxiliary processes other than production processes constitute the basis of many good management practices in general. Establishing process profiles on a plant-wide and production process basis facilitates the identification of unnecessary water use points and high water use points, evaluation of water recovery opportunities, process modifications and determination of water losses (TOB, 2021).

## Measures in the nature of General Measures

### • **Identification and reduction of water losses**

Water losses occur in equipment, pumps and pipelines in industrial production processes. First of all, water losses should be identified and equipment, pumps and pipelines should be regularly maintained and kept in good condition to prevent leaks (IPPC BREF, 2003). Regular maintenance procedures should be established, paying particular attention to

- Adding pumps, valves, level switches, pressure and flow regulators to the maintenance checklist,
- Inspections not only of the water system, but also, in particular, of heat transfer and chemical distribution systems, broken and leaking pipes, drums, pumps and valves,
- Regular cleaning of filters and pipelines,
- Calibrate, routinely check and monitor measurement equipment such as chemical measuring and dispensing devices, 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).

### • **Minimizing spills and leaks**

Both raw material and water losses can occur due to spills and leaks in enterprises. In addition, if wet cleaning methods are used to clean the areas where spills occur, water consumption, wastewater amounts and pollution loads of wastewater may also increase (TOB, 2021). In order to reduce raw material and product losses, spill and splash losses are reduced by using splash guards, flaps, drip trays, screens (IPPC BREF, 2019).

### • **Prevention of mixing of clean water flows with polluted water flows**

By identifying wastewater generation points in industrial facilities and characterizing wastewater, wastewater with high pollution load and relatively clean wastewater can be collected in separate lines (TUBITAK MAM, 2016; TOB, 2021). In this way, wastewater streams with appropriate quality can be reused with or without treatment. By separating wastewater streams, water pollution is reduced, treatment performances are improved, energy consumption can be reduced in relation to the reduction of treatment needs, and emissions are reduced by recovering wastewater and recovering valuable materials. It is also possible to recover heat from separated hot wastewater streams (TUBITAK MAM, 2016; TOB, 2021). Separation of wastewater streams usually requires high investment costs, which can be reduced where it is possible to recover large amounts of wastewater and energy (IPPC BREF, 2006).

- ***Determination of wastewater flows that can be reused with or without treatment by characterizing wastewater quantities and qualities at all wastewater generation points***

By identifying and characterizing wastewater generation points in industrial facilities, it is possible to reuse various wastewater streams with or without treatment (Öztürk, 2014; TUBİTAK MAM, 2016; TOB, 2021). In this context, filter backwash waters, TO concentrates, blowdown waters, condensate waters, relatively clean washing and rinsing waters can be reused without treatment in the same/different processes and in areas that do not require high water quality (such as facility and equipment cleaning). In addition, wastewater streams that cannot be directly reused can be reused in production processes after treatment 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 generally used for pre-treatment of water before it goes to NF or TO (Singh et al., 2014).

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

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

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

In different sub-sectors of the manufacturing industry, waters with different water quality can be used for production purposes. In industrial plants, raw water from groundwater sources is generally used in production processes after treatment. However, in some cases, although it is costly, drinking water can be used directly in production processes or raw water is disinfected with chlorinated compounds and then used in production processes. These waters containing residual chlorine can react with organic compounds (natural organic matter (DOM)) in water in production processes and form disinfectant by-products harmful to living metabolisms (Özdemir & Toröz, 2010; Oğur et al.) The use of drinking water containing residual chlorine compounds or raw water disinfected with chlorinated compounds should be avoided as much as possible. Highly oxidizing disinfection methods such as ultraviolet (UV), ultrasound (US) or ozone can be used instead of chlorine disinfection for disinfection of raw water. In order to increase the technical, economic and environmental benefits of the application, it helps to reduce unnecessary water supply and treatment costs by determining and using the water quality parameters required in each production process. With this application, it is possible to reduce water, energy and chemical costs (TUBİTAK MAM, 2016).

- ***Use of automatic hardware and equipment (sensors, smart hand washing systems, etc.) to 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 maintain the necessary hygiene standards. Water consumption in the production processes of industrial facilities can be achieved in various ways, and water consumption can be saved by using equipment such as sensor faucets and smart hand washing systems in the water usage areas of personnel. Smart hand washing systems provide resource efficiency in addition to water savings while adjusting the water, soap and air mixture at the right ratio.

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

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

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

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

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

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

- **Reuse of nanofiltration (NF) or reverse osmosis (RO) concentrates with or without treatment depending on their characterization**

Based on the wastewater characterization and appropriate point of use, the potential for reuse of other wastewater from membrane processes (backwashing without or with chemicals, CIP cleaning, module cleaning, cleaning of chemical tanks, etc.) should be assessed.

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

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

- **Use of automatic control-close valves to optimize water use**

Monitoring and controlling water consumption using flow control devices, meters and computer-aided monitoring systems provides significant technical, environmental and economic advantages (Öztürk, 2014). Monitoring the amount of water consumed in the plant and in various processes prevents water losses (TUBITAK MAM, 2016). It is necessary to use flow meters and meters in the plant in general and in production processes in particular, to use automatic shut-off valves and valves in continuously operating machines, and to develop monitoring-control mechanisms according to water consumption and some determined quality parameters by using computer-aided systems (TUBITAK MAM, 2016). With this practice, it is possible to save up to 20-30% of 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 in process water consumption can be achieved (Öztürk, 2014).



<https://genesiswatertech.com/wp-content/uploads/2019/08/RO-waste-water-recycling-1.jpg>

Reverse Osmosis System

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

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

Water is used as a refrigerant in many processes in the manufacturing industry, led by product cooling. During this cooling process, water can be reused through cooling towers 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 is reduced. However, the need for energy for cooling and recirculation of cooling water is a side interaction.

Heat recovery is also provided by the use of heat exchangers in cooling water. Generally, closed loop systems are used in plants using water cooling systems. However, cooling system blowdowns are discharged directly to the wastewater treatment plant channel. This blowdown water can be reused in appropriate production processes.

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

Closed and impermeable waste/scrap storage sites can be constructed in industrial facilities to prevent the transportation of toxic or hazardous chemicals for the aquatic environment to receiving environments. This practice is already being implemented in our country within the scope of existing environmental regulations. Within the scope of the field studies carried out, a separate collection channel can be built in the storage areas of toxic or hazardous substances in industrial facilities to collect the leachate separately and prevent it from mixing into natural water environments.

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

Rinsing wastewater in industrial plants is relatively clean wastewater that can be reused without treatment in floor washing and garden irrigation processes that do not require high water quality (Öztürk, 2014). Raw water consumption can be reduced with the recovery of rinse water.

Savings between 1-5% can be achieved.

- ***Implementing time optimization in production and organizing all processes to be completed as soon as possible***

In industrial production processes, planning the process from raw material to product by using the minimum number of processes is an effective practice to reduce labor costs, resource utilization costs and environmental impacts and to ensure efficiency. In this context, it may be necessary to revise the production processes so that the minimum number of process steps is used (TUBITAK MAM, 2016). In cases where the desired product quality cannot be achieved due to some inadequacies, inefficiencies and design errors in basic production processes, production processes may need to be renewed. Therefore, in this case, the resource utilization and the amount of waste, emissions and solid waste generated in the production of a unit amount of product increases. Time optimization in production processes is an effective practice (TUBITAK MAM, 2016).



- ***Avoiding the need to rinse between activities by using compatible chemicals in sequential processes***

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

Various chemicals are used in industrial plants to increase washing and rinsing efficiency. The fact that these chemicals are compatible and act as solvents shows a positive trend in increasing the efficiency. Therefore, the 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 reusing the washing water containing solvents used in washing rinsing processes.

Water savings of 25-50% are possible by reusing wash water. The application may require reserve tanks and new pipelines. Alternatively, the wash solution can be kept directly in the system and used repeatedly until it loses its properties.

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

Since inefficient resource utilization and environmental problems in industrial facilities are directly linked to input-output flows, it is necessary to define the process inputs and outputs in the best way for production processes (TUBITAK MAM, 2016). Thus, it becomes possible to develop measures to improve resource efficiency, economic and environmental performance. The organization of 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). On the basis of the implementation processes, the use of measurement equipment and some routine analyzes/measurements specific to the processes are required. Utilizing computerized monitoring systems as much as possible in order to maximize the efficiency of the application increases the technical, economic and environmental benefits (TUBITAK MAM, 2016).



Computer Aided Control System

- ***Production procedures are documented and used by employees to prevent water and energy waste***

In order to ensure efficient production in an enterprise, effective procedures should be implemented to identify and evaluate potential problems and resources and to control 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 ensures reliability and quality in production processes (Ayan, 2010). The existence of documented production procedures in production processes contributes to the development of the ability to evaluate business performance and develop immediate reflexes to solve problems (TUBITAK MAM, 2016; TOB, 2021). Effective implementation and monitoring of procedures created specifically for production processes is one of the most effective ways to ensure product quality, receive feedback and develop solutions (Ayan, 2010). Documenting, effectively implementing and monitoring production procedures is a good management practice and an effective tool in structuring and ensuring the continuity of the cleaner production approach and environmental management system. In addition to the potential benefits, the cost and economic gains of the application may vary from sector to sector or depending on the facility structure (TUBITAK MAM, 2016; TOB, 2021). Although establishing and monitoring production procedures is not costly, the payback period may be short considering the savings and benefits (TUBITAK MAM, 2016; TOB, 2021).



Industrial Steam Boilers

## 2.1.3 Precautions for Auxiliary Processes

Water Efficiency Guidance Document

### **BATs for steam generation**

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

Steam losses may occur if steam lines are not properly designed, routine maintenance and repairs of steam lines are not carried out, mechanical problems occurring in the lines and the lines are not operated properly, steam lines and hot surfaces are not fully insulated. This situation affects both water consumption and energy consumption of the plant. Control systems with automatic control mechanisms should be used in order to ensure steam isolation and continuous monitoring of steam consumption. Depending on 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 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 will also be reduced. Full steam isolation application and automatic control mechanisms to minimize steam losses are used in many plants with high steam consumption. With the configuration of the application, fuel savings of 2-4% are achieved in steam boilers.

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

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

When steam indirect heating techniques are used to transfer thermal energy in production processes, recovery of condensed steam (condensate) is an effective practice to reduce water consumption (IPPC BREF, 2009). Condensate recovery can reduce water consumption by 5% on average (Greer et al., 2013). Moreover, the potential payback period varies between 4-18 months (considering energy savings) (Öztürk, 2014; TUBITAK MAM, 2016).

#### **• *Prevention of flash steam losses due to boiler unloading***

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

#### **• *Minimization of boiler discharge water (blowdown) in steam boilers***

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

In automatic systems, blowdowns in the boilers are continuously monitored and the system is re-analyzed 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 blowdown frequency is reduced, the amount of wastewater decreases. Energy and cooling water used for cooling this wastewater is saved (IPPC BREF, 2009). By optimizing the steam boiler blowdown process, operating costs are reduced by saving on boiler water consumption, waste costs, treatment and heating.

#### **• *Reducing the amount of blowdown by using degassers in steam boilers***

Free oxygen dissolved in the feed water of steam boilers and hot water boilers and carbon dioxide formed by the breakdown of carbonates in boilers can cause corrosion in the form of pores, rusting and melting in steam boilers, steam appliances and especially in installations. The effects of these gases increase as the fresh feed water ratio and system operating pressure increase. 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 a degasser. Degasser systems are mechanical systems that allow dissolved gases to evaporate from the water by supplying air to the water with a fan. Dissolved gas removal can be increased by increasing the water and air contact surface in the degasser system. In this way, corrosion formation is reduced and boiler efficiency is increased (TUBITAK MAM, 2016; TOB, 2021).

## ***BATs for cooling systems***

- ***Reducing water consumption by increasing the number of cycles in closed loop cooling systems and improving the quality of make-up water***

Water is used as a refrigerant in many processes such as production processes of the manufacturing industry and cooling of products. The water is recirculated through cooling tower or central cooling systems and cooling process is carried out. If an unwanted microbial growth occurs in the cooling water, it can be controlled by adding chemicals to the recirculated water (TUBITAK MAM, 2016). The number of cycles can be increased with good chemical conditioning in the recirculation process. In this way, the amount of fresh water fed to the system can be reduced and water savings can be achieved. In addition, good conditioning of the cooling make-up water can also increase the number of cycles (TOB, 2021).

- ***Cooling with local dry air in some periods of the year when the cooling need is low***

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

- ***Use of air cooling systems instead of water cooling in cooling systems***

Industrial cooling systems are used to cool heated products, processes and equipment. For this purpose, closed and open circuit cooling systems can be used, as well as industrial cooling systems using a fluid (gas or liquid) or dry air (IPPC BREF, 2001b; TOB, 2021). Air cooling systems consist of finned pipe elements, condenser and air fans (IPPC BREF, 2001b; TOB, 2021). Air cooling systems can have different operating principles. In industrial air cooling systems, the heated water is cooled by air in closed circuit cooling condensers and heat exchangers (IPPC BREF, 2001b; TOB, 2021). In water cooling systems, the heated water is taken into a cooling tower and the water is cooled in trickling systems. However, although water-cooled systems operate in closed circuit, a significant amount of evaporation occurs. In addition, since some water is discharged as blowdown in cooling systems, water is also lost in this way (IPPC BREF, 2001b; TOB, 2021). The use of air cooling systems instead of water in cooling systems is effective in reducing evaporation losses and also in reducing the risk of contamination of cooling water (IPPC BREF, 2001b; TOB, 2021).

- ***Avoiding unnecessary cooling processes by identifying processes that need wet cooling***

The boundaries of the plant site affect design parameters such as cooling tower height. In cases where the tower height has to be reduced, a hybrid cooling system can be applied. Hybrid cooling systems are a combination of evaporative and non-evaporative (wet and dry) cooling systems. Depending on the ambient temperature, the hybrid cooling tower can be operated as a fully wet cooling tower or as a combined wet/dry cooling tower (TUBITAK MAM, 2016). In regions where there is not enough cooling water or where water costs are high, the evaluation of dry cooling systems or hybrid cooling systems can be an effective solution to reduce the amount of cooling makeup water (TUBITAK MAM, 2016).

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

Cooling water is collected separately and used for cooling purposes or recycled in appropriate processes (EC, 2009). A water softening system is required for this system to work properly. Cooling water has suitable water quality for reuse as cleaning and irrigation water. However, since it contains some hardness in its use as cooling water, additional softening is required to prevent corrosion problems that will occur over time. These waters should be subjected to an appropriate disinfection process before being reused as cooling water or in the process. In addition, these waters can be treated with appropriate treatment techniques (membrane filtration, advanced oxidation, chemical precipitation, granular activated carbon adsorption, etc. processes) and reused not only in cooling processes but also in all production processes (TUBITAK MAM, 2016). As the hardness of the cooling water increases, limestone and deposit formation occurs on the walls. The formation of deposits negatively affects heat transfer, reducing energy efficiency and increasing energy costs. With the increase in evaporation in the system, the ion concentration and conductivity value in the water increases. In order to prevent these negativities, chemical treatment of the cooling water to prevent scale and corrosion, disinfection with a biocide that prevents biological activation, chemical and mechanical cleaning of cooling towers at least twice a year and cleaning of deposits, hardness and conductivity values should be kept as low as possible (TUBITAK MAM, 2016).



Synthetic Fiber

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