



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



## Water Efficiency Guide Documents Series

# ACTIVITIES TO SUPPORT OIL AND NATURAL GAS EXTRACTION

NACE CODE: 09.10

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## Abbreviations

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

# 1 Introduction

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

For 2022, the annual amount of usable water per capita in our country is 1,313 m<sup>3</sup>, and it is expected that the annual amount of usable water per capita will fall below 1,000 cubic meters after 2030 due to human pressures and the effects of climate change. It is obvious that if the necessary measures are not taken, Turkey will become a country suffering from water scarcity in the very near future and will bring many negative social and economic consequences. As can be understood from the results of future projections, the risk of drought and water scarcity awaiting our country necessitates the efficient and sustainable use of our existing water resources.

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

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

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

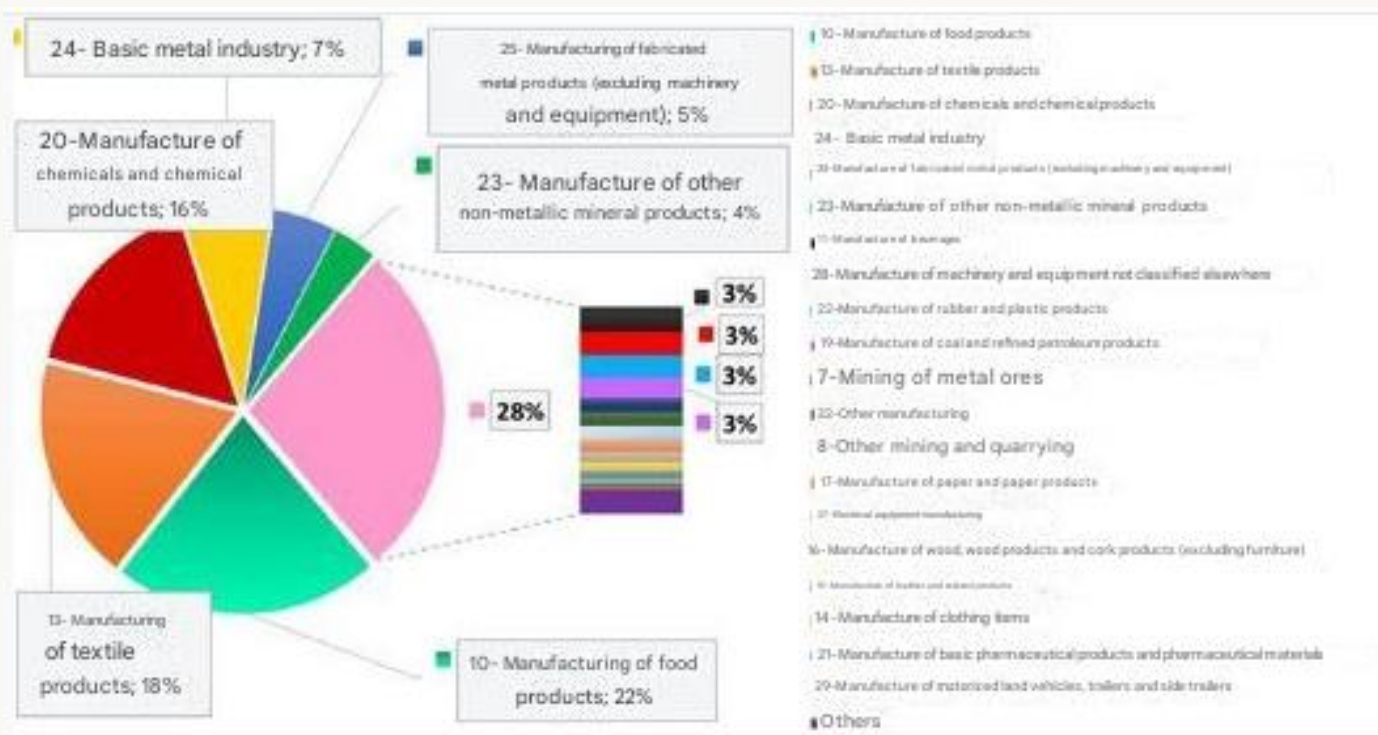
In the European Green Deal Action Plan prepared by our country within the scope of the European Green Deal, where member countries agree on goals such as implementing a clean, circular economy model with the goal of carbon neutrality, expanding the efficient use of resources and reducing environmental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

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

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

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

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



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

As a result of the studies, specific water consumption and potential savings rates for the processes of the enterprises were determined for 152 different 4-digit NACE codes with high water consumption, and water efficiency guidance documents were prepared by taking into account the EU best available techniques (MET) and other cleaner production techniques. The guidelines include 500 techniques for water efficiency (MET);

It has been examined under 4 main groups: (i) Good Management Practices, (ii) General Water Efficiency BATs, (iii) Measures Related to Auxiliary Processes and (iv) Sector-Specific Measures.

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

## 2 Scope of the Study

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

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



- Accommodation (including 1 sub-production area represented by a four-digit NACE Code)
- Educational Activities (Higher Education Campuses) (including 1 sub-production area represented by a four-digit NACE Code)
- Sports, entertainment and recreational activities (including 1 sub-production area represented by a four-digit NACE Code )

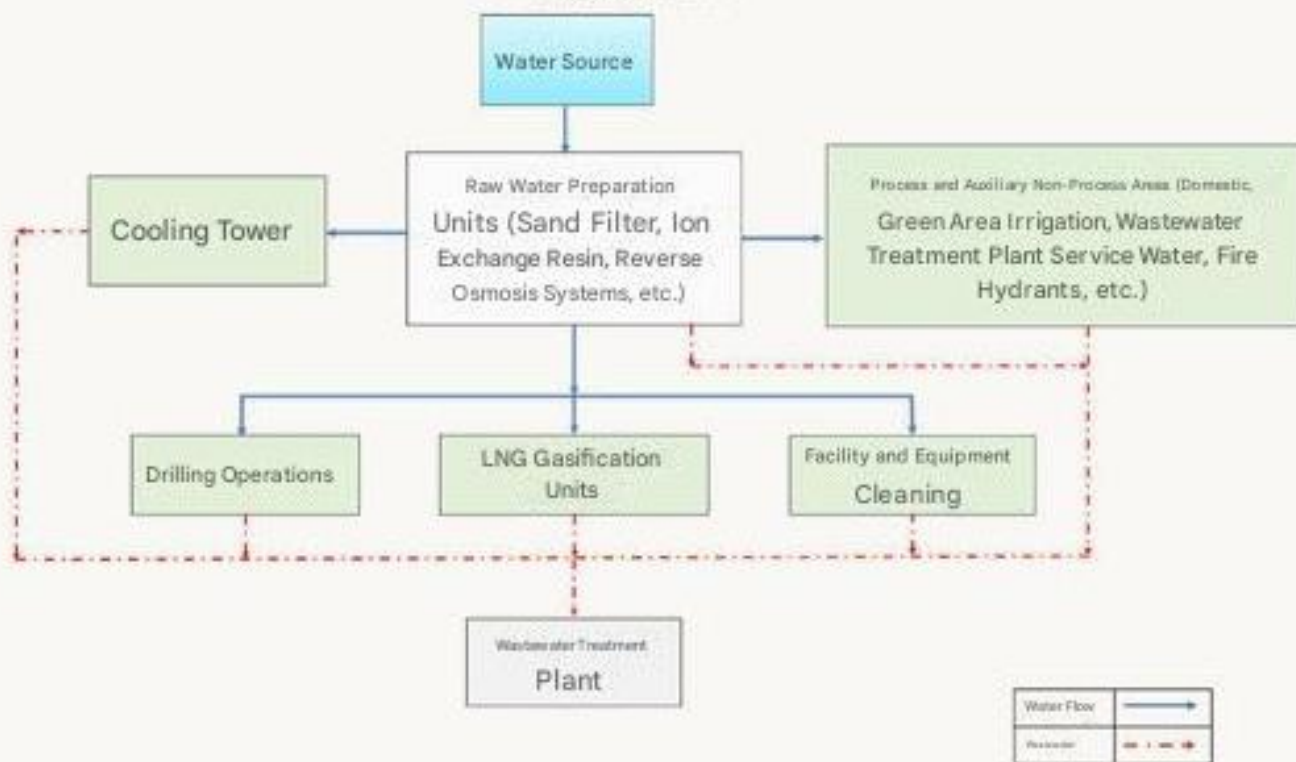
## Service activities to support mining

Under the sector of service activities supporting mining, the sub-production branches for which guide documents have been prepared are as follows:

### 09.10 Activities to support oil and natural gas extraction

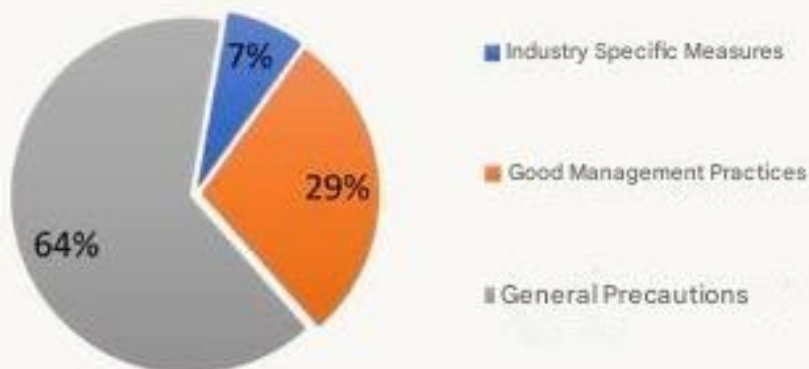
## 2.1 Activities to Support Oil and Natural Gas Extraction (NACE 09.10)

Oil and Natural Gas Extraction Supporting Activities Sector Water Flow Chart



	Minimum	Maximum
Specific Water Consumption of Facilities Visited within the Scope of the Project (L/Sm <sup>3</sup> product)	0.03	
Reference Specific Water Consumption	There is no reference specific water consumption value.	

Percentage Distribution of Water Efficiency Practices



Natural gas is brought to the surface by drilling to the determined reserve point. Processes such as hydraulic fracturing, horizontal drilling, and acidification expand the amount of gas available to the natural gas well, thereby increasing its productivity. After extraction, natural gas is cooled and converted into liquefied natural gas (LNG). Thus, it is easily stored and transported in places where there is no pipeline. LNG is transported by specially insulated tankers.

Various drilling operations are also applied in oil extraction. If the oil is to be extracted from the sea or ocean floor, an oil platform is installed on the water. In onshore oil extraction, drilling is carried out with steel tower-like structures. The drill at the end of the drilling rig reaches the reserve by drilling into the ground. When the reserve is reached, the drill is removed from the well and the inside of the wells is covered with concrete. Mechanical systems called horseheads are used in oil extraction on land.

In the oil processing sector, high amounts of water are consumed. However, no significant water consumption occurs in activities that support the exploration, extraction or extraction of oil. Only drilling activities consume water. Within the scope of the study, LNG gasification and storage activity was analyzed.

There is the use of water in activities supporting oil and natural gas extraction, drilling services and LNG gasification units. If there are raw water preparation units such as activated carbon filter, ion exchange resin, reverse osmosis used to produce soft water for use in production processes, significant water consumption is also realized for filter washing, resin regeneration and membrane cleaning processes. In addition, there is water consumption in auxiliary units such as cooling towers.

There is no reference specific water consumption value in the activities supporting oil and natural gas extraction sector. The specific water consumption of the production branch analyzed within the scope of the study is 0.03 L/Sm<sup>3</sup>. With the implementation of sector-specific measures, good management practices and general measures, it is possible to achieve 9-19% water recovery in the sector.



Oil Extraction System

09.10 Activities to Support Oil and Natural Gas Extraction  
The priority water efficiency implementation techniques recommended under the NACE code are presented in the table below.

NACE Code	NACE Code Description	Industry-First Available Best Techniques
09.10	Activities to support oil and natural gas extraction	<p><b>Industry-Specific Measures</b></p> <p>Continuous monitoring of surface and/or groundwater resource quality, and</p> <ol style="list-style-type: none"> <li>1. Exploitation of potential water resources, such as rainwater harvesting, in operations that do not require high water quality</li> </ol> <p><b>Good Management Practices</b></p> <ol style="list-style-type: none"> <li>1. Using an integrated wastewater management and treatment strategy to reduce the amount of wastewater and the pollutant load</li> <li>2. Establishment of an environmental management system</li> <li>3. Setting water efficiency targets</li> </ol> <p>The water used in production processes and auxiliary processes and the formed</p> <ol style="list-style-type: none"> <li>4. Monitoring wastewater in terms of quantity and quality and adapting this information to the environmental management system</li> </ol> <p><b>General Water Efficiency BATs</b></p> <p>It will save water at water usage points such as showers/toilets, etc.</p> <ol style="list-style-type: none"> <li>1. Use of automated hardware and equipment (sensors, smart handwashing systems, etc.)</li> <li>2. Avoiding the use of drinking water in production lines</li> <li>3. Use of automatic check-off valves to optimise water use</li> <li>4. Documentation of production procedures and use by employees to prevent waste of water and energy</li> <li>5. Optimising the frequency and duration of regeneration (including rinses) in water softening systems</li> <li>6. Transport of toxic or hazardous chemicals for the aquatic environment</li> <li>7. Construction of closed storage and impermeable waste/scrap yard to prevent</li> <li>8. Prevention of mixing of clean water streams with dirty water streams</li> <li>9. Use of closed-loop water cycles in appropriate processes Use of computer-aided control systems in production processes</li> <li>10. Separate collection and treatment of grey water in the plant and high water quality</li> <li>11. To be used in areas that do not require (green area irrigation, floor, floor washing, etc.)</li> <li>12. Collecting rainwater and evaluating it as an alternative water source in facility cleaning or in appropriate areas</li> </ol>

A total of 16 techniques have been proposed in this sector.

Activities Supporting Oil and Natural Gas Extraction Towards NACE Code;

- (i) Sector-Specific Measures,
- (ii) Good Management Practices,
- (iii) General Measures are given under separate headings.

## 2.1.1 Industry-Specific Measures

- ***Continuous monitoring of surface and/or groundwater resource quality and utilization of potential water resources such as rainwater harvesting in operations where high water quality is not required***

The roads are wetted by using water to settle the dust formed on the roads during the transportation of the products. The use of water for dusting prevention is 1% of the total water consumption of the activity.

It can range from 15%.

The water used for dust suppression does not have to be of high quality. In this process, water can be saved by using water from rainwater harvesting (COCHILCO, 2008).



## 2.1.2 Good Management Practices

- **Establishment of an environmental management system**

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

The most widely used Environmental Management Standard is ISO 14001. Alternatives include the Eco Management and Audit Programme Directive (EMAS) (761/2001). It has been developed for the evaluation, improvement and reporting of the environmental performance of enterprises. It is one of the leading practices within the scope of eco-efficiency (cleaner production) in EU legislation and participation is provided voluntarily (TUBITAK MAM, 2016; 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, resulting in greater compliance with global legal and regulatory requirements (Christopher, 1998).
- While the penalty risks related to environmental responsibilities are minimized, the amount of waste, resource consumption and operating costs are reduced (Delmas, 2009).
- The use of internationally accepted environmental standards eliminates the need for multiple registrations and certifications for businesses operating in different locations around the world (Hutchens Jr., 2017).
- Especially in recent years, the improvement of the internal control processes of companies is also important to consumers. The implementation of environmental management systems provides a competitive advantage over companies that do not adopt the standard. It also contributes to the better position of institutions in international areas/markets (Potoski & Prakash, 2005).

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

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

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• ***t strategy to reduce the amount of wastewater and the pollutant load***

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

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

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

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



Industrial Wastewater Treatment Plant

- ***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***

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

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

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

- ***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. Thus, unnecessary water use, water losses, wrong practices affecting water efficiency, process losses, reusable water-wastewater resources with or without treatment can be determined. It is also extremely important to set water saving potential and water efficiency targets for each production process and the plant as a whole (TOB, 2021).

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## 2.1.3 General Water Efficiency BATs

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

In regeneration processes, washing, regeneration and rinsing wastewater are usually removed directly. However, if the washing and final rinsing water is of raw water quality, it can be sent to the raw water tank or reused in processes that do not require high water quality, such as facility cleaning and green area irrigation (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 frequency recommended by the supplier or depending on the flow rate and time entering the softening system, this frequency also varies depending on the calcium concentration in the raw water. For this reason, online hardness measurement is applied when determining the frequency of regeneration. Thus, regeneration frequencies can be optimized, as well as excessive washing, rinsing or backwashing with salt water can be prevented by using online hardness sensors.



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

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

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

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

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

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

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



Computer Aided Control System

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

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

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