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MINISTRY OF AGRICULTURE AND FORESTRY
GENERAL DIRECTORATE OF WATER MANAGEMENT

Water Efficiency Campaign

Water Efficiency
Guide Documents Series

MANUFACTURING OF OTHER CHEMICAL PRODUCTS NOT ELSEWHERE CLASSIFIED

NACE CODE: 20.59

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Abbreviations

WTP	Wastewater Treatment Plant
EU	European Union
SSM	Suspended Solid Matter
BATRD	Best Available Techniques Reference Document
EMS	Environmental Management System
MEUCC	Republic of Türkiye Ministry of Environment, Urbanisation and Climate Change
NOM	Natural Organic Matter
EMAS	Eco-Management and Audit Programme Directive
EPA	United States Environmental Protection Agency
IPPC	Industrial Pollution Prevention and Control
ISO	International Standards Organisation
BAT	Best Available Techniques
NACE	Statistical Classification of Economic Activities
GDWM	General Directorate of Water Management
RO	Reverse Osmosis
MAF	Republic of Türkiye Ministry of Agriculture and Forestry
TSI	Turkish Statistical Institute
NF	Nanofiltration
MF	Microfiltration
UF	Ultrafiltration
GW	Groundwater
SW	Surface Water

1 Introduction

Our country is located in the Mediterranean basin, where the effects of global climate change are intensely felt, and is considered to be among the regions that will be 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 for 2022 is 1,313 m^3, and with human pressures and the effects of climate change, the usable annual water amount per capita is expected to fall below 1,000 cubic meters after 2030. It is obvious that if the necessary measures are not taken, Turkey will become a country suffering from water scarcity in the very near future, bringing with it many negative social and economic consequences. As can be understood from the results of the projections for the future, 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; It is based on the rational, sharing, equitable, efficient and effective use of water in all sectors, especially drinking water, agriculture, industry and households, by protecting the amount 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 more and more important every day. For this reason, it has become imperative to create a road map based on efficiency and optimization in order to protect and use limited water resources with sustainable management practices.

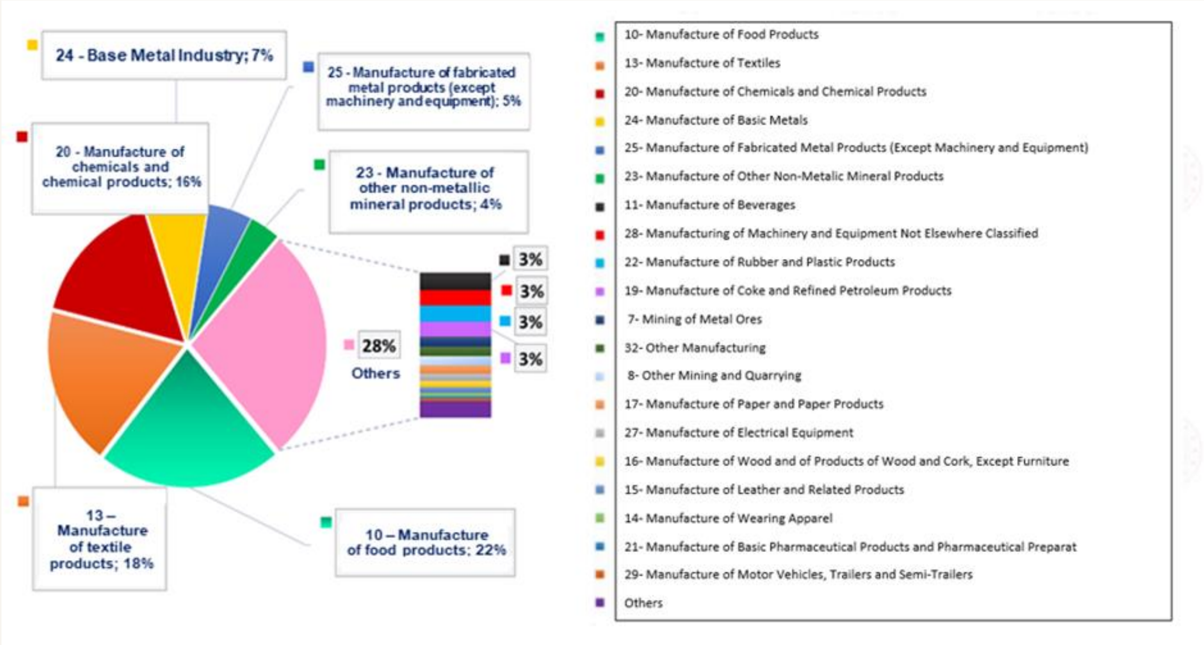
In the sustainable development vision determined by the United Nations, within the scope of Goal 7 of the Millennium Development Goals: Ensuring Environmental Sustainability, Goal 9 of the Sustainable Development Goals: Industry, Innovation and Infrastructure and Goal 12 of the Responsible Production 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) have been 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 high-level 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. The Ministry of Agriculture and Forestry, General Directorate of Water Management is carrying 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 2023-2033 period in the Industrial Water Efficiency Action Plan, and responsible and relevant institutions have been assigned 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 (MET) 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 use in industry by sector in our country

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 taking into account the EU best available techniques (BAT) and other clean production techniques. 500 techniques (BAT) for water efficiency in the guides 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 scope of the project carried out, environmental benefits, operational data, technical specifications-requirements and applicability criteria were taken into consideration during the determination of BATs for each sector. 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 and 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

The 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)

• Manufacture of food products (including 22 four-digit NACE Code sub-production areas)

• Manufacture of beverages (including 4 four-digit NACE Code sub-production areas)

• Manufacture of tobacco products (including 1 four-digit NACE Code sub-production area) sub-production area)

• Manufacture of textiles (including sub-production area represented by 9 four-digit NACE Codes)

• Manufacture of apparel (including sub-production area represented by 1 four-digit NACE Code)

• Manufacture of leather and related products (including sub-production area represented by 3 four-digit NACE Codes)

• Manufacture of wood, wood products and cork products (excluding furniture); Manufacture of articles made of straw, straw and similar materials (including sub-production areas represented by 5 four-digit NACE Codes)

• Manufacture of paper and paper products (including sub-production areas represented by 3 four-digit NACE Codes)

• Manufacture of coke and refined petroleum products (including sub-production areas represented by 1 four-digit NACE Code)

• Manufacture of chemicals and chemical products (including sub-production areas represented by 13 four-digit NACE Codes)

• Manufacture of basic pharmaceutical products and pharmaceutical preparations (including sub-production areas represented by 1 four-digit NACE Code)

• Manufacture of rubber and plastic products (including sub-production areas represented by 6 four-digit NACE Codes)

• Manufacture of other non-metallic mineral products (including sub-production areas represented by 12 four-digit NACE Codes)

• Basic metal industry (including sub-production areas represented by 11 four-digit NACE Codes)

• Manufacture of fabricated metal products (excluding machinery and equipment) (including sub-production areas represented by 12 four-digit NACE Codes) NACE Code sub-area represented)

• Manufacture of computers, electronic and optical products (including 2 four-digit NACE Code sub-areas)

• Manufacture of electrical equipment (including 7 four-digit NACE Code sub-areas)

• Manufacture of machinery and equipment not elsewhere classified (including 8 four-digit NACE Code sub-areas)

• Manufacture of motor vehicles, trailers and semi-trailers (including 3 four-digit NACE Code sub-areas)

• Manufacture of other transportation equipment (including 2 four-digit NACE Code sub-areas)

• Other manufacturing (including 2 four-digit NACE Code sub-areas)

• Installation and repair of machinery and equipment (including 2 four-digit NACE Code sub-areas)

• Production and distribution of electrical, gas, steam and air conditioning systems (including 2 four-digit NACE Code sub-areas)

• Collection, treatment and disposal activities; recovery of materials (including sub-production area represented by 1 four-digit NACE Code)

• Construction of external 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 sub-production area represented by 1 four-digit NACE Code)

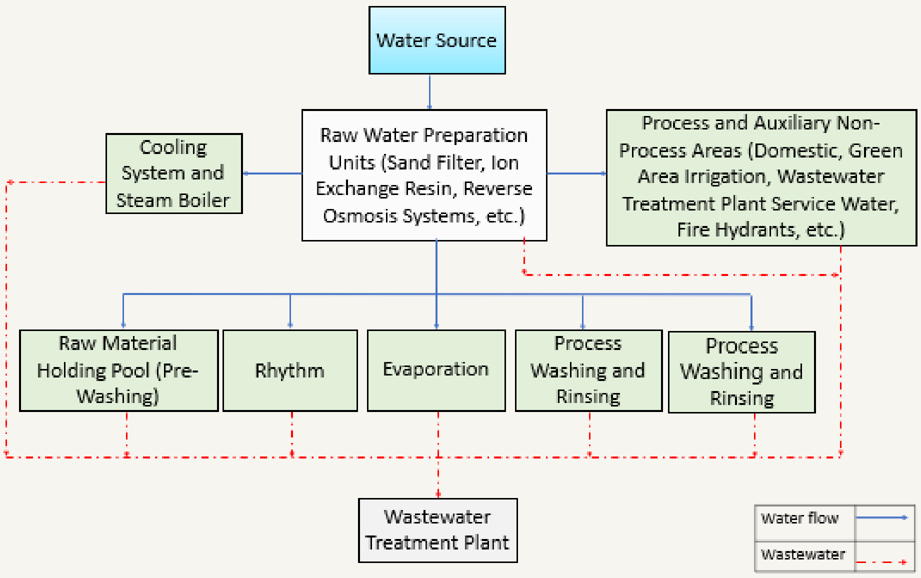
Manufacture of chemicals and chemical products

Under the Manufacture of chemicals and chemical products sector, the sub-production branches for which guidance documents have been prepared are as follows:

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

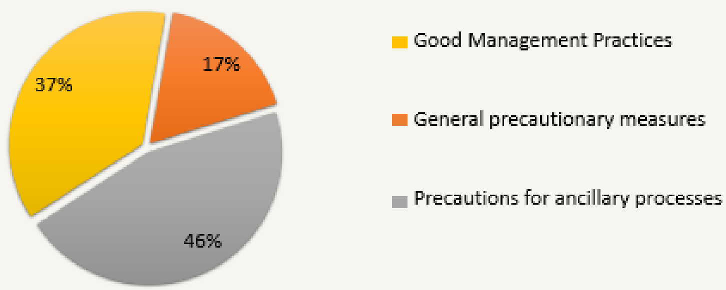
2.1 Manufacture of Other Chemical Products Not Elsewhere Classified (NACE 20.59)

Manufacture of Other Chemical Products Not Elsewhere Classified Sector
Water Flow Chart



	Minimum	Maximum
Specific Water Consumption of the Facilities Visited within the Scope of the Project (L/kg product)	0,4	235,8
Reference Specific Water Consumption (L/kg product)	0,5	600

Percentage Distribution of Water Efficiency Applications



The manufacturing of other chemical products not classified elsewhere covers many sectors from food to textile. Within the scope of the project; facilities producing gelatin, biodiesel, glycerin, plasticizer and auxiliary chemicals-adhesives for the textile sector were visited. Gelatin production processes consist of two basic stages in their simplest form: pre-treatment and extraction. The purpose of pre-treatment is to convert the water-insoluble collagen in the raw material into water-soluble gelatin by treating it with acid and/or alkali. In this stage, the dual method is often applied and the material is wetted with intense alkali after a short acid process. Then, gelatin can be obtained by going through five basic stages: washing, extraction, purification, concentration and drying. In addition to the melting and evaporation processes in gelatin production, water is also consumed for the purpose of washing and rinsing the process. In biodiesel production, plant oils generally contain free fatty acids, phospholipids, sterols, water, odorants and other impurities, so they cannot be used directly as fuel. Therefore, it needs to be chemically modified by transesterification (re-esterification), pyrolysis, microemulsion and thinning processes. Among these, transesterification is a method that aims to produce clean and environmentally friendly biodiesel from plant oils. In the transesterification process, plant oils react with alcohol under acid or base catalysts to form glycerin and fatty acid ester. At this stage, the ester becomes fuel, while glycerin is used as a valuable product in many sectors. In addition to the neutralization and melting processes in biodiesel production, water is also consumed for bottle washing purposes. Within the scope of the project; in addition to the chemical preparation processes in other facilities visited (production of auxiliary chemicals-adhesives etc. for the plasticizer and textile sector), water is also consumed in process washing and rinsing lines.

https://cdn.autobild.es/sites/navi.axelspringer.es/public/media/image/2022/07/razones-europa-quiere-prohibir-biodiesel-2769563.jpg

There are also waters that go directly to the product depending on the final product produced in the sector. Significant amounts of water are consumed for filter washing, resin regeneration and membrane cleaning processes in raw water preparation units such as active carbon filters, ion exchange resins and reverse osmosis used to produce the demineralized water needed in the sector. In addition, water consumption occurs in auxiliary units such as cooling towers and steam boilers.

In the manufacturing sector of other chemical products not classified elsewhere, the reference specific water consumption is between 0.5 - 600 L/kg. The specific water consumption of the production line analyzed within the scope of the study is 0.4 - 235.8 L/kg. With the implementation of good management practices, general precautions and measures related to auxiliary processes, it is possible to achieve a water recovery of 24 - 63% in the sector.
Since the most intensive water consumption in the relevant sector is in gelatin production, the water flow chart has been prepared by taking gelatin production processes into consideration.

20.59 The priority water efficiency application techniques recommended under the NACE code for Manufacture of Other Chemical Products Not Elsewhere Classified are presented in the table below.

NACE Code	NACE Code Explanation		Industry-Prioritized Best Available Techniques
20.59	Manufacture of other chemical products not classified elsewhere		Good Management Practices
		1.	Using an integrated wastewater management and treatment strategy to reduce wastewater volume and pollutant load
		2.	Establishing an environmental management system
		3.	Preparing water flow charts and mass balances for water
		4.	Preparing a water efficiency action plan to reduce water usage and prevent water pollution
		5.	Providing technical training to personnel to reduce and optimize water usage
		6.	Producing good production planning to optimize water consumption
		7.	Determining water efficiency targets
		8.	Monitoring the quantity and quality of water used in production processes and auxiliary processes and the wastewater generated and adapting this information to the environmental management system
			General Precautions
		1.	Minimizing spills and leaks
		2.	Recovering water from rinse solutions and reusing the recovered water in processes suitable for 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, etc.
		4.	Equipment cleaning, general cleaning, etc. Use of pressure washing systems in processes
		5.	Reuse of filter wash water in filtration processes, reuse of relatively clean cleaning water in production processes and reduction of water consumption by using cleaning in place systems (CIP)
		6.	Avoidance of use of drinking water in production lines
		7.	Use of cooling water as process water in other processes
		8.	Detection and reduction of water losses
		9.	Use of automatic control-shutoff valves to optimize water usage
		10.	Keep production procedures documented and used by employees to prevent water and energy waste
		11.	Reuse of pressure filtration backwash water before water softening at appropriate points
		12.	Optimization of regeneration frequency and duration (including rinses) in water softening systems
		13.	Covered storage and impermeable waste/scrap area to prevent the transfer of toxic or hazardous chemicals to the aquatic environment
		14.	Storage, preservation and prevention of mixing of substances that pose a risk to the aquatic environment (such as oils, emulsions, binders) with wastewater after use
		15.	Use of suitable wastewater as steam boiler feed water by treating it where technically possible
		16.	Clean Preventing water flows from mixing with polluted water flows
		17.	Determining wastewater flows that can be reused with or without treatment by characterizing the quantities and qualities of wastewater at all wastewater generation points
		18.	Using closed-loop water cycles in appropriate processes
		19.	Using computer-aided control systems in production processes

2.1.1 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 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 the 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).

Expamle of Industrial Wastewater Treatment Plant

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

• **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, it is necessary to monitor the amount and quality of water and wastewater used in production processes and auxiliary processes (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 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:
• 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 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 (ÇŞİDB, 2020e).

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

Planning the process of turning a raw material into a 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 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).

- **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 and wastewater amounts and prevent water pollution in industrial facilities is important for water efficiency. At this point, water needs should be determined throughout the facility and in production processes, quality requirements at water usage points should be determined, wastewater generation points and wastewater characterization should be carried out (TOB, 2021). At the same time, it is necessary to determine the measures to be implemented to reduce water consumption, wastewater generation and pollution loads, to conduct their feasibility studies and to prepare action plans for the short, medium and 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 achieving water efficiency in industrial facilities is to determine targets (TOB, 2021). For this, a detailed water efficiency analysis should be carried out on a process basis. Thus, 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 charts and mass balances for water**

Determining water use 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 on a facility-wide and production process basis; It facilitates the determination of unnecessary water use points and high water use points, evaluation of water recovery opportunities, process modifications and determination of water losses (TOB, 2021).

2.1.2 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 consideration:
• Adding pumps, valves, level switches, pressure and flow regulators to the maintenance checklist,
• Conducting inspections not only in the water system but also especially in heat transfer and chemical distribution systems, broken and leaking pipes, barrels, pumps and valves,
• Regular cleaning of filters and pipelines,
• Calibrating measuring equipment such as chemical measuring and distribution devices, thermometers, etc., checking and monitoring them at routinely determined periods (IPPC BREF, 2003).

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

• Minimizing spills and leaks

Both raw material and water losses can occur due to spills and leaks in businesses. In addition, if wet cleaning methods are used in cleaning the areas where spills occur, water consumption, wastewater amounts and pollution loads of wastewater may also increase (TOB, 2021). In order to reduce raw material and product losses, 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, and savings of 1-5% can be achieved in raw water consumption. The initial investment costs required for the application consist of the establishment of new pipelines and reserve tanks (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 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 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). Re-use of cooling waters can save 2-9% in total water consumption (Greer et al., 2013). Up to 10% in energy consumption can be saved (Öztürk, 2014; TOB, 2021).

- **Where technically possible, appropriate wastewater should be treated and used as steam boiler feed water.**

Although it is difficult to implement in industrial facilities, it is possible to purify suitable 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). A combination of membrane systems (ultrafiltration (UF), nanofiltration (NF) and reverse osmosis (TO) 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**

By determining the wastewater generation 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 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 in cases where it is possible to recover high amounts of wastewater and energy (IPPC BREF, 2006).

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

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

- **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 achieve savings of 1-5% in raw water consumption (TOB, 2021).

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

By determining and characterizing wastewater generation points in industrial facilities, it is possible to reuse various wastewater flows with or without treatment (Öztürk,2014; TUBİTAK MAM, 2016; TOB, 2021). 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 flows 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 processes (Singh et al., 2014).

• 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 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).

• 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 used 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).

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

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

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

Nowadays, rainwater harvesting is frequently preferred especially in regions with low rainfall, as 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 (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 in 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 reuse the collected water by recovering 95% of its use with biological treatment (Şahin, 2010).

• Optimizing the regeneration frequency and duration (including rinsing) in water softening systems

Cationic ion exchange resins, which are one of the most frequently 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 wastewaters are usually directly removed. However, if the washing and final rinsing 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 time entering the softening system, this frequency also varies depending on the calcium concentration in the raw water. For this reason, online hardness measurement is applied when determining the regeneration frequency. Thus, regeneration frequencies can be optimized and excessive washing and rinsing or backwashing with salt water can be prevented by using online hardness sensors.

- **Reuse of pressurized filtration backwash waters at appropriate points before water softening**

Softened waters with low calcium and magnesium concentrations are needed for many industrial processes. With water softening systems, calcium, magnesium and some other metal cations in hard water are removed from the water and soft water is obtained.

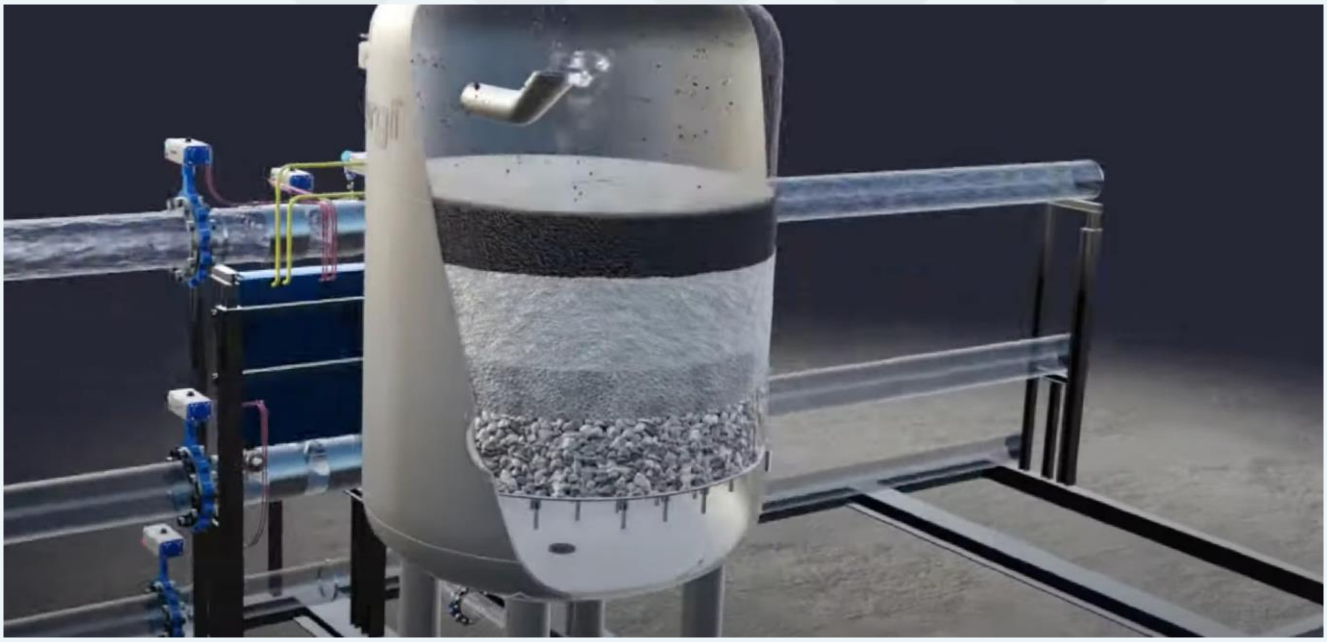
Savings are achieved by reusing pressurized filtration backwash waters at appropriate points before water softening. This measure is similar in content to applications such as “Reuse of filter backwash waters in filtration processes, relatively cleaning waters in production processes, and reduction of water consumption by using on-site cleaning systems”.

• Storage, preservation and prevention of mixing of substances that pose a risk to the aquatic environment (such as oils, emulsions, binders) with wastewater after use as much as possible

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

• Construction of closed storage and impermeable waste/scrap areas to prevent the transport of toxic or hazardous chemicals for the aquatic environment

Closed and impermeable waste/scrap storage areas can be constructed in industrial facilities to prevent the transport of toxic or hazardous chemicals for the aquatic environment to the receiving environment. 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 constructed 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.



Water Softening Systems

https://www.youtube.com/watch?v=Deazp2Ukgio

- ***Use of closed loop water cycles in appropriate 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 refrigerant 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 suitable production processes.

- ***Preventing the need for rinsing between activities by using compatible chemicals in successive processes***

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

Various chemicals are used in industrial facilities to increase washing and rinsing efficiency. The fact that these chemicals are compatible and act as solvents shows a positive trend in increasing efficiency. Therefore, dirt on the material can be removed in a shorter time and more effectively, and the amount of water used in washing processes can be significantly reduced. In this case, even if the amount of wastewater can be reduced, the chemical loads carried by the wastewater can increase. By ensuring that the solvent-containing washing waters used in washing and rinsing processes are reused, these negative effects can be minimized.

Water savings of 25-50% are possible with the reuse of washing waters. Reserve tanks and new pipelines may be needed for the application. In alternative cases, the washing solution is kept directly in the system and can be used repeatedly until it loses its properties.

- ***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 (TUBITAK MAM, 2016). Thus, it becomes possible to develop measures to increase 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 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 increases the technical, economic and environmental benefits to be obtained (TUBITAK MAM, 2016).

- **Keeping production procedures documented and used 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). Determining and implementing appropriate procedures in production processes ensures more efficient use of resources (such as raw materials, water, energy, chemicals, personnel, and time) and ensures reliability and quality in production processes (Ayan, 2010). Having documented production procedures in production processes contributes to the evaluation of business performance and the development of the ability to develop immediate reflexes to solve problems (TUBITAK MAM, 2016; TOB, 2021). Effective implementation and monitoring of procedures created specifically for production processes is one of the most effective ways to ensure product quality, receive feedback, and develop 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 creating and monitoring 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).

• Implementing time optimization in production and organizing all processes to be completed in the shortest time

Planning the process from raw material to product in industrial production processes using the least amount of processes is an effective practice in reducing labor costs, resource usage costs and environmental impacts and ensuring efficiency. In this context, it may be necessary to review production processes and revise them to use the fewest process steps (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).

• 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.)

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 treating this gray water with various treatment processes and using it in areas that do not require high water quality.

Computer Aided Control System
https://sayachizmet.com/wp-content/uploads/2020/01/SCADA-nedir-1280x720-1.jpg.webp

• ***Reuse of filter wash water in filtration processes, reuse of relatively clean cleaning water in production processes and reduction of water consumption by using cleaning in place systems (CIP)***

Wastewater originating 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 are achieved (URL - 1, 2021).

Regeneration wastewater formed after the regeneration process is soft water with high salt content and constitutes approximately 5-10% of total water consumption. Regeneration wastewater is 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 required. Reuse of regeneration wastewater provides a reduction of approximately 5-10% in water consumption, energy consumption, wastewater volumes and salt content of wastewater (Öztürk, 2014). 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), the potential payback period is estimated to 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. The concentrates formed in RO systems used for additional hardness removal can be used in garden irrigation, in-plant and tank-equipment cleaning (TUBİTAK MAM, 2016; TOB, 2021). In addition, with the structuring of monitoring for raw water quality, it is possible to re-evaluate RO concentrates by feeding them back into raw water tanks and mixing them (TOB, 2021).

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

Reverse Osmosis System

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

2.1.3 Precautions Regarding Auxiliary Processes

BATs for 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 them with a computer system

If steam lines are not designed properly in facilities, 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, steam losses may occur. This situation 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 additional soft water used 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 (including 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
https://hohwatertechnology.com/wp-content/uploads/2021/03/boiler_175594851-1024x688.jpeg

• Water savings by reusing steam boiler condensate

When indirect heating techniques with steam are used to transfer thermal energy in production processes, the recovery of condensed steam (condensate) is an effective application in terms of reducing water consumption (IPPC BREF, 2009). An average of 5% reduction in water consumption can be achieved by recovering condensate water (Greer et al., 2013). In addition, the potential payback period varies between 4-18 months (when energy savings are also taken into account) (Öztürk, 2014; TUBİTAK MAM, 2016).

• Preventing excessive steam losses due to boiler discharge

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

• 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, the blowdowns in the boilers are continuously monitored and the system is re-analyzed with the water taken after the blowdown. In the analysis, data such as dissolved and undissolved particles in the water and water density are processed. If the density for the boiler is above the system limits, the blowdown process is repeated. The system should be automated and the optimum blowdown frequency should be determined. When the blowdown frequency is reduced, the amount of wastewater decreases. 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 the steam condenser

With a simple change to the piping system, the 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 in steam boilers by using deaerators

Free oxygen dissolved in the feed water of steam boilers and the 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, and corrosion and various deformations may occur. These gases also cause excessive corrosion in carbon dioxide serpentines, steam devices and condensate pipes. Boiler feed waters 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 evaporated from the water by giving 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).

METs related to cooling systems

• Using a closed-loop cooling system to reduce water use

Closed-loop cooling systems significantly reduce water consumption compared to open-loop systems with more intensive water use. In closed-loop systems, while the same water is recirculated in the system, cooling water addition is generally required as much as the amount of evaporated water. Evaporation losses can also be reduced by optimizing cooling systems.

• Increasing the number of cycles in closed-loop cooling systems, improving the quality of the make-up water and reducing water consumption

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

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

It is possible to save water by cooling with dry air in cases where the cooling need is low.

• Water recovery with tower cooling application in systems without closed loop

Cooling towers are divided into two according to their working principles: counter-flow and cross-flow. In counter-flow cooling towers, the water flows downwards while the air flow moves upwards, while in cross-flow cooling towers, the water flows downwards while the air flow moves horizontally. The water exposed to fresh air cools down until it reaches the cold water pool, where it is collected and sent to the facility. Some of the water evaporates during these processes. The air, whose humidity increases as a result of the evaporation of the water, is discharged into the atmosphere from the fan chimney at the top of the tower. Evaporation losses in cooling towers should be managed effectively.

Various chemicals are used in cooling towers to prevent the formation of bacteria and parasites and to control lime residues. These chemicals condense with the evaporation of water and cause unwanted sediments and deposits in the tower. A blowdown system is used to keep this condensation at a certain level. Blowdown waters can be purified and recovered by using membrane filtration systems or ion exchange resins. Recycling of blowdown wastewater is important in terms of water efficiency.

• Using surface runoff water with a separate collection system for cooling water, process water, etc.

In most industrial facilities, wastewater is generated from process sources or non-process areas. The wastewater generated can be treated and reused in appropriate places. By reusing the wastewater generated in the facility after treatment, savings can be achieved at varying rates in various industrial facilities. Surface runoff water can be collected with a separate collection system and used as cooling water (TOB, 2021).

Tower Type Cooling Systems
https://www.revueconflits.com/geopolitique-de-lenergie-francois-campagnola

• Increasing the number of cycles by using corrosion and scale inhibitors in closed water cycle systems

Cooling towers and evaporative condensers are effective and low-cost systems that remove heat from air conditioning and industrial process cooling systems (IPPC BREF, 2001b; TOB, 2021).

More than 95% of the circulating water in these systems can be recovered (TUBITAK MAM, 2016). In cooling systems, since a portion of the recirculation water is operated on the principle of evaporation, impurities remain in the recirculation water and impurity concentrations gradually increase in each cycle. Impurities that can enter the cooling system together with air can cause contamination in recirculation water (TUBITAK MAM, 2016). If impurities and pollutants are not effectively controlled, they can cause scale and corrosion formation, unwanted biological growth and sludge accumulation. This situation can become a chronic problem that causes the efficiency of heat transfer surfaces to decrease and operating costs to increase. In this case, a water treatment program specially designed in terms of the quality of the feed water given to the cooling system, the construction material of the cooling water system and operating conditions should be implemented. In this context; blowdown control, control of biological growth, corrosion control, avoiding the use of hard water, using sludge control chemicals, using filtration and screening systems may be appropriate (TUBITAK MAM, 2016). In addition, the establishment of an effective cleaning procedure and program and its periodic implementation is a good management practice in terms of protecting cooling systems. Corrosion is one of the most important problems in cooling systems. In tower recirculation water, as the degree of hardness increases, the formation of limestone and deposits on the walls and the dissolved solids (sulfate, chloride, carbonate, etc.) that cause corrosion will cause surface wear over time. In addition, the formation of deposits negatively affects heat transfer and reduces energy efficiency. In order to prevent these negativities, a chemical conditioning program that prevents scale and corrosion should be implemented, disinfection should be carried out with biocides that prevent biological activation, cooling towers in use should be subjected to chemical and mechanical cleaning at least twice a year to remove deposits, and the hardness and conductivity values of the makeup water should be as low as possible (IPPC BREF, 2001; Kayabek et al., 2005). In order to increase the quality of the makeup water, it may be necessary to treat (condition) it using an appropriate treatment system. In addition, unwanted microbial growth should be kept under control (IPPC BREF, 2001b; TOB, 2021). Blowdown occurs in cooling systems as well as in steam boilers due to micro-residues and deposits in the cooling water. The deliberate draining of the cooling system to balance the increasing density of solids in the cooling system is called cooling blowdown. By pre-treating cooling water with appropriate methods and continuously monitoring the cooling water quality, biocide usage and blowdown amounts can be reduced (TUBITAK MAM, 2016). Although the investment cost depends on the scale of the application, the payback period for the expected investment expenses varies between 3 and 4 years (IPPC BREF, 2001).

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

Industrial cooling systems are used to cool heated products, processes and equipment. For this purpose, closed and open circuit cooling systems can be used, as well as industrial cooling systems 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 water is cooled by air in closed circuit cooling condensers and heat exchangers (IPPC BREF, 2001b; TOB, 2021). In water cooling systems, the heated water is taken to a cooling tower and the water is cooled in drip systems. However, despite the closed circuit operation of water-cooled systems, a significant amount of evaporation occurs. In addition, since some water is discharged as blowdown in cooling systems, water is lost in this way (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 cooling water (IPPC BREF, 2001b; TOB, 2021).

- ***Avoiding unnecessary cooling processes by determining processes that require wet cooling***

The boundaries of the plant site affect design parameters such as cooling tower height. In cases where it is necessary to reduce the tower height, a hybrid cooling system can be applied. Hybrid cooling systems are a combination of evaporative and non-evaporative (wet and dry) cooling systems. A hybrid cooling tower can be operated as a completely wet cooling tower or as a combined wet/dry cooling tower depending on the ambient temperature (TUBITAK MAM, 2016). In regions where there is insufficient cooling water or where water costs are high, the evaluation of dry cooling systems or hybrid cooling systems can be an effective solution to reduce the amount of cooling water (TUBITAK MAM, 2016).

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

Cooling waters are collected separately and used for cooling purposes or re-evaluated in appropriate processes (EC, 2009). A water softening system is required for the healthy operation of this system. Cooling water has suitable water quality for re-use as cleaning and irrigation water. However, since it contains some hardness in its use as cooling water, additional softening is required to prevent corrosion problems that will occur over time. These waters must undergo an appropriate disinfection process before being re-used as cooling water or in the process. In addition, it is possible to reuse the water in question not only in cooling processes but also in all production processes by purifying it with appropriate purification techniques (membrane filtration, advanced oxidation, chemical precipitation, granular active carbon adsorption, etc. processes) (TUBITAK MAM, 2016). As the hardness level of the cooling water increases, limestone and deposits form on the walls. Deposit formation negatively affects heat transfer, reduces energy efficiency and increases energy costs. With the increase in evaporation in the system, the ion concentration and conductivity value in the water increase. In order to prevent these negativities, the cooling water should be chemically treated to prevent lime and corrosion, disinfected with a biocide that prevents biological activation, the cooling towers should be subjected to chemical and mechanical cleaning at least twice a year and the deposits should be cleaned, and the hardness and conductivity values should be kept as low as possible (TUBITAK MAM, 2016).

• Reducing evaporation losses in closed-loop cooling water

A certain amount of water evaporates during the cooling of heated water in cooling systems. Therefore, cooling water is added in the amount of evaporated water in closed-loop cooling systems. Evaporation losses can be prevented by optimizing cooling systems. In addition, applications such as purifying the make-up water added to cooling systems and preventing biological growth in cooling systems can also reduce the amount of blowdown. Within the scope of field studies carried out, blowdown water formed in the cooling system is generally removed by directly discharging it into the wastewater channel. Up to 50% savings can be achieved in the water consumption of cooling systems by reusing the blowdown water of the cooling system. The installation of new pipelines and reserve tanks may be required for the implementation of this measure. (TOB, 2021).

BATs for ventilation and air conditioning systems

• Reuse of liquid formed by condensation from the ventilation system

Condensation water with good water quality can be produced in the system during the ventilation cycle. For example, in a facility in Spain, condensate water with a conductivity of approximately 200 µS in the ventilation system is collected in a tank and used for washing the automatic galvanizing line (MedClean, n.d).

• Replacing old equipment in the ventilation system with ion exchange resins (systems that produce demineralized water) based on the principle of reverse osmosis and reusing the water

By using ion exchange resins in the ventilation system, the conductivity of the final outlet water is brought to a conductivity level suitable for use in equipment cleaning. For example, in a facility in Spain, by replacing the equipment in the ventilation system with ion exchange resins, outlet water with a conductivity value of approximately 1000 µS is obtained and reused in the system (MedClean, n.d).

BATs related to cogeneration systems

• Use of hot water produced in cogeneration systems in heating processes

By including cooling systems in cogeneration systems (trigeneration), it is possible to convert 10-30% of the efficiency losses into hot water, water vapor, cold air, hot air and water (absorption heat exchangers must be used for this). Thus, it is possible to meet a portion of the energy required for processes such as cooling and drying in the facility from the waste heat in cogeneration systems. Energy costs can be reduced by up to 40% in facilities using cogeneration systems (TUBITAK MAM, 2016).

• Use of cold water produced in cogeneration systems in cooling processes

It is possible to save water by using cold water produced in cogeneration systems in cooling processes (TUBITAK MAM, 2016).

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