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MINISTRY OF AGRICULTURE AND FORESTRY
GENERAL DIRECTORATE OF WATER MANAGEMENT

Water Efficiency
Campaign

Water Efficiency Guidance Document

IRON ORE MINING

NACE CODE: 07.10

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Abbreviations

WTP	Wastewater Treatment Plant
EU	European Union
SS	Suspended Solids
BREF	Best Available Techniques Reference Document
EMS	Environmental Management System
MoEUB	Republic of Turkey Ministry of Environment, Urbanization and Climate Change
NOM	Natural Organic Matter
EMAPD	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
SYGM	General Directorate of Water Management
TOB	Reverse Osmosis
MoFA	Ministry of Agriculture and Forestry of the Republic of Turkey
TUIK	Turkish Statistical Institute
NF	Nanofiltration
MF	Microfiltration
UF	Ultrafiltration
GW	Groundwater
SW	Surface Water

1 Introduction

Türkiye 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 the year 2022, the annual amount of usable water per capita in our country is 1,313 m^3, 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, Türkiye 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, and the increase in population, urbanization and pollution, it is becoming more and more important to share available 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; within the scope of the goals of *"Goal 7: Ensuring Environmental Sustainability"* from the Millennium Development Goals, *"Goal 9: Industry, Innovation and Infrastructure"* and *"Goal 12: Responsible Production and Consumption"* from the Sustainable Development Goals, issues such as efficient, fair and sustainable use of resources, especially water, environment-friendly production and consumption that carries concerns for future generations are included.

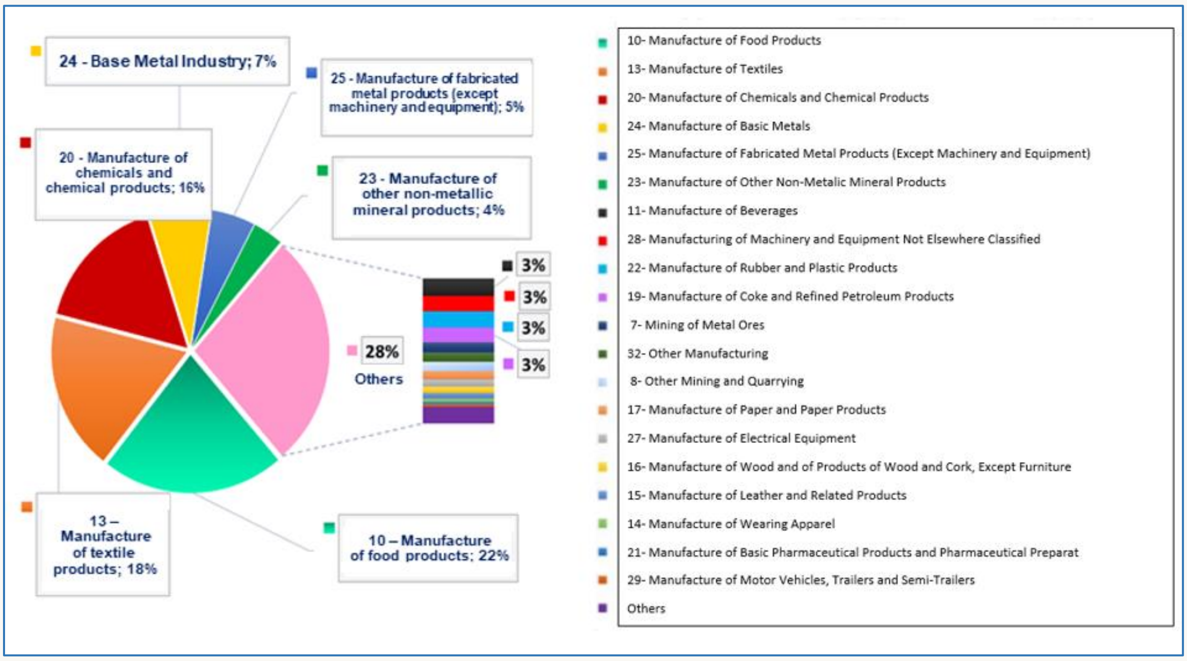
In the European Green Deal Action Plan prepared by Türkiye within the scope of the European Green Deal, where member countries agree on goals such as implementing a clean, circular economy model with the goal of carbon neutrality, expanding the efficient use of resources and reducing environmental impacts,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

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

The Ministry of Agriculture and Forestry, General Directorate of Water Management carries out studies aimed at disseminating efficient practices in urban, agricultural, industrial, and individual water use and increasing social awareness. "Water Efficiency Strategy Document and Action Plan within the Framework of Adaptation to the Changing Climate (2023-2033)" entered into force with the Presidential Circular No:2023/9 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 Türkiye 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 Türkiye, have been prepared.

As in the world, the sectors with the highest share in water consumption in Turkey are the food, textile, chemical, and basic metal sectors. Within the scope of the studies, field visits were carried out in businesses representing 152 sub-sectors in 35 main sectors, primarily food, textile, chemical, and basic metal industries, which represent different capacities and a variety of production areas within the scope of NACE Codes operating in Türkiye and with high water consumption and data on water supply, sectoral water usage, wastewater generation, and recycling were obtained. In addition, information was provided on the best available techniques, sectoral reference documents published by the European Union, water efficiency, clean production, water footprint, etc.



Distribution of water use in industry on a sectoral basis in Türkiye

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

In the determination processes of BATs for each sector within the scope of the project carried out; environmental benefits, operational data, technical specifications-requirements, and applicability criteria were taken into consideration. In determining BATs, it was not limited to BREF documents only, different data sources such as current literature data on a global scale, real case studies, innovative applications, and reports of sector representatives were examined in detail and sectoral MET lists were created. In order to evaluate the suitability of the created MET lists to the local industrial infrastructure and capacity of our country, MET lists prepared specifically for each NACE code were prioritized by businesses by scoring them based on water saving, economic saving, environmental benefit, applicability, cross-media impact criteria, and the final MET lists were determined using the scoring results. By considering the BAT list which was determined by considering the water and wastewater data of the facilities visited within the scope of the project, taking into account the local dynamics specific to Türkiye, and brought to the fore by sectoral stakeholders, sectoral water efficiency guidelines were created based on NACE codes.

2 Scope of the Study

The guide documents prepared within the scope of water efficiency measures in 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 sub-production area represented by 1 four-digit NACE Code)
- Coal and lignite extraction (including sub-production areas represented by 2 four-digit NACE Codes)
- Mining support service activities (including sub-production area represented by 1 four-digit NACE Code)
- Mining of metal ores (including sub-production areas represented by 2 four-digit NACE Codes)
- Other mining and quarrying (including sub-production areas represented by 2 four-digit NACE Codes)
- Manufacturing of food products (including sub-production areas represented by 22 four-digit NACE Codes)
- Manufacturing of beverages (including sub-production areas represented by 4 four-digit NACE Codes)
- Tobacco products manufacturing (including sub-production area represented by 1 four-digit NACE Code)
- Manufacturing of textile products (including sub-production areas represented by 9 four-digit NACE Codes)
- Manufacturing of clothing (including the sub-production area represented by 1 four-digit NACE Code)
- Manufacturing of leather and related products (including sub-production areas represented by 3 four-digit NACE Codes)
- Manufacturing of wood, wood products and cork products (excluding furniture); manufacturing of articles made of reeds, straw and similar materials (including the sub-production area represented by 5 four-digit NACE Codes)
- Manufacturing of paper and paper products (including sub-production areas represented by 3 four-digit NACE Codes)
- Manufacturing of coke and refined petroleum products (including the sub-production area represented by 1 four-digit NACE Code)
- Manufacturing of chemicals and chemical products (including sub-manufacturing areas represented by 13 four-digit NACE Codes)
- Manufacturing of basic pharmaceutical products and pharmaceutical supplies (including sub-production area represented by 1 four-digit NACE Code)
- Manufacturing of rubber and plastic products (including sub-production areas represented by 6 four-digit NACE Codes)
- Manufacturing of other non-metallic mineral products (including sub-production areas represented by 12 four-digit NACE Codes)
- Main metal industry (including sub-production areas represented by 11 four-digit NACE Codes)
- Manufacturing of fabricated metal products (excluding machinery and equipment) (including sub-production areas represented by 12 four-digit NACE Codes)

- Manufacturing of computers, electronic and optical products (including sub-manufacturing areas represented by 2 four-digit NACE Codes)
- Electrical equipment manufacturing (including sub-production areas represented by 7 four-digit NACE Codes)
- Machinery and equipment manufacturing not classified elsewhere (including sub-production areas represented by 8 four-digit NACE Codes)
- Manufacturing of motor vehicles, trailers and semi-trailers (including sub-production areas represented by 3 four-digit NACE Codes)
- Manufacturing of other transportation vehicles (including the sub-production area represented by 2 four-digit NACE Codes)
- Other manufacturing (including sub-production areas represented by 2 four-digit NACE Codes)
- Installation and repair of machinery and equipment (including sub-production area represented by 2 four-digit NACE Codes)
- Electricity, gas, steam and ventilation system production and distribution (including sub-production areas represented by 2 four-digit NACE Codes)
- Waste collection, treatment and disposal activities; recovery of materials (including sub-production area represented by 1 four-digit NACE Code)
- Construction of off-premise/non-building structures (including sub-production area represented by 1 four-digit NACE Code)
- Storage and support activities for transportation (including sub-production area represented by 1 four-digit NACE Code)
- Accommodation (including sub-production area represented by 1 four-digit NACE Code)
- Educational Activities (Higher Education Campuses) (Including sub-production area represented by 1 four-digit NACE Code)
- Sports activities, entertainment and recreational activities (including the sub-production area represented by 1 four-digit NACE Code)

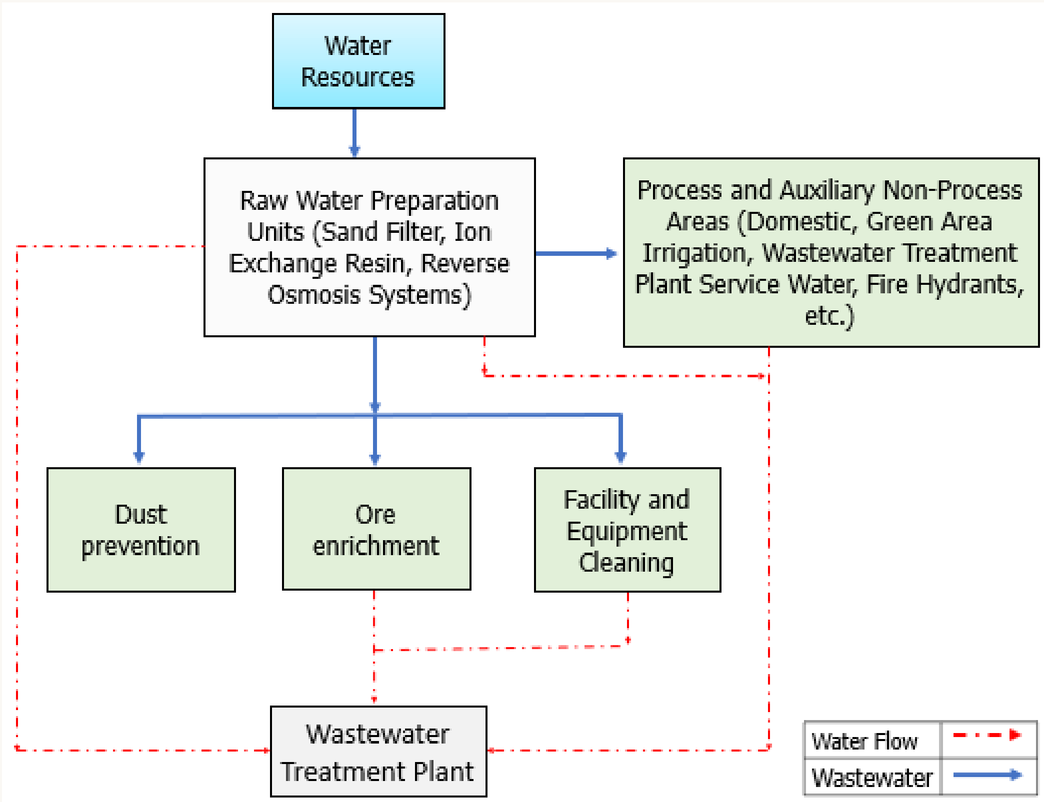
Mining of metal ores

Under the metal ore mining sector, the sub-production branches for which guidance documents have been prepared are as follows:

07.10	Iron ore mining
07.29	Mining of other non-ferrous metal ores

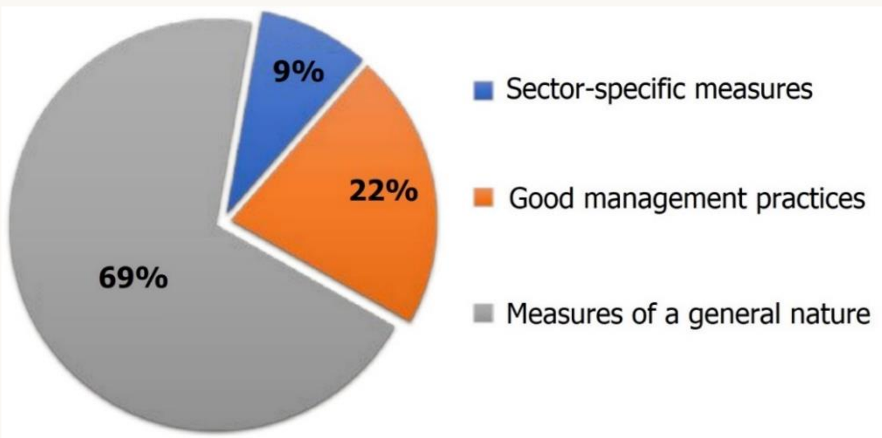
2.1 Iron Ore Mining (NACE 07.10)

Iron Ore Mining Industry Water Flow Diagram



	Minimum	Maximum
Specific Water Consumption of Facilities Visited within the Scope of the Project (L/kg product)	0,57	
Reference Specific Water Consumption (L/kg product)	0,1	0,9

Percentage Distribution of Water Efficiency Practices



Mining activities can be carried out by open mining or underground mining with closed gallery systems. Mineral preparation or ore enrichment process separates the minerals with economic value from the parts that do not have economic value. In ore enrichment; ADR (adsorption desorption, regeneration), crushing, grinding, screening, separation, drying, roasting, fragmentation, agglomeration (briquetting, sintering, sieving) processes are carried out.

In the iron ore mining sector, water is used in the ore enrichment process. Significant amounts of water are also consumed for the active carbon filter, ion exchange resin, raw water preparation units such as reverse osmosis and filter washing, resin regeneration, and membrane cleaning processes used to produce soft water for use in production processes in the sector. Water is also used to prevent dust in transportation and similar processes.

In mining facilities with tailings dams, water and material recovery is provided. Wastewater originating from mining sites is stored in tailings storage facilities (WSD) or in other words tailings dams as a watery mixture consisting of liquid, solid, or fine particles. In tailings dams, the upper clear phase is recirculated and reused in necessary areas of the facility (e.g. ore washing). The amount of water recovered in mining facilities is much higher than the water drawn from fresh water sources such as wells etc.

The reference specific water consumption in iron ore mining is between 0.1 and 9 L/kg. The specific water consumption of the production analyzed within the scope of the study is 0.57 L/kg. With the implementation of sector-specific measures, good management practices, and General Water Efficiency BATs, it is possible to achieve 6-9% water recovery in the sector.

Use of Water for Dust Prevention at the Mine Site

07.10 Iron Ore Mining: The priority water efficiency application techniques recommended under the 07.10 Iron Ores Mining NACE code are presented in the table below.

NACE Code	NACE Code Explanation	Industry-Prioritized Best Available Techniques
7.10	Mining of iron ores	**Industry-Specific Measures**
		1. Accumulation of flood and rainwater by building reservoirs
		2. Covering the dam bottom with sealed materials in tailings dams and the construction of a drainage system that recovers seeps from tailings dams
		Good Management Practices
		1. Using an integrated wastewater management and treatment strategy to reduce the amount of wastewater and the pollutant load
		2. Preparation of water flow charts and mass balances for water
		3. Providing technical training to personnel for reducing and optimizing water use
		4. Good production planning to optimize water consumption
		5. 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.
		General Water Efficiency BATs
		1. Minimizing spills and leaks
		2. Recovering water from rinse solutions and reusing the recovered water in processes appropriate to its quality
		3. Use of automatic equipment and tools (sensors, smart hand washing systems, etc.) that will save water at water usage points such as showers/toilets etc.
		4. Avoiding the use of drinking water in production lines
		5. Use of cooling water as process water in other processes
		6. Detection and reduction of water losses
		7. Use of automatic control-shutoff valves to optimize water usage
		8. Establishing closed storage and impermeable waste/scrap areas to prevent the transport of toxic or hazardous chemicals to the aquatic environment
		9. Preventing substances that pose a risk to the aquatic environment (such as oils, emulsions, binders) from being stored, accumulated, and mixed with wastewater after use.
		10. Preventing clean water streams from mixing with dirty water streams
		11. Determination of wastewater streams that can be reused with or without treatment by characterizing the quantities and qualities of wastewater at all wastewater generation points.

NACE Code	NACE Code Explanation	Industry-Prioritized Best Available Techniques
		12. Use of closed loop water cycles in suitable processes
		13. Use of computer-aided control systems in production processes
		14. Reuse of relatively clean wastewater resulting from washing, rinsing and equipment cleaning in production processes without treatment.
		15. Determining the scope and framework of reuse of washing and rinsing waters
		16. Grey water is collected and purified separately in the facility and used in areas that do not require high water quality (green area irrigation, ground washing, etc.)
		17. Implementation of time optimization in production and organization of all processes to be completed in the shortest time possible
		18. Collecting rainwater and using it as an alternative water source for facility cleaning or in suitable areas.
A total of 25 techniques have been proposed in this sector.		

Iron Ores Mining

NACE Code-Oriented;

(i) Sector-Specific Measures,
(ii) Good Management Practices,
(iii) General Measures

are given under separate headings.

2.1.1 Industry-Specific Measures

- ***Covering the dam bottom with impermeable materials in tailings dams and establishing a drainage system that allows the recovery of leakages from tailings dams***

  The establishment of drainage systems enables the recovery of water from tailings dams. Recovered water can be reused in processes (COCHILCO, 2008).

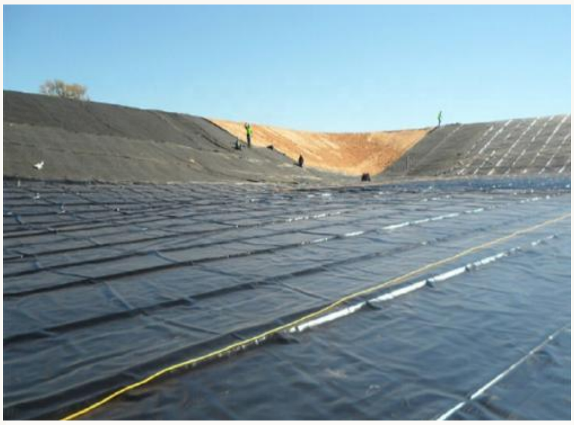
- ***Building reservoirs to collect flood and rainwater***

  One of the applications aimed at increasing the existing water resources is the construction of reservoirs to collect flood and rainwater. Thus, possible water resources originating from rain and floods can be utilized (COCHILCO, 2008).

https://gridarendal-website-live.s3.amazonaws.com/production/activities/:s_picture/461/medium/fortknoxdam.jpg?1574321215

https://ballaratgoldmine.com.au/wp-content/uploads/tailings-dam.jpg

Tailings Dams at Mine Sites



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Mine Waste Dam Construction Geo-membrane Application

2.1.2 Good Management Practices

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

Wastewater management should be based on a holistic approach from wastewater generation to final disposal and includes functional elements such as composition, collection, treatment including sludge disposal, and reuse. The selection of 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 in the facility not only improves the quality of water bodies but also reduces the demand for freshwater. Therefore, it is very important to determine appropriate treatment strategies for different reuse targets.

Within the framework of 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, methods such as the SWOT method (strengths, weaknesses, opportunities, and threats), PESTEL method (political, economic, social, technological, environmental, and legal factors), and decision tree can be combined with expert opinions to determine the integrated wastewater management framework (Naghedi et al., 2020). Integration of Analytical Hierarchy Process (AHP) and Combined Consensus Solution (CoCoSo) techniques can be used to determine priorities based on multiple criteria for industrial wastewater management processes (Adar et al., 2021).

By implementing integrated wastewater management strategies, an average reduction of up to 25% in water consumption, wastewater amount and wastewater pollution loads can be achieved. The potential payback period of the application varies between 1-10 years (TOB, 2021).


http://www.asw-eg.com/en/images/products/116567Water-Sewage-Treatment-System-With-Plant-And-Facility.jpg

Industrial Wastewater Treatment Plant

- ***Providing technical training to personnel for the reduction and optimization of water usage***

  With this measure, water saving and water recovery can be achieved by increasing the training and awareness of personnel, and water efficiency can be achieved by reducing water consumption and costs.

  Problems related to high amounts of water use and wastewater generation can occur due to the lack of necessary technical knowledge in industrial facilities. For example, it is important for cooling tower operators, who represent a significant proportion of water consumption in industrial operations, to be properly trained and have technical knowledge. The relevant personnel must also 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 provide training to personnel on water use reduction, optimization, and water-saving policies. Practices such as including personnel in water-saving studies, creating regular reports on water usage amounts before and after water efficiency initiatives, and sharing these reports with personnel support participation and motivation in the process. Technical, economic, and environmental benefits to be obtained with personnel training yield results in the medium or long term (TUBİTAK MAM, 2016; TOB, 2021).

- ***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***

  There are resource uses in industrial facilities, and inefficiency and environmental problems resulting from resource use can arise from input-output flows. For this reason, the amount and quality of water and wastewater used in production processes and auxiliary processes must be monitored (TUBITAK MAM, 2016; TOB, 2021). Process-based quantity and quality monitoring, together with other good management practices (personnel training, the establishment of an environmental management system, etc.), can provide a reduction of 6-10% in energy consumption and up to 25% in water consumption and wastewater amounts (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 basis.

  - Establishing monitoring procedures
  - Determining the usage/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 quantity and quality
  - Monitoring raw material losses in production processes where raw materials are transformed into products and taking precautions against raw material losses (MoEUB, 2020e).

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

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

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

  Determining water usage and wastewater generation points in industrial facilities, creating water-wastewater balances in production processes and auxiliary processes outside of production processes generally form the basis of many good management practices. Creating process profiles throughout the facility and on the basis of production processes; facilitates the determination of unnecessary water usage points and high water usage points, the evaluation of water recovery opportunities, process modifications, and the determination of water losses (TOB, 2021).

2.1.3 General Water Efficiency BATs

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

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

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

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

- ***Minimizing spills and leaks***

  Spills and leaks in businesses can cause both raw material and water losses. In addition, if wet cleaning methods are used to clean spilled areas, water consumption, wastewater amounts and pollution loads of wastewater may increase (TOB, 2021). In order to reduce raw material and product losses, spillage and splash losses are reduced by using splash guards, wings, drip trays, and sieves (IPPC BREF, 2019).

- ***Reuse of relatively clean wastewater resulting from washing, rinsing and equipment cleaning in production processes without treatment.***

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

- ***Determining the scope and framework of reuse of washing and rinsing waters***

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

- ***Preventing clean water streams from mixing with dirty water streams***

  By determining the wastewater formation points in industrial facilities and characterizing the 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 increased, energy consumption can be reduced in relation to the reduction of treatment needs, and emissions are reduced by ensuring wastewater recovery and valuable materials recovery. In addition, heat recovery from separated hot wastewater streams is also possible (TUBITAK MAM, 2016; TOB, 2021). Separation of wastewater streams generally requires high investment costs, and costs can be reduced in cases where it is possible to recover high amounts of wastewater and energy (IPPC BREF, 2006).

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

  By determining and characterizing wastewater formation points in industrial facilities, it is possible to reuse various wastewater streams with or without treatment (Öztürk, 2014; TUBİTAK MAM, 2016; TOB, 2021). In this context, filter backwash waters, RO concentrates, blowdown waters, condensate waters, and 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). Apart from this, it is possible to reuse wastewater streams that cannot be directly reused in production processes after being treated using appropriate treatment technologies.

  Membrane filtration processes are an integral part of many wastewater reuse systems. Nanofiltration (NF) and Reverse Osmosis (RO) filtration systems are used for industrial wastewater recovery. Microfiltration (MF) and ultrafiltration (UF) are generally used for pre-treatment of water before going to the NF or RO process (Singh et al., 2014).

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

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

- ***Use of automatic control-shutoff valves to optimize water usage***

Monitoring and controlling water consumption using flow control devices, meters, and computer-aided monitoring systems provides significant advantages in technical, environmental, and economic terms (Öztürk, 2014). Monitoring the amount of water consumed within the facility and in various processes prevents water losses (TUBİTAK MAM, 2016). It is necessary to use flow meters and meters in the facility in general and in production processes, to use automatic shut-off valves and valves in continuously operating machines, and to develop monitoring-control mechanisms according to water consumption and certain quality parameters determined by using computer-aided systems (TUBİTAK MAM, 2016). With this application, it is possible to achieve savings of 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, savings of 3-5% can be achieved in process water consumption (Öztürk, 2014).

- ***Grey water is collected and purified separately in the facility and used in areas that do not require high water quality (green area irrigation, ground 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 generated from showers, sinks, kitchens, etc. is called gray water. Water savings can be achieved by purifying this gray water with various purification processes and using it in areas that do not require high water quality.

- ***Use of automatic equipment and tools (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 ensure the necessary hygiene standards. Water consumption in industrial facilities can be provided in various ways in production processes, and savings can be achieved in water consumption by using equipment such as sensor taps and smart hand washing systems in personnel water usage areas. Smart hand washing systems adjust the water, soap, and air mixture in the right proportions, while also providing resource efficiency in addition to water savings.

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

In different sub-sectors of the manufacturing industry, waters with different water quality can be used in accordance with production purposes. In industrial facilities, raw waters usually obtained from underground water sources are used in production processes after being purified. However, in some cases, although it is costly in production processes, drinking water can be used directly, or raw waters are disinfected with chlorinated compounds and then evaluated in production processes. These waters containing residual chlorine can react with organic compounds (natural organic substances (NOM)) in water during production processes and form disinfectant by-products that are harmful to living metabolisms (Özdemir & Toröz, 2010; Oğur et al.; TOB, 2021). The use of drinking waters containing residual chlorine compounds or raw waters disinfected with chlorinated compounds should be avoided as much as possible. In the disinfection of raw waters, disinfection methods with high oxidation capacity 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. It is possible to reduce water, energy, and chemical costs with this application (TUBITAK MAM, 2016).

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

Today, 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, 50% water saving has been achieved in landscape irrigation by storing roof rainwater collected in industrial facilities and using it inside the building and in landscape areas (Yaman, 2009). In order to increase the permeability of the ground and to ensure that rainwater passes into the soil and is absorbed on the field, perforated stones and green areas can be preferred (Yaman, 2009). Rainwater collected on building roofs can be used for vehicle washing and garden irrigation. It is possible to recover 95% of the collected water after use with biological treatment and reuse it (Şahin, 2010).

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

Refrigerants are generally chemical compounds with certain thermodynamic properties that cool the substances to be cooled by taking heat from them and affecting the performance of the cooling process (Kuprasertwong et al., 2021).

Water is used as a coolant in many processes, especially in manufacturing industry processes and 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 are reduced. However, the need for energy for cooling and recirculation of cooling waters emerges as a side interaction.

Heat recovery is also achieved by using heat exchangers in cooling waters. Closed loop systems are generally used in facilities where water cooling systems are used. However, cooling system blowdowns are removed by being given directly to the wastewater treatment plant channel.

- ***Preventing substances that pose a risk to the aquatic environment (such as oils, emulsions, binders) from being stored, accumulated, and mixed with wastewater after use***

In industrial facilities, dry cleaning techniques can be used to prevent chemicals that pose a risk to the aquatic environment, such as oils, emulsions, and binders, from mixing into wastewater streams and preventing leaks. In this way, the protection of water resources can be ensured (TUBITAK MAM, 2016).

- ***Establishing closed storage and impermeable waste/scrap areas to prevent the transport of toxic or hazardous chemicals to the aquatic environment***

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

- ***Recovering water from rinse solutions and reusing the recovered water in processes appropriate to its quality***

In industrial facilities, rinsing wastewater is relatively clean and can be reused without treatment in floor washing and garden irrigation processes that do not require high water quality (Öztürk, 2014). By recycling rinsing water, savings of 1-5% can be achieved in raw water consumption.

- ***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, it is necessary to define the process inputs and outputs in the best way possible in terms of production processes (TUBITAK MAM, 2016). Thus, it becomes possible to develop measures to increase resource efficiency and economic and environmental performance. The organization of input-output inventories is accepted as a prerequisite for continuous improvement. While such management practices require the participation of technical personnel and senior management, they pay for themselves in a short time with the work of various experts (IPPC BREF, 2003). The use of measurement equipment on the basis of application processes and some routine analyses/measurements specific to processes are required. In order to obtain the highest level of efficiency from the application, the use of computerized monitoring systems as much as possible ensures that the technical, economic, and environmental benefits to be obtained are increased (TUBITAK MAM, 2016).

- ***Implementation of time optimization in production and organization of all processes to be completed in the shortest time possible***

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

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