T.R.
MINISTRY OF AGRICULTURE AND FORESTRY
GENERAL DIRECTORATE OF WATER MANAGEMENT

Water Efficiency Campaign

# Water Efficiency Guidance Documents Series

# GLASS FIBER MANUFACTURING

**NACE CODE: 23.14**

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# Abbreviations

| | |
|---|---|
| WWTP | Wastewater Treatment Plant |
| EU | European Union |
| SSM | Suspended Solid Matter |
| BREF | Best Available Techniques Reference Document |
| EMS | Environmental Management System |
| MOEUU | Republic of Turkey Ministry of Environment, Urbanization and Climate Change |
| NOM | Natural Organic Matter |
| EMAS | Eco-Management and Audit Program Directive |
| EPA | United States Environmental Protection Agency |
| IPPC | Industrial Pollution Prevention and Control |
| ISO | International Organization for Standardization |
| BAT | Best Available Techniques |
| NACE | Statistical Classification of Economic Activities |
| GDWM | General Directorate of Water Management |
| RO | Reverse Osmosis |
| TOB | Republic of Turkey Ministry of Agriculture and Forestry |
| TUIK | 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 m³, 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 country suffering from water scarcity 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.

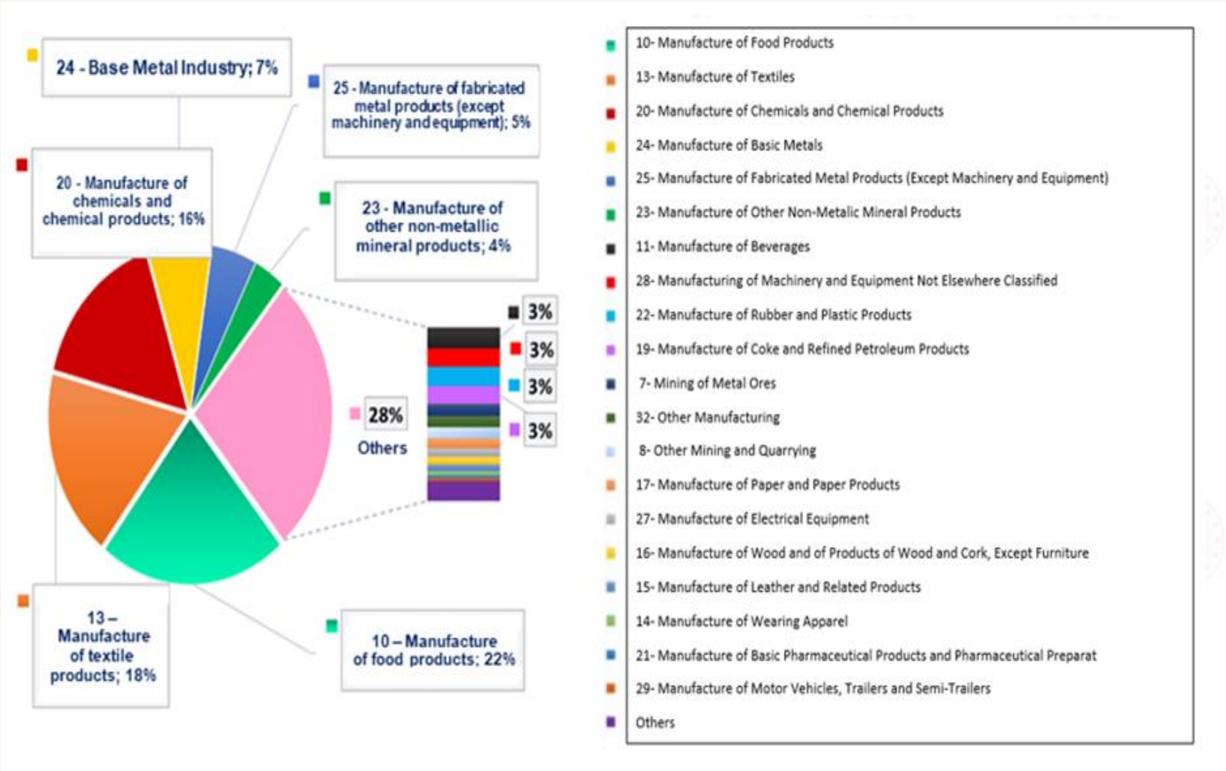
Within the scope of the European Green Deal, where member countries have agreed on goals such as implementing a clean, circular economy model with a carbon neutral target, expanding the efficient use of resources and reducing environmental impacts, actions emphasizing water and resource efficiency in 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 to improve 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, especially 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 uses in industry in Türkiye

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 assess 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 (excluding 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)
- Sporting activities, leisure and recreation activities (including sub-production area represented by 1 four-digit NACE Code)

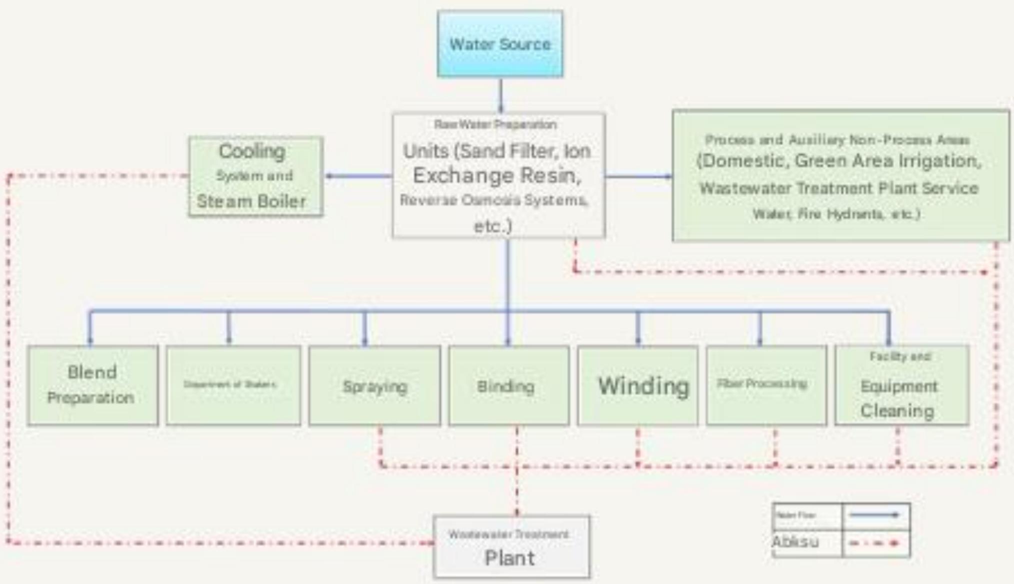
## Manufacture of other non-metallic mineral products

Under the Manufacture of other non-metallic mineral products sector, the sub-production branches for which guidance documents were prepared are as follows

| | |
|---|---|
| 23.11 | Flat glass manufacturing |
| 23.13 | Pit glass manufacturing |
| 23.14 | Glass fiber production |
| 23.20 | Manufacture of refractory products |
| 23.31 | Manufacture of ceramic tiles and paving stones |
| 23.41 | Manufacture of ceramic household and ornaments |
| 23.42 | Manufacture of ceramic sanitary products |
| 23.52 | Lime and plaster production |
| 23.61 | Manufacture of concrete products for construction purposes |
| 23.62 | Manufacture of gypsum products for construction purposes |
| 23.64 | Powder mortar production |
| 23.99 | Manufacture of other non-metallic mineral products not elsewhere classified |

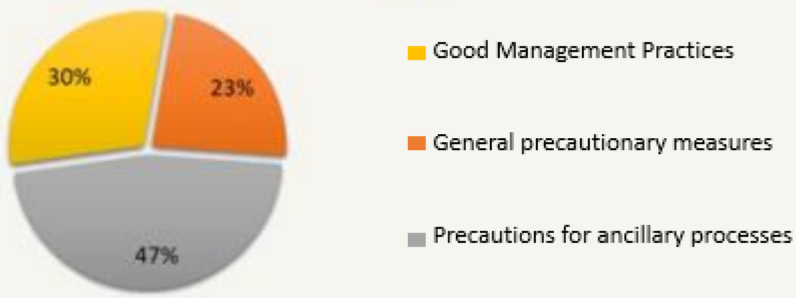
# 2.1 Glass Fiber Manufacturing (NACE 23.14)

Glass Fiber Manufacturing Industry Water Flow Diagram




| | Minimum | Maximum |
|---|---|---|
| Specific Water Consumption of Facilities Visited within the Scope of the Project (L/kg product) | 4.86 | |
| Reference Specific Water Consumption (L/kg product) | 4 | 15 |

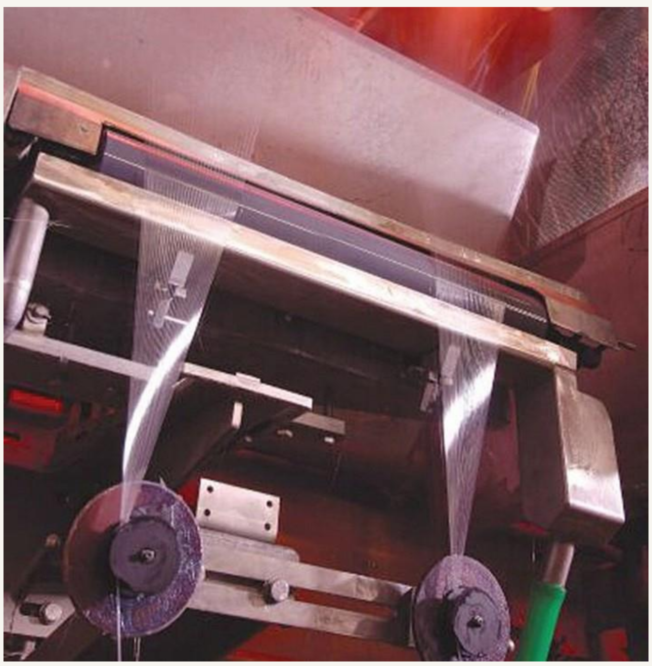
Percentage Distribution of Water Efficiency Practices



Glass fiber is basically produced by hardening the melted glass by passing it through a sieve with many holes. The raw materials, which are weighed in quantities appropriate to the glass composition, are sent to the mixer unit to obtain a homogeneous blend with the conveyor belt system and blended. Ready glass cullet is added to this blend and sent to the furnace for melting. The molten glass is sent to the shaking chamber through channels, passed through sieves and flowed into micro-sized fibers. A binder is applied to the glass fiber cooled with water and wound into bobbins to increase the durability of the fiber. Fiber is processed with various binders according to the desired end product.

In glass fiber manufacturing, water is used in spraying, felt binding and winding 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 filter, ion exchange resin, reverse osmosis, which are used to produce soft water for use in production processes in the sector. Water consumption also occurs in auxiliary processes such as cooling towers and steam boilers.

The reference specific water consumption in the glass fiber manufacturing sector is in the range of 4 - 15 L/kg. The specific water consumption of the production line analyzed within the scope of the study is 4.86 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 41 - 56% in the sector.



Glass Fiber Production - Fiber Drawing and Winding Process

https://l24.im/bnR

Chopped Glass Fiber

https://l24.im/GBNZcf1

23.14 Priority water efficiency implementation techniques recommended within the scope of Glass Fiber Manufacturing NACE code are presented in the table below.

| NACE Code | NACE Code Description | | Prioritized Sectoral Water Efficiency Techniques |
|---|---|---|---|
| 23.14 | Glass fiber production | | **Good Management Practices** |
| | | 1. | Establishment of an environmental management system |
| | | 2. | Preparation of water flow diagrams and mass balances for water |
| | | 3. | Preparing a water efficiency action plan to reduce water use and prevent water pollution |
| | | 4. | Providing technical trainings to staff for the reduction and optimization of water use |
| | | 5. | Good production planning to optimize water consumption |
| | | 6. | Setting water efficiency targets |
| | | 7. | 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 |
| | | | **Measures in the nature of General Measures** |
| | | 1. | Recovery of water from rinsing solutions and reuse of recovered water in processes appropriate to its quality |
| | | 2. | Use of automatic hardware and equipment (sensors, smart hand washing systems, etc.) to save water at water usage points such as showers/toilets etc. |
| | | 3. | Use of pressure washing systems for equipment cleaning, general cleaning, etc. |
| | | 4. | Identification and reduction of water losses |
| | | 5. | Use of automatic control-close valves to optimize water use |
| | | 6. | Production procedures are documented and used by employees to prevent water and energy waste |
| | | 7. | Construction of closed storage and impermeable waste/scrap sites to prevent the transportation of toxic or hazardous chemicals for the aquatic environment |
| | | 8. | Storage and storage of substances that pose a risk to the aquatic environment (such as oils, emulsions, binders) and prevention of their mixing with wastewater after use |
| | | 9. | Where technically feasible, treating appropriate wastewater and using it as steam boiler feed water |
| | | 10. | Prevention of mixing of clean water flows with polluted water flows |
| | | 11. | Determination of wastewater flows that can be reused with or without treatment by characterizing wastewater quantities and qualities at all wastewater generation points |
| | | 12. | Use of closed loop water cycles in appropriate processes |
| | | 13. | Use of computer-aided control systems in production processes |
| | | 14. | Determining the scope of reuse of washing and rinsing water |

| NACE Code | NACE Code Descriptio | | Prioritized Sectoral Water Efficiency Techniques |
|---|---|---|---|
| 23.14 | Glass fiber | 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. | Collecting rainwater and utilizing it as an alternative water source for facility cleaning or in suitable areas |
| | | | **Precautions for Auxiliary Processes** |
| | | 1. | Saving water by reusing steam boiler condensate |
| | | 2. | Saving water by insulating 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 computer system |
| | | 3. | Old equipment in the ventilation system based on the principle of reverse osmosis replacement with ion exchange resins (systems producing demineralized water) and water reuse |
| | | 4. | Avoiding unnecessary cooling processes by identifying processes that need wet cooling |
| | | 5. | Reducing water consumption by increasing the number of cycles in closed loop cooling systems and improving the quality of make-up water |
| | | 6. | Increasing the number of cycles by using corrosion and scale inhibitors in systems with closed water cycles |
| | | 7. | Installation of water softening systems for the healthy operation of cooling water recovery systems |
| | | 8. | Use of closed loop cooling system to reduce water usage |
| | | 9. | Reducing the amount of blowdown by using degassers in steam boilers |

A total of 32 techniques have been proposed in this sector.

For Glass Fiber Manufacturing NACE Code;

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

# 2.1.1 Good Management Practices

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

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 implementation of the relevant standard aims to reduce the use of fresh water required for production and environmental impacts. In addition, the ISO 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.

- ***Providing technical trainings to staff 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. 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 saving 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).

- ***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 water and wastewater used in production processes and auxiliary processes should be monitored in terms of quantity and quality (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, 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).

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

  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 facilities, taking into account the water efficiency factor, reduces water consumption and wastewater amount. Industrial modification of production processes in plants or combining some processes water efficiency and time planning (MoAF, 2021).

- ***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, measures to be implemented to reduce water consumption, wastewater generation and pollution loads should be determined, feasibility should be made and action plans should be prepared for the short-medium-long term. In this way, water efficiency and sustainable water use in facilities are ensured (MoAF, 2021).

- ***Setting 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***

  Determination of water use and wastewater generation points in industrial plants, production processes and auxiliary processes other than production processes, water-wastewater balances is the basis for many good governance 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 identification of water losses (TOB, 2021).

# 2.1.2 General Water Efficiency BATs

- ***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,
  - Also, 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).

- ***Where technically feasible, treating appropriate wastewater and using it as steam boiler feed water***

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

- ***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.

- ***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 through wastewater recovery and recovery of valuable materials. It is also possible to recover heat from separated hot wastewater streams (TUBITAK MAM, 2016; TOB, 2021). Separation of wastewater streams generally 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).

- ***Determining the scope of reuse of washing and rinsing water***

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

- ***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 (TUBITAK 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.

- ***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 unnecessary water losses (TUBITAK MAM, 2016). It is necessary to use flow meters and meters for the plant in general and for production processes in particular, to use automatic shut-off valves and valves in continuously operating machines, and to develop monitoring and 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).

- ***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.

- ***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).

- ***Collecting rainwater and utilizing it as an alternative water source for facility cleaning or in suitable areas***

Nowadays, when 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, ground infiltration, surface collection and filter systems are used. Rainwater collected with 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 (Tanık et al., 2015).

In various examples, roof rainwater collected in industrial facilities was stored and then used inside the building and in landscape areas, resulting in 50% water savings in landscape irrigation (Yaman, 2009). Perforated stones and green areas can be preferred to increase the permeability of the ground and allow rainwater to pass through and be absorbed into the soil on site (Yaman, 2009). Rainwater collected on building roofs can be used for car washing and garden irrigation. It is possible to recover and reuse 95% of the collected water after use through biological treatment (Şahin, 2010).

- ***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.

- ***Preventing substances that pose a risk to the aquatic environment (such as oils, emulsions, binders) from being mixed into wastewater as much as possible after storage, storage and use***

In industrial facilities, substances that pose a risk to the aquatic environment such as oils, emulsions and binders dry cleaning techniques to prevent the mixing of chemicals into wastewater streams water recovery is ensured by using water and preventing leakages (TUBITAK MAM, 2016).

- ***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.

- ***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).

Computer Aided Control System

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# 2.1.3 Precautions for Auxiliary Processes

***BATs for steam generation***

- ***Ensuring water saving by insulation of 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*** Failure to design steam lines properly in the facilities, routine maintenance and maintenance of steam lines

repairs, mechanical problems occurring on the lines, and inadequate maintenance of the lines. If steam lines and hot surfaces are not fully insulated and not operated properly, steam losses may occur. This situation affects both water consumption and energy consumption of the plant. Analyzers and control systems with automatic control mechanisms should be used in order to insulate the areas with steam insulation deficiencies and to continuously monitor 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, regeneration water amounts, salt amounts used in regeneration and reverse osmosis concentrates can also be reduced. Full steam isolation and automatic control mechanisms to minimize steam losses are used in many plants with high steam consumption. By configuring the application, fuel savings of 2-4% can be 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).

Industrial Steam Boilers

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- ***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). In addition, the potential payback period varies between 4-18 months (considering energy savings) (Öztürk, 2014; TUBİTAK MAM, 2016).

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

Carbon dioxide gases formed by the breakdown of carbonates in the boilers with free oxygen dissolved in the feed water of steam boilers and hot water boiler booster water 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 the boiler feed water is not purified from these dissolved gases, the useful life of these systems is shortened, corrosion and various deformations may occur. In addition, carbon dioxide causes excessive corrosion in 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. Deaerator systems are mechanical systems that provide the evaporation of dissolved gases 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. The unit cost of a vacuum degasser with a capacity of approximately 2,000 L/hour varies between 2,200-10,000 USD (TUBITAK MAM, 2016; TOB, 2021).

***BATs for cooling systems***

- ***Use of closed loop cooling system to reduce water usage***

Some water evaporates during the cooling of heated water in cooling systems. Therefore, cooling water is added as much as the amount of evaporated water in closed cycle cooling systems. Evaporation losses can be prevented by optimizing cooling systems. In addition, the amount of blowdown can be reduced with applications such as treatment of make-up water added to cooling systems and prevention of biological growth in cooling systems. Within the scope of the field studies carried out, the blowdown water generated in the cooling system is not reused and is disposed of directly into the wastewater channel. With the reuse of cooling system blowdown water, water consumption in cooling systems can be reduced.

Savings of up to 50% can be achieved. The initial investment costs required for this application may consist of the installation of new pipelines and reserve tanks. In this case, it can be predicted that the required initial investment cost will vary between 5,000-20,000 TL (TOB, 2021).

- ***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 will also decrease and savings in water consumption can be achieved. In addition, the number of cycles can be increased with good conditioning of the cooling make-up water (TOB, 2021).

- ***Increasing the number of cycles by using corrosion and scale inhibitors in systems with closed water cycles***

  Cooling towers and evaporative condensers are efficient and low-cost systems that remove heat from air conditioning and industrial process cooling systems (IPPC BREF, 2001b; TOB, 2021). In these systems, more than 95% of the circulating water can be recovered (TUBITAK MAM, 2016). In cooling systems, impurities remain in the recirculated water due to the evaporation of a portion of the recirculated water, and impurity concentrations gradually increase with each cycle. Impurities that can enter the cooling system together with air can cause contamination in recirculation water (TUBITAK MAM, 2016). If impurities and contaminants are not effectively controlled, they can cause scaling and corrosion, unwanted biological growth and sludge accumulation. This can become a chronic problem leading to reduced efficiency of heat transfer surfaces and increased operating costs. In this case, it may be necessary to implement a water treatment program specifically designed for the quality of the feed water supplied to the cooling system, the cooling water system construction material and the operating conditions. This may include blowdown control, control of biological growth, corrosion control, avoidance of hard water, use of sludge control chemicals, filtration and screening systems (TUBITAK MAM, 2016). Establishing and periodically implementing an effective cleaning procedure and program is also a good management practice for the protection of cooling systems. Corrosion is one of the most important problems in cooling systems. The main factors that can cause corrosion and scale formation in the system are closely related to the feed water quality. As the pH value of the water used in the cooling tower decreases ($pH<7$), the amount of corrosion increases in metal parts and as the pH increases ($pH>9$), the amount of corrosion increases in copper parts. In the tower recirculation water, as the degree of hardness increases, limestone and deposit formation can occur on the walls. In this case, dissolved solids that cause corrosion such as sulfate, chloride, carbonate will cause corrosion of metals over time. In addition, the formation of deposits affects heat transfer, reduces energy efficiency and increases energy costs. With the increase in evaporation in the system, the ion concentration and conductivity value in the water increases (TUBITAK MAM, 2016). The increase in conductivity increases in parallel with the total salinity and accelerates corrosion formation (Kayabek et al., 2005).

In order to prevent these problems, a chemical treatment program to prevent scale and corrosion, disinfection with a biocide that prevents biological activation, chemical and mechanical cleaning of the cooling towers in use at least twice a year and removal of sediments, hardness and conductivity values of the make-up water should be as low as possible (IPPC BREF, 2001; Kayabek et al., 2005). Treatment (conditioning) using an appropriate treatment system may be necessary to improve the quality of the makeup water. It is also necessary to control undesirable microbial growth (IPPC BREF, 2001b; TOB, 2021). Blowdown occurs in cooling systems as well as in steam boilers due to micro-residues and deposits in cooling water. In addition, biocides are used to prevent unwanted microbial growth in cooling systems (TUBITAK MAM, 2016). For many reasons, it is more attractive to use open circulation systems. Regardless of the cooling system, water circulation or climate, biological activity does not continue under limited nutrient conditions. Therefore, all treatment processes should aim to reduce biological growth by removing undissolved nutrients from the cooling water cycle. The dead volume of the cooling water system (or the volume in the loop) is important for an effective treatment process. It is a fact that the dead volume is filtered and then continuously chlorinated at small levels. This can be done by installing a continuous sand filter on the side stream which breaks down the undissolved food and at the same time filters out transient micro-organisms and other undissolved nutrients. Thus, less chlorine is required and more concentration cycles are possible. This technique can be enhanced by creating an active biology within the sand filter with a high concentration of micro-organisms, called side-stream biofiltration. To maintain the active biology, sand filters are eliminated at high biocide (chlorine) concentrations in the cooling water cycle, because the high concentration breaks down the biology in the sand filter and reduces its effectiveness. As soon as the effect of the chlorine in the cooling water is reduced, passage through the sand filter is allowed again. In practice, the cooling water only needs to be passed through once or twice a day. The reduction is based on an optimal combination of flow, biocide use and side-stream filtration. For the cooling system to function properly, the cooling water must be treated against equipment corrosion, micro- and macro-fouling. The deliberate draining of the cooling system to compensate for the increased concentration of solids in the cooling system is called cooling blowdown. Pre-treatment of cooling water with appropriate methods and continuous monitoring of cooling water quality can reduce the use of biocides and the amount of blowdown. It can be applied to existing cooling systems by compatible upgrading of the filter capacity (TUBITAK MAM, 2016). Investment cost depends on the scale of the application. Chlorination operating costs can be reduced by around 85%. The expected payback period on investment costs is between 3 and 4 years (IPPC BREF, 2001).

- ***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).

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

  If cooling water is collected separately, it is often possible to use the collected water for cooling purposes or to reuse it in appropriate processes (EC, 2009). A water softening system is needed 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 will give better results in order to prevent corrosion problems that will occur over time. Before being reused as cooling water or in the process, these waters should be subjected to an appropriate disinfection 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 deposits form 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 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 sediment removal, hardness and conductivity values as low as possible level (TUBITAK MAM, 2016).

***BATs for ventilation and air conditioning systems***

- ***Replacement of old equipment in the aeration system with ion exchange resins based on the principle of reverse osmosis (systems producing demineralized water) and water reuse***

  When ion exchange resins are used in the aeration system, the conductivity of the final effluent reaches a conductivity level suitable to be used for equipment cleaning. A plant in Spain has replaced the equipment in its aeration system with ion exchange resins to obtain effluent with a conductivity of around 1000 μS, which is reused in the system (MedClean, n.d.).

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