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

Water Efficiency
Campaign

Water Efficiency Guidance Documents Series

MINING OF OTHER NON-FERROUS METAL ORE

NACE CODE: 07.29

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Contents

Abbreviations

WWTP	Wastewater Treatment Plant
EU	European Union
SS	Suspended Solids
BREF	Best Available Techniques Reference Document
EMS	Environmental Management System
ÇŞİDB	Republic of Turkey Ministry of Environment, Urbanization and Climate Change
NOM	Natural Organic Matter
EMAS	Eco-Management and Audit Scheme 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
GW	Surface Water

1 Introduction

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

The usable annual water amount per capita in our country is 1,313 m³ for 2022, and it is expected that the usable annual water amount 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, bringing with it many negative social and economic consequences. As can be understood from the results of the 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". The water efficiency approach is based on the rational, sharing, equitable, efficient and effective use of water in all sectors, primarily drinking water, agriculture, industry and households, by protecting the quantity and quality of water and taking into account the needs of not only people but also all living things with ecosystem sensitivity.

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, the fair and balanced distribution of usable water resources among users is becoming increasingly important every day. For this reason, it has become imperative 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 Goal 7 of the Millennium Development Goals: Ensuring Environmental Sustainability, Goal 9 of the Sustainable Development Goals: Industry, Innovation and Infrastructure and Goal 12 of the Responsible Production and Consumption, issues such as efficient, equitable and sustainable use of resources, especially water, environmentally friendly production and consumption that are concerned about future generations are included.

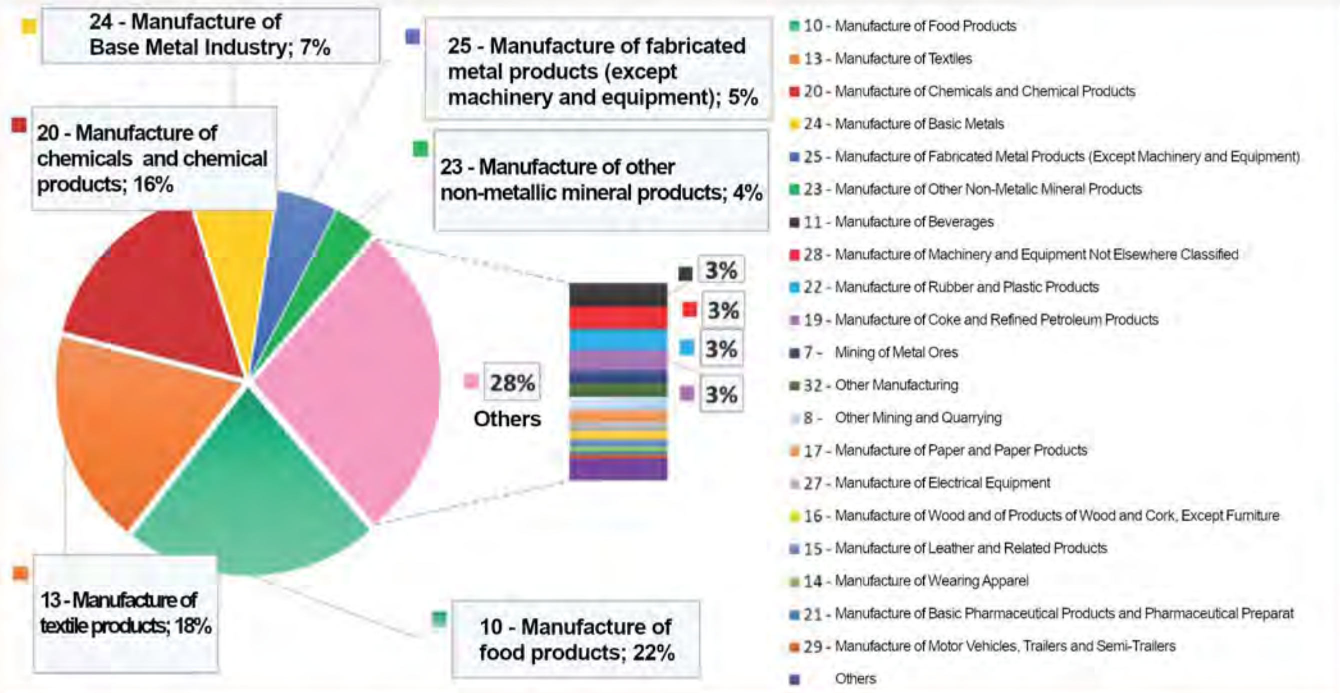
Within the scope of the European Green Deal, in which member countries have agreed on targets such as implementing a clean, circular economy model with a carbon neutral target, expanding the efficient use of resources and reducing environmental impacts, actions emphasizing water and resource efficiency 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 (IED), one of the most important components of the European Union environmental legislation in terms of industry, includes measures to be taken to control, prevent or reduce discharges / emissions originating from industrial activities and made 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 implementation. BATs are the most effective application techniques for a high level of protection of the environment when their costs and benefits are taken into account. In accordance with the Directive, Reference Documents (BAT-BREF) have been prepared in which BATs are explained in detail for each sector. In BREF documents, BATs are presented within a general framework such as good management practices, techniques of general precautions, chemical use and management, techniques for various production processes, wastewater management, emission management and waste management.

Ministry of Agriculture and Forestry, General Directorate of Water Management carries out studies aimed at spreading efficient practices in urban, agricultural, industrial and individual water use and increasing social awareness. Within the scope of the ***"Water Efficiency Strategy Document and Action Plan (2023-2033) within the Framework of Adaptation to the Changing Climate"***, which entered into force with the Presidential Circular No. 2023/9, water efficiency action plans addressing all sectors and stakeholders have been prepared. A total of 12 actions have been determined for the 2023-33 period in the Industrial Water Efficiency Action Plan, and responsible and relevant institutions have been appointed for the said actions. Within the scope of the said Action Plan; conducting studies on determining specific water use intervals and quality requirements on a sub-sector basis in the industry, organizing technical training programs and workshops on a sectoral basis and preparing water efficiency guide documents have been defined as the responsibility of the General Directorate of Water Management.

On the other hand, within the scope of studies on improving water efficiency in industry, the best sectoral techniques specific to our country have been determined with the ***"Industrial Water Use Efficiency According to NACE Codes Project"*** carried out by the General Directorate of Water Management of the Ministry of Agriculture and Forestry. As a result of the study, sectoral guide documents and action plans classified with NACE codes, which include recommended measures for improving 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 the 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, primarily food, textile, chemical and basic metal industries, representing different capacity and variety of production areas 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 and recovery were obtained and the best available techniques (BAT) and sectoral reference documents (BREF) published by the European Union, water efficiency, clean production, water footprint, etc. information was provided on the issues.



Distribution of water usage in our country in industry on sectoral basis

As a result of the studies, specific water consumption and potential saving rates for the processes of enterprises for 152 different 4-digit NACE codes with high water consumption were determined, and water efficiency guide documents were prepared by considering the EU best available techniques (BAT) and other cleaner production techniques. In the guides, 500 techniques (BAT) for water efficiency were examined under 4 main groups as (i) Good Management Practices, (ii) General Measures, (iii) Measures Related to Auxiliary Processes and (iv) Sector-Specific Measures.

In the determination 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, and different data sources such as current literature data on a global scale, real case studies, innovative applications, reports of sector representatives were examined in detail and sectoral BAT lists were created. In order to evaluate the suitability of the created MET lists to our country's local industrial infrastructure and capacity, MET lists prepared specifically for each NACE code were prioritized by businesses by scoring them on the criteria of water saving, economic saving, environmental benefit, applicability, and cross-media impact, and the final MET lists were determined using the scoring results. Sectoral water efficiency guides were created on the basis of NACE codes based on the final MET lists determined by sectoral stakeholders and taking into account the local dynamics specific to our country and the water and wastewater data of the facilities visited within the scope of the project.

2 Scope of the Study

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

- Plant and animal production, hunting and related service activities (including 6 four-digit NACE Code sub-production areas)
- Fishing and aquaculture (including 1 four-digit NACE Code sub-production area)
- Coal and lignite extraction (including 2 four-digit NACE Code sub-production areas)
- Mining support service activities (including 1 four-digit NACE Code sub-production area)
- Metal ore mining (including 2 four-digit NACE Code sub-production areas)
- Other mining and quarrying (including 2 four-digit NACE Code sub-production areas)
- Food products manufacturing (including 22 four-digit NACE Code sub-production areas)
- Beverage manufacturing (including 4 four-digit NACE Code sub-production areas)
- Tobacco products manufacturing (including 1 sub-production area represented by 4-digit NACE Codes)
- Manufacture of textiles (including sub-production area represented by 9 4-digit NACE Codes)
- Manufacture of apparel (including sub-production area represented by 1 4-digit NACE Code)
- Manufacture of leather and related products (incl. sub-prod.area represented by 3 4-digit NACE Codes)
- Manufacture of wood, wood products and cork products (excluding furniture); Manufacture of articles made of straw, straw and similar materials (including sub-area represented by 5 4-digit NACE Codes)
- Manufacture of paper and paper products (including sub-area represented by 3 4-digit NACE Codes)
- Manufacture of coke and refined petroleum products (incl.sub-area represented by 1 4-digit NACE Code)
- Manufacture of chemicals and chemical products (incl. sub-area represented by 13 4-digit NACE Codes)
- Manufacture of basic pharmaceutical products and pharmaceutical preparations (including sub-area represented by 1 4-digit NACE Code)
- Manufacture of rubber and plastic products (including sub-area represented by 6 4-digit NACE Codes)
- Manufacture of other non-metallic mineral products (incl. sub-area represented by 12 4-digit NACE Codes)
- Basic metal industry (including sub-area represented by 11 4-digit NACE Codes)
- Manufacture of fabricated metal products (excluding machinery and equipment) (including sub-area represented by 12 4-digit NACE Codes) (Including sub-area represented by 4-digit NACE Codes)
- Manufacture of computers, electronic and optical products (Incl. sub-area represented by 2 4-digit NACE Codes)
- Manufacture of electrical equipment (Including sub-area represented by 7 4-digit NACE Codes)
- Manufacture of machinery and equipment not elsewhere classified (Incl. sub-area represented by 8 4-digit NACE Codes)
- Manufacture of motor vehicles, trailers and semi-trailers (including sub-area represented by 3 4-digit NACE Codes)

- Manufacture of other transportation equipment (including sub-production area represented by 2 4-digit NACE Codes)
- Other manufacturing (including sub-production area represented by 2 4-digit NACE Codes)
- Installation and repair of machinery and equipment (including sub-production area represented by 2 4-digit NACE Codes)
- Production and distribution of electricity, gas, steam and ventilation systems (including sub-production area represented by 2 4-digit NACE Codes)
- Collection, treatment and disposal activities of waste; materials recovery (including sub-production area represented by 1 4-digit NACE Code)
- Construction of external structures (including sub-production area represented by 1 4-digit NACE Code)
- Storage and support activities for transportation (including sub-production area represented by 1 4-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 4-digit NACE Code)
- Sports activities, entertainment and recreation activities (including sub-production area represented by 1 4-digit NACE Code)

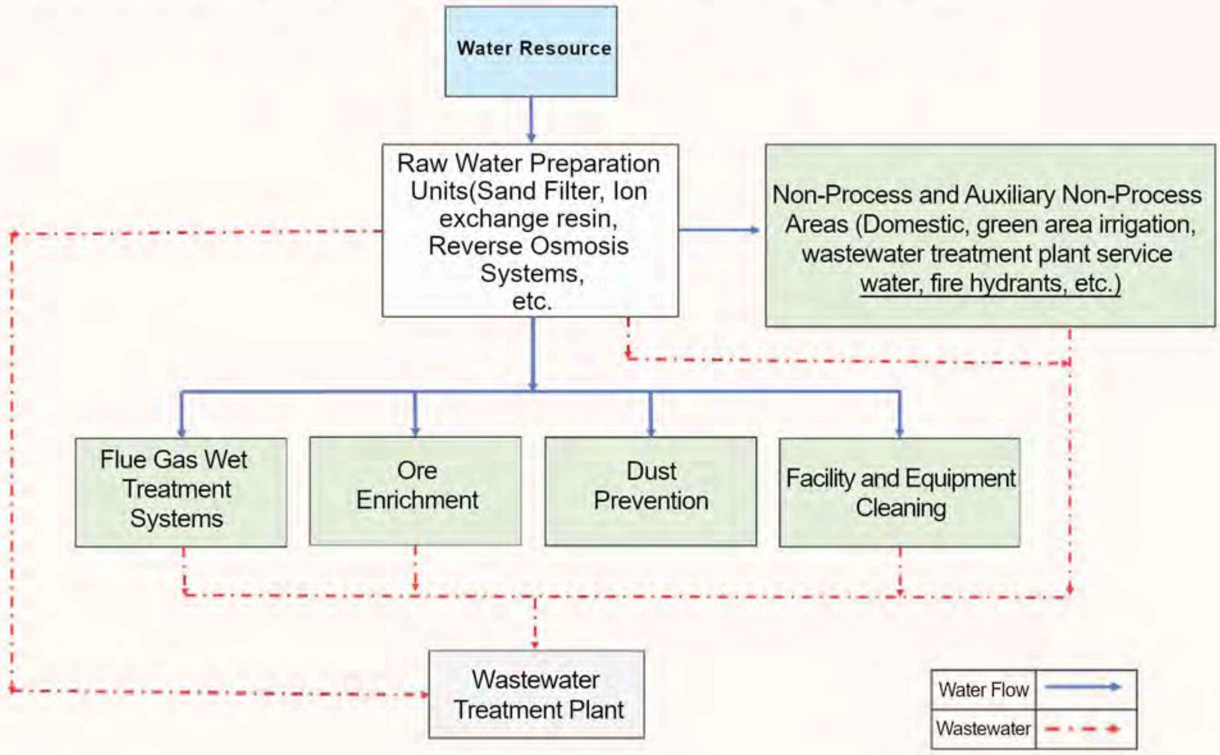
Mining of metal ores

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

07.10	Mining of iron ores
07.29	Mining of other non-ferrous metal ores

2.1 Other Non-Ferrous Metal Ore Mining (NACE 07.29)

Other non-ferrous metal ore mining Sector Water Flow Diagram



	Minimum	Maximum
Specfic Water Consumption of Facilities Visited Witihin the Scope of the Project (L/kg)	0,1	95
Reference Specfic Water Consumption (L/kg)	0,1	14

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, pelletizing) processes are carried out.

In other non-ferrous metal ore mining sector, water is used for dust prevention purposes in flue gas wet treatment systems, ore enrichment processes, transportation and similar processes. Significant amounts of water are also consumed for raw water preparation units such as active carbon filters, ion exchange resins, reverse osmosis used to produce soft water for use in production processes, and filter washing, resin regeneration and membrane cleaning processes.

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

The reference specific water consumption in the other non-ferrous metal ore mining sector is in the range of 0.1 - 14 L/kg. The specific water consumption of the production branch analyzed within the scope of the study is in the range of 0.1 - 95 L/kg. It is possible to achieve 7 - 59% water recovery in the sector with the implementation of sector-specific measures, good management practices, general measures and measures related to auxiliary processes.

Use of Water to Prevent Dust in Mining Sites

07.29 The priority water efficiency application techniques recommended under the Other Nonferrous Metal Ores Mining NACE code are presented in the table below.

NACE Code	NACE Code Explanation		Sector-Prioritized Best Available Techniques
07.29	Mining of other non-ferrous metal ores		**Sector Specific Measures**
		1.	Building reservoirs to collect flood and rain water
		2.	Covering the dam base with impermeable materials in tailings dams and establishing a drainage system that allows the recovery of leakages from tailings dams
		3.	Purifying and reusing wastewater containing heavy metals and acidic character
		4.	Reusing the upper clear phase in the tailings dam
		5.	Recovering more water by using high-efficiency concentrators
		6.	Continuous monitoring of surface and/or groundwater source quality and using potential water resources such as rainwater harvesting in processes that do not require high water quality
		7.	Preventing water losses by creating impermeable areas
			Good Management Practices
		1.	Using an integrated wastewater management and treatment strategy to reduce the amount of wastewater and pollutant load
		2.	Establishing an environmental management system
		3.	Preparing water flow diagrams and mass balances for water
		4.	Preparing a water efficiency action plan to reduce water use and prevent water pollution
		5.	Reducing and optimizing water use Providing technical training to personnel
		6.	Making good production planning to optimize water consumption
		7.	Determining water efficiency targets
		8.	Monitoring the amount and quality of water used in production processes and auxiliary processes and wastewater generated and adapting this information to the environmental management system

NACE Code	NACE Code Explanation		Sector-Prioritized Best Available Techniques
07.29	Mining of other non-ferrous metal ores		**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.	Using automatic equipment and hardware (sensors, smart hand washing systems, etc.) that will save water at water usage points such as showers/toilets
		4.	Equipment cleaning, general cleaning, etc. Using pressure washing systems in processes
		5.	Reusing filter wash water in filtration processes, reusing relatively clean cleaning water in production processes and reducing water consumption by using cleaning-in-place (CIP) systems
		6.	Avoiding the use of drinking water in production lines
		7.	Using cooling water as process water in other processes
		8.	Detecting and reducing water losses
		9.	Using automatic control-shutoff valves to optimize water use
		10.	Keeping production procedures documented and used by employees to prevent water and energy waste
		11.	Optimizing the frequency and duration of regeneration (including rinsing) in water softening systems
		12.	Creating closed storage and impermeable waste/scrap areas to prevent the transfer of toxic or hazardous chemicals to the aquatic environment
		13.	Storing, storing and disposing of substances that pose a risk to the aquatic environment (such as oils, emulsions, binders)
		14.	Where technically possible, use of suitable wastewater as steam boiler feed water by treating it
		15.	Preventing mixing of clean water streams with dirty water streams
		16.	Determining wastewater streams that can be reused with or without treatment by characterizing the amounts and qualities of wastewater at all wastewater generation points
		17.	Use of closed-loop water cycles in appropriate processes
		18.	Use of computer-aided control systems in production processes
		19.	Reuse of relatively clean wastewater originating from washing, rinsing and equipment cleaning in production processes without treatment
		20.	Determining the scope of reuse of washing and rinsing water

NACE Code	NACE Code Explanation		Sector-Prioritized Best Available Techniques
07.29	Mining of other non-ferrous metal ores	21.	Separate collection and treatment of gray water in the facility and use in areas that do not require high water quality (green area irrigation, floor, ground washing, etc.)
		22.	Implementation of time optimization in production and organization of all processes in a way that they are completed in the shortest time
		23.	Collection of rain water and evaluation of it as an alternative water source in facility cleaning or in suitable areas
		24.	Reuse of nanofiltration (NF) or reverse osmosis (RO) concentrates with or without treatment depending on their characterization
		25.	Regular monitoring of the amount of water used in each process
		26.	Regular control of water cycle systems
		27.	Determination of the quality of water usage areas and use of water according to the appropriate need
		28.	Reuse of appropriate wastewater by treating it
			Measures Regarding Auxiliary Processes
		1.	Water saving by isolating steam and water lines (hot and cold), preventing water and steam losses in pipes, valves and connection points in the lines and monitoring with a computer system
		2.	Steam Reducing the amount of blowdown in boilers by using deaerators
		3.	Minimizing the boiler discharge water (blowdown) in steam boilers
		4.	Reusing the energy produced from the steam condenser
A total of 47 techniques have been proposed in this sector.			

Mining of Other Non-Ferrous Metal Ores
NACE Code;

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

2.1.1 Sector-Specific Measures

- ***Continuous monitoring of surface and/or groundwater source quality and use of potential water sources such as rainwater harvesting in processes where high water quality is not required***
  Water is used to wet the roads to settle the dust formed on the roads during the transportation of products. Water use for dust suppression can vary between 1% and 15% of the total water consumption of the activity.

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

- ***Covering the dam base with impermeable materials in tailings dams and establishing a drainage system that allows the recovery of leaks from tailings dams***
  Water is recovered from tailings dams by establishing drainage systems. Recovered water can be reused in processes (COCHILCO, 2008).

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

- ***Recovering more water by using high-efficiency concentrators***
  High-efficiency concentrators increase the concentrate ratio (65-75%) compared to normal concentrators and increase the waste weight by 8%. (COCHILCO, 2008). With the increased concentrate ratio and waste weight, more water can be recovered.

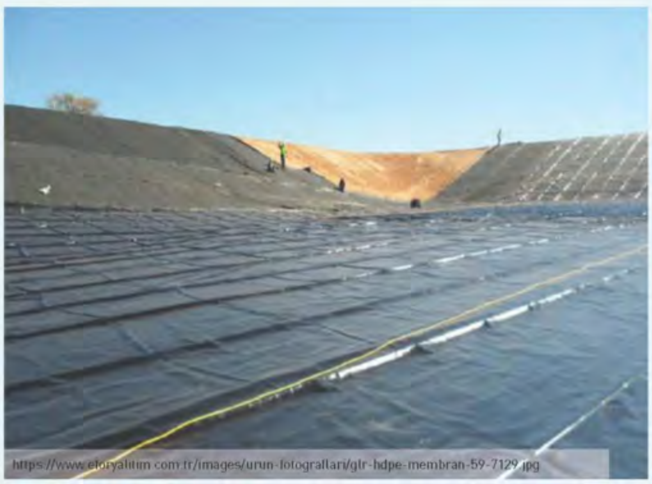
- ***Reuse of the upper clear phase in the tailings dam***
  The clear water in the upper clear phase formed in the tailings dam can be recirculated to the mine site and can be easily used in various processes due to the lime and reagents in its content.Approximately 30%-50% water recovery can be achieved from tailings dams (COCHILCO, 2008).

- ***Preventing water losses by creating leak-proof areas***
  In industrial facilities, both raw material and water losses can occur due to leaks. In addition, if wet cleaning methods are used in cleaning areas where spills occur, water consumption, wastewater amounts and pollution loads of wastewater may also increase. In the food sector, equipment such as splash guards, wings and drip trays can be used to reduce raw material and product losses as much as possible in processes where the possibility of falling to the ground, spilling and splashing is high(TUBITAK MAM,2016). With the use of these additional equipment, both raw material and resource losses can be prevented, and waste formation and organic material contamination of wastewater can be reduced to the lowest level possible. It is known that a decrease of up to 19% in water consumption is achieved by preventing spills and leaks in a food company producing starch (IPPC BREF, 2006a; TUBITAK MAM, 2016).

- ***Reuse of wastewater containing heavy metals and acidic wastewater***

  Acidic wastewater containing heavy metals can be recycled by passing through electroflocculation and ultrafiltration. The electroflocculation process requires simple equipment and operating conditions. Heavy metal removal occurs at rates close to 100% in wastewater, and this water,which does not contain heavy metals, can be recycled and reused after passing through the ultrafiltration process (Köksal, 2021).

Tailings Dams in Mining Sites



Mine Waste Dam Construction Geomembrane Application

2.1.2 Good Management Practices

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

Environmental Management Systems (EMS) include the organizational structure, responsibilities, procedures and resources required to develop, implement and monitor environmental policies of industrial organizations. Establishment of environmental management system improves decision-making processes of institutions regarding raw materials, water-wastewater infrastructure, planned production process, different treatment techniques. Environmental management organizes how to manage resource supply 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. Among its alternatives, there is the Eco-Management and Audit Program Directive (EMAS) (761/2001). It was developed for the assessment, improvement and reporting of environmental performance of enterprises. It is one of the leading applications 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).
- By adopting International Standards Organization (ISO) standards, greater compliance with global legal and regulatory requirements is achieved (Christopher, 1998).

- While the risks of penalties related to environmental liabilities are minimized, there is a decrease in the amount of waste, resource consumption and operating costs (Delmas, 2009).

- The use of internationally accepted environmental standards eliminates the need for multiple registrations and certificates 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 considered important 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 institutions' better position in international areas/markets (Potoski & Prakash, 2005).

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

Industrial organizations are also conducting 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 water footprints. 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 their water efficiency policies by conducting monitoring, benchmarking and review studies.

- ***Use of an integrated wastewater management and treatment strategy to reduce wastewater volume and 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 an appropriate treatment technology for industrial wastewater depends on integrated factors such as land availability, desired treated water quality, compliance with national and local regulations (Abbassi & Al Baz, 2008).

  Reuse of treated wastewater in the facility not only improves the quality of water bodies but also reduces the demand for fresh water. Therefore, it is very important to determine 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, methods such as SWOT method (strengths, weaknesses, opportunities and threats), PESTEL method (political, economic, social, technological, environmental and legal factors), decision tree can be combined with expert opinions to determine an integrated wastewater management framework (Naghedi et al., 2020). The integration of Analytical Hierarchy Process (AHP) and Combined Consensus Solution (CoCoSo) techniques can be used to determine priorities based on a large number of criteria for industrial wastewater management processes (Adar et al., 2021). With the implementation of integrated wastewater management strategies, an average of up to 25% reduction 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).

Industrial Wastewater Treatment Plant

- ***Providing technical training to personnel for water use reduction and optimization***
  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. In industrial facilities, problems related to high amounts of water use and wastewater generation can occur due to the lack of necessary technical knowledge of personnel. 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 in the process and motivation. The technical, economic and environmental benefits to be obtained through personnel training yield results in the medium or long term (TUBITAK MAM, 2016; TOB, 2021).

- ***Monitoring the amount 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 the 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 should be monitored (TUBITAK MAM, 2016; TOB, 2021). Process-based quantity and quality monitoring, together with other good management practices (personnel training, establishment of an environmental management system, etc.), can provide a reduction of up to 6-10 % in energy consumption and 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:
  - Using 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 their quantity and quality,
  - Monitoring raw material losses in production processes where raw materials are transformed into products and taking precautions against raw material losses (ÇŞİDB, 2020e).

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

  Planning the process from raw material to product in industrial production processes using the least amount of processes 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 wastewater amount. Modifying production processes or combining some processes in industrial facilities provides significant benefits in terms of water efficiency and time planning (TOB, 2021).

- ***Preparing a water efficiency action plan to reduce water use and prevent water pollution***

  Preparing an action plan that includes short, medium and long-term actions to reduce water-wastewater amounts and prevent water pollution in industrial facilities is important in terms of water efficiency. At this point, water needs should be determined throughout the facility and in production processes, quality requirements should be determined at water usage points, wastewater generation points and wastewater characterization should be performed (TOB, 2021). At the same time, it is necessary to determine the measures to be implemented to reduce water consumption, wastewater generation and pollution loads, to conduct their feasibility studies and to prepare action plans for the short-medium-long term. In this way, water efficiency and sustainable water use are ensured in facilities (TOB, 2021).

- ***Determining water efficiency targets***

  The first step in ensuring water efficiency in industrial facilities is to determine the targets (TOB, 2021). For this, a detailed water efficiency analysis should be carried out on a process basis. In this way, unnecessary water use, water losses, incorrect practices affecting water efficiency, process losses, water-wastewater resources that can be reused with or without treatment, etc. can be determined. It is also extremely important to determine water saving potential and water efficiency targets for each production process and the facility in general (TOB, 2021).

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

  Determination of water usage and wastewater generation points in industrial facilities, creation of water-wastewater balances in production processes and auxiliary processes outside of production processes generally constitute the basis of many good management practices. Creation of process profiles throughout the facility and on the basis of production processes; It facilitates the determination of unnecessary water usage points and high water usage points, evaluation of water recovery opportunities, process modifications and 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 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 and the following points should be taken into account:

- Inclusion of pumps, valves, level switches, pressure and flow regulators in the maintenance checklist,
- Inspection of broken and leaking pipes, barrels, pumps and valves, not only in the water system but also in heat transfer and chemical distribution systems,
- Regular cleaning of filters and pipelines,
- Calibration of measuring equipment such as chemical measuring and distribution devices, thermometers etc., routine inspection and monitoring at specified intervals (IPPC BREF, 2003).

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

- ***Minimizing spills and leaks***

Both raw material and water losses can occur due to spills and leaks in businesses. In addition, if wet cleaning methods are used in cleaning areas where spills occur, increases in water consumption, wastewater amounts and pollution loads of wastewater may occur (TOB, 2021). In order to reduce raw material and product losses, spill and splash losses are reduced by using splash preventers, wings, drip trays and sieves (IPPC BREF, 2019).

- ***Determining wastewater streams that can be reused with or without treatment by characterizing the amount and quality of wastewater at all wastewater generation points***

It is possible to reuse various wastewater streams with or without treatment by determining and characterizing wastewater generation points in industrial facilities (Öztürk, 2014). In this context, filter backwash waters, RO 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). 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 NF or RO process (Singh, et al., 2014).

- ***Where technically possible, using appropriate wastewater as steam boiler feed water by treating it***
  Although it is difficult to implement in industrial facilities, it is possible to treat appropriate wastewater to process water quality and reuse it in production processes, including steam boilers. In this way, savings ranging from 20-50 % can be achieved in total water consumption and wastewater generation (Öztürk, 2014; TUBİTAK MAM, 2016). The initial investment cost required for the application is the treatment system to be used. Payback periods vary when the amount of water to be recovered, the amount of economic savings, the applied unit water-wastewater costs, and the treatment system operation-maintenance costs are taken into consideration (TOB, 2021). Membrane systems (a combination of ultrafiltration(UF), nanofiltration(NF) and reverse osmosis(RO) systems) can be used for recovery. For example, in some industrial facilities, it is possible to purify cooling system blowdown water and reuse it as process water (TOB, 2021).

- ***Preventing the mixing of clean water streams with dirty water streams***
  In industrial facilities, by determining the wastewater formation points 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 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 generally requires high investment costs, and costs can be reduced when it is possible to recover high amounts of wastewater and energy (IPPC BREF, 2006).

- ***Regular monitoring of the amount of water used in each process***
  Inefficiency and environmental problems in resource use in industrial facilities are directly linked to input-output flows. Therefore, it is necessary to have as much information as possible about the amount and quality of process water use in production processes (TUBITAK MAM, 2016).The proposed application may require the use of measurement equipment on a process basis. In order to obtain the highest level of efficiency from the application, utilizing the computerized monitoring systems used today as much as possible will increase the technical, economic and environmental benefits to be obtained (Ozturk and Cinperi, 2018). The application of monitoring process-based quantities and qualities, which constitutes one of the inseparable and basic components of general good management practices, together with other good management practices (personnel training, establishment of an environmental management system, etc.), can enable reductions of up to 6-10% in energy consumption and 25% in water consumption and wastewater amounts (Öztürk, 2014).

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

  In industrial facilities, wastewater with relatively clean characteristics, especially washing-final rinsing 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 save 1-5 % in raw water consumption (TOB, 2021).

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

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

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

  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). The use of flow meters and meters in the facility in general and in production processes, the use of automatic shut-off valves and valves in continuously operating machines, and the development of monitoring-control mechanisms according to water consumption and certain quality parameters 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, 3-5% savings can be achieved in process water consumption (Öztürk, 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 achieve water and energy savings by using heat exchangers in cooling water return, preventing cooling water pollution and increasing cooling water return rates (TUBİTAK MAM, 2016; TOB, 2021). In addition, in cases where cooling waters are 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).

- ***Reuse of filter wash water in filtration processes, reuse of relatively clean cleaning water in production processes, reduce water consumption by using on-site cleaning systems***

Wastewater resulting from backwashing of activated carbon filters and softening devices mostly contains only high levels of suspended solids(SS). Backwash water, which is one of the easiest wastewater types to recover, can be filtered and recovered with ultrafiltration facilities. In this way, up to 15% water savings can be achieved.This investment can pay for itself in 1-2 months (URL-1, 2021). Regeneration wastewater formed after the regeneration process is soft water with a high salt content and constitutes approximately 5-10 % of total water consumption. Regeneration wastewater can be collected in a separate tank and used in processes requiring high salt, facility cleaning and domestic uses. For this, a reserve tank, water installation and pump are needed. By reusing regeneration wastewater, approximately 5-10 % reductions can be achieved in water consumption, energy consumption, wastewater quantities and salt content of wastewater (Öztürk E. , 2014). The initial investment cost for the application is expected to be around 250-350 USD/m³ (TUBİTAK MAM, 2016; TOB, 2021). The payback period varies depending on whether regeneration water is consumed in production processes, facility cleaning and domestic purposes. In case of reuse of regeneration water in production processes requiring high salt(since both water and salt will be recovered), it is estimated that the potential payback period will be less than one year. In facility and equipment cleaning and domestic uses, the payback period is estimated to be over one year (TOB, 2021). In our country, reverse osmosis(RO) concentrates are combined with other wastewater streams and given to the wastewater treatment plant channel.It is possible to use the concentrates formed in RO systems used for additional hardness removal in garden irrigation, in-plant and tank-equipment cleaning (TUBITAK MAM, 2016; TOB, 2021). In addition, with the structuring of continuous monitoring applications of raw water quality, it is possible to re-evaluate the RO concentrates by feeding them back to the raw water tanks and mixing them (TOB, 2021).

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

Water with different water quality can be used in different sub-sectors of the manufacturing industry in accordance with production purposes. In industrial facilities, raw water, usually obtained from underground water sources, is used in production processes after being purified. However, in some cases, drinking water can be used directly, despite being costly in production processes, or raw water is disinfected with chlorinated compounds and then evaluated in production processes. These waters containing residual chlorine can react with organic compounds (natural organic substances (DOM)) in the 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 water containing residual chlorine compounds or raw water disinfected with chlorinated compounds should be avoided as much as possible. Disinfection methods with high oxidation capacity such as ultraviolet (UV), ultrasound (US) or ozone can be used instead of chlorine disinfection in the disinfection of raw water. 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 (TUBİTAK MAM, 2016).

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

  Nowadays, rainwater harvesting is frequently preferred especially in regions with low rainfall, where water resources are decreasing. 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 (Tanik et al., 2015).

  In various examples, roof rainwater collected in industrial facilities has been stored and used inside the building and in landscape areas, thus providing 50% water saving in landscape irrigation (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 into the soil and is absorbed in the field (Yaman, 2009). Rainwater collected on building roofs can be used for vehicle washing and garden irrigation. After the collected water is used, it is possible to recover 95% of it with biological treatment and reuse it (Şahin, 2010).

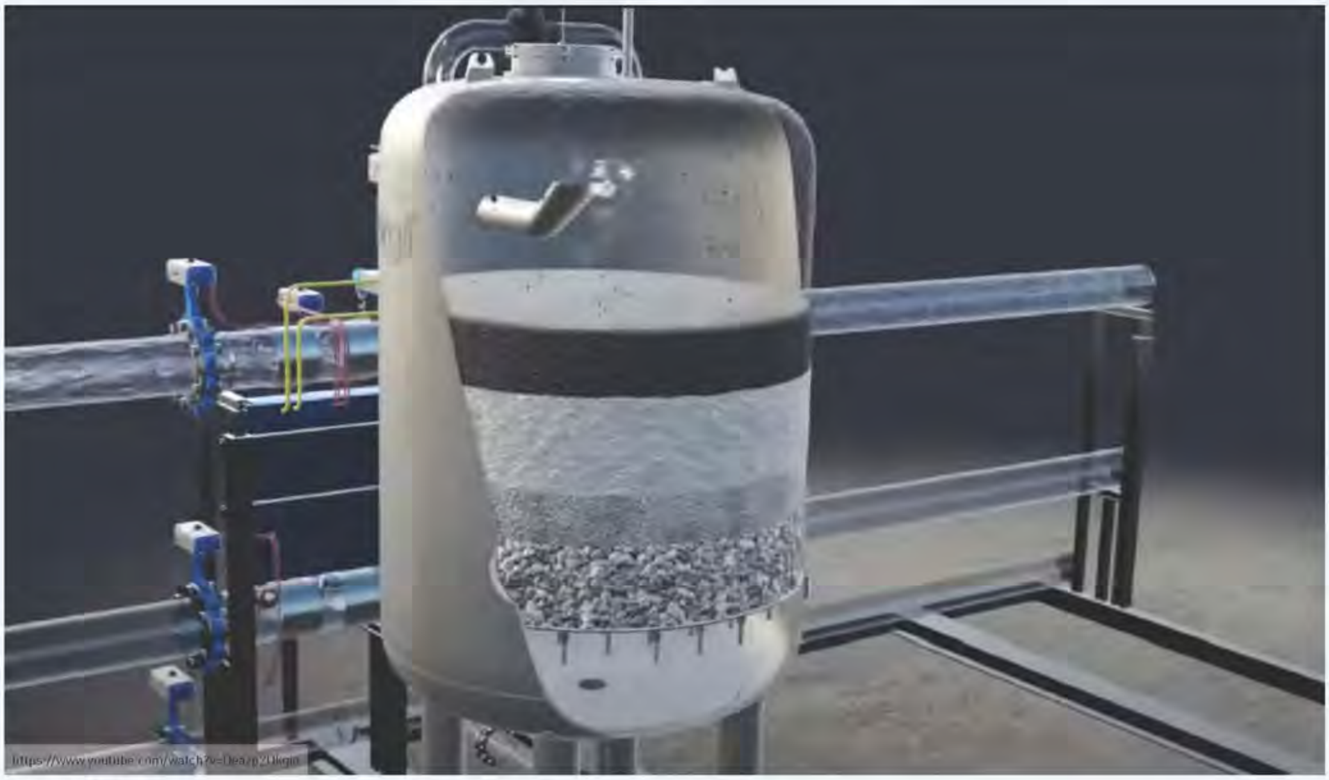
- ***Treating and reusing suitable wastewater***

  One of the most important water efficiency applications in providing water saving in the industry is the treatment and reuse of suitable wastewater streams. For this application, it is necessary to determine the wastewater generation points within the facility, characterize the wastewater streams, determine the necessary water quality requirements in the areas to be reused, determine the processes / areas to be reused and determine the necessary water needs at these points. In addition, in the selection of the treatment technique / technology to be used for the treatment of the determined wastewater streams, it is also important to perform a preliminary treatability test in order to obtain effective results. In facilities operating in many sub-sectors of the manufacturing industry, a large portion of the wastewater originating from both production processes and auxiliary processes can be suitable for treatment and reuse. In sensitive sectors such as the food industry, there may be reservations about the recovery / reuse of process wastewater that is at risk of contamination due to other wastewaters. However, suitable process wastewater can be collected in separate systems and treated and reused in the same process or similar processes. In sectors with high water consumption such as the iron and steel industry and the textile industry, both process wastewater and composite (end-of-pipe) wastewater can be treated and reused. For example, in the textile industry (yarn finishing and dyeing), by treating and reusing process wastewater, total water consumption and total wastewater amounts can be reduced by 30-65% (Ozturk et al., 2015). Chemical loads carried by wastewater can also be reduced by 25-50% (Ozturk et al., 2015). In the woolen textile industry, by treating and reusing suitable wastewater streams, water consumption and wastewater amounts can be reduced by 20-23%. The payback period for the initial investment costs for the application can be approximately 5 years (Ozturk and Cinperi, 2018). As can be seen, the savings/reductions and payback periods to be achieved with the application may vary even in different sub-sectors of the same sector. However, when evaluated in general, it is possible to achieve water savings and reductions in wastewater amounts of up to 50 % with the application of reusing appropriate wastewater streams after treatment, especially in industrial facilities/sectors with high water consumption.

- ***Optimizing the regeneration frequency and duration (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, the resin is pre-washed using raw water, regenerated with salt water, and final rinsed, respectively. Regeneration periods are determined depending on the hardness of the water. If the hardness is high, regeneration should be done more frequently in water softening systems.

  In regeneration processes, washing, regeneration, and rinsing wastewater are usually directly removed. However, if the washing and final rinse waters are of raw water quality, they 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).

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



Water Softening Systems

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

  According to the wastewater characterization and appropriate usage points, the reuse potential of other wastewaters originating from membrane processes (backwashing without or with chemicals, CIP cleaning, module cleaning, cleaning of chemical tanks, etc.) should be evaluated.

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

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

- ***Regular control of water cycle systems***

  Regular control of water cycle systems is a good management practice that enables industrial facilities to evaluate and improve their own water performance (IPPC BREF, 2003). Applications such as preparation of annual inventory reports and monitoring of inputs and outputs in production processes in terms of quantity and quality can provide savings of 3-5% in water consumption (IPPC BREF, 2009; Öztürk, 2014). This BAT is similar to "establishing an environmental management system".

- ***Determining the quality of water usage areas and using water according to the appropriate need***

  By determining water quality requirements on a process basis, water supply of appropriate quality can be provided for the process. In this way, the options for using the water supplied to the facility with or without treatment will also be determined. In addition, it is possible to reuse wastewater generated from process or non-process areas in industrial facilities in the same process without any treatment or after a simple filtration. In this case, water can be supplied according to the water quality required in the processes (IPPC BREF, 2006).

Reverse Osmosis System

- ***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, affecting the performance of the cooling process (Kuprasertwong et al., 2021).

  Water is used as a cooling fluid in manufacturing industry processes and many processes, led by product cooling. While this cooling process is carried out, 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).

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

  Heat recovery is also provided by the use of 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 directly feeding them to the wastewater treatment plant channel. These removed blowdown waters can be reused in appropriate production processes.

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

  In industrial facilities, water recovery is achieved by using dry cleaning techniques and preventing leaks in order to prevent chemicals that pose a risk to the aquatic environment such as oils, emulsions and binders from mixing with wastewater streams (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 established to prevent the transport of toxic or hazardous chemicals to the aquatic environment to the receiving environments. This practice is currently implemented within the scope of current environmental regulations in our country. 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 leakage water in question can be collected separately and prevented from mixing with natural water environments.

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

  Water is very important for both production processes and for personnel to provide the necessary hygiene standards in many sectors of the manufacturing industry. Water consumption in the production processes of industrial facilities can be provided in various ways, as well as savings in water consumption can be achieved 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.

- ***Recovering water from rinse solutions and reusing the recovered water in processes suitable for its quality***

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

- ***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 process inputs and outputs in the best way possible in production processes (TUBİTAK MAM, 2016). Thus, it becomes possible to develop measures in terms of increasing resource efficiency, 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 amortize themselves in a short time with the work of various experts (IPPC BREF, 2003). The use of measurement equipment based on application processes and some routine analyses/measurements specific to the processes are required. In order to obtain the highest level of efficiency from the application, utilizing computerized monitoring systems as much as possible increases the technical, economic and environmental benefits to be obtained (TUBITAK MAM, 2016).

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

  Wastewater generated in industrial facilities is not only industrial wastewater originating from production processes, but also includes wastewater originating from areas such as showers, sinks, kitchens, etc. Wastewater generated from areas such as 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.

Computer Aided Control System

- ***Implementation of time optimization in production, organization of all processes to be completed in the shortest time***
  Planning the process of raw material turning into a product by using the least amount of processes in industrial production processes can be an effective application in terms of reducing labor costs, resource usage costs, efficiency and environmental impacts. In this context, it may be necessary to review the production processes and revise them to use the least number of process steps (TUBITAK MAM, 2016). In cases where the desired product quality cannot be achieved due to some inadequacies, inefficiency and design errors in basic production processes, production processes may need to be renewed. Therefore, in this case, the amount of resource usage required in 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 application that can be used effectively together with other good management practices (TUBITAK MAM, 2016).

- ***Documentation of production procedures and their use by employees to prevent water and energy waste***
  In order to ensure efficient production in a business, effective procedures should be implemented to identify, evaluate potential problems and their sources and control production stages (Ayan, 2010). Determination and implementation of 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 evaluation of business performance and the development of the ability to develop immediate reflexes for solving 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 solution suggestions (Ayan, 2010). Documenting and 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 differences in the cost and economic gains of the application depending on the sector or facility structure (TUBITAK MAM, 2016; TOB, 2021). Although the creation and monitoring of production procedures is not costly, the payback period may be short when the savings and benefits it will provide are considered (TUBITAK MAM, 2016; TOB, 2021).

- ***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, and savings of 1-5 % in raw water consumption can be achieved. The initial investment costs required for the application consist of the establishment of new pipelines and reserve tanks (Öztürk, 2014).

2.1.4 Precautions Regarding Auxiliary Processes

BATs regarding steam generation

- ***Water saving by isolating steam and water lines (hot and cold) and preventing water and steam losses in pipes, valves and connection points in the lines and monitoring with a computer system***

Steam losses may occur if steam lines in facilities are not designed appropriately, routine maintenance and repairs of steam lines are not performed, mechanical problems in the lines and lines are not operated properly, and steam lines and hot surfaces are not fully insulated. This affects both the water consumption and energy consumption of the facility. Automatic control mechanisms must be used in order to perform steam insulation and continuously monitor steam consumption. Similar savings can be achieved in fuel consumption and additional soft water consumption in boilers due to the reduction of steam losses. Since fuel consumption in steam boilers will decrease, it is expected that waste gas emissions will decrease at the same rate. Since the use of additional soft water in steam boilers will decrease with the application, reductions are also achieved in regeneration water amounts, salt amounts used in regeneration and reverse osmosis concentrates. Full steam insulation application and automatic control mechanisms to minimize steam losses are used in many facilities where intensive steam consumption occurs. With the configuration of the application, fuel savings of 2-4% are achieved in steam boilers.

In order to prevent losses in production processes; adding the most important parts of equipment such as pumps, valves, adjustment knobs, pressure, flow regulators to the maintenance checklist, inspections of not only water systems but also heating and chemical distribution systems, drums, pumps and valves, regular cleaning of filters and pipelines, regular calibration of measurement equipment (thermometers, chemical scales, distribution/dosing systems, etc.) and routine inspection and cleaning of heat treatment units (incl. chimneys) at specified periods, effective maintenance-repair, cleaning and loss control applications can provide savings of 1-6% in water consumption (Hasanbeigi, 2010; Öztürk, 2014; TOB, 2021).

Industrial Steam Boilers

- ***Minimizing boiler discharge water (blowdown) in steam boilers***

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

  In automatic systems, blowdowns in boilers are continuously monitored and the system is re-analyzed with the water taken after blowdown. In the analysis, data such as dissolved and undissolved particles in the water and water density are processed.If the density for the boiler is above the system limits, the blowdown process is repeated. The system should be automated and the optimum blowdown frequency should be determined. When the blowdown frequency is reduced, the amount of wastewater decreases. The energy used for cooling this wastewater and cooling water are saved (IPPC BREF, 2009). By optimizing the steam boiler blowdown process, operating costs are reduced by providing savings in boiler water consumption, waste costs, conditioning and heating.

- ***Reuse of energy produced from steam condenser***

  With a simple change in the piping system, water feeding the water conditioning/decarbonization unit can be obtained from the outlet of the turbine condenser unit. This water has sufficient temperature for the conditioning/decarbonization unit. Therefore, this water does not need to be heated by steam produced by the heat exchanger system. Thanks to this study, significant steam gain can be achieved. Cooling water consumption can also be reduced (CPRAC, 2021).

- ***Reducing the blowdown amount by using deaerators in steam boilers***

  Free oxygen dissolved in the feed water of steam boilers and make-up water of hot water boilers and carbon dioxide formed by the breakdown of carbonates in boilers can cause corrosion in the form of pores, rust and melting in steam boilers, steam-using devices and especially installations. The effects of these gases increase as the fresh feed water ratio and system operating pressure increase. If these dissolved gases are not removed from the boiler feed water, the useful life of the systems in question is shortened, corrosion and various deformations can occur. These gases also cause excessive corrosion in carbon dioxide coils, steam devices and condensate pipes. Boiler feed water must be passed through a deaerator to be purified from dissolved gases such as oxygen and carbon dioxide.Deaerator systems are mechanical systems that allow dissolved gases to be removed from 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 deaerator system. In this way, corrosion formation is reduced and boiler efficiency is increased (TUBITAK MAM, 2016; TOB, 2021).

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

  Industrial cooling systems are used to cool heated products, processes and equipment. Closed and open circuit cooling systems can be used for this purpose, as well as industrial cooling systems where a fluid (gas or liquid) or dry air is used (IPPC BREF, 2001b; TOB, 2021). Air cooling systems consist of finned pipe elements, condensers and air fans (IPPC BREF, 2001b; TOB, 2021). Air cooling systems may have different operating principles. In industrial air cooling systems, the heated closed circuit cooler is cooled with air in condensers and heat exchangers (IPPC BREF, 2001b; TOB, 2021). In water cooling systems, the heated water is taken to a cooling tower and cooling of the water is provided in drip systems. However, despite the closed circuit operation of water-cooled systems, a significant amount of evaporation occurs. In addition, some water is discharged as blowdown in cooling systems. In this way, water is lost (IPPC BREF, 2001b; TOB, 2021). Using air cooling systems instead of water in cooling systems is effective in reducing evaporation losses and also in reducing the risk of contamination of the cooling water (IPPC BREF, 2001b; TOB, 2021). However, the capacity of air cooling systems is low. On the other hand, although there is no water use in air cooling systems, electricity is consumed to operate the air fans. Air cooling systems have a very wide range of uses. In addition, air cooling systems require a larger surface area than water cooling systems and may have higher costs (IPPC BREF, 2001b; TOB, 2021).

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