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MINISTRY·OF·AGRICULTURE·AND·FORESTRY¶
GENERAL·DIRECTORATE·OF·WATER·MANAGEMENT¶

WATER EFFICIENCY GUIDANCE DOCUMENTS SERIES

INTERIOR AND OUTER TYRE MANUFACTURING

NACE KODU: 22.11

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CONTENTS

Abbreviations

WWTP Wastewater Treatment Plant

EU European Union

SUS Suspended Solids

BREF Best Available Techniques Reference Document

EMS Environmental Management System

CSIDB Republic of Turkey Ministry of Environment, Urbanization and Climate Change

DOM Natural Organic Matter

EMAS Eco Management and Audit Program Directive

EPA United States Environmental Protection Agency

IPPC Industrial Pollution Prevention and Control

ISO International Organization for Standardization

MET Best Available Techniques

NACE Statistical Classification of Economic Activities

SYGM General Directorate of Water Management

RO Reverse Osmosis

TOB Republic of Turkey Ministry of Agriculture and Forestry

TÜİK Turkish Statistical Institute

NF Nanofiltration

MF Microfiltration

UF Ultrafiltration

GW Groundwater

SW Surface Water

1 Introduction

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

For the year 2022, the annual amount of water available per capita in Turkey is 1,313 m³, and it is expected that the annual amount of water available per capita will fall below 1,000 cubic meters after 2030 due to human pressures and the effects of climate change. If the necessary measures are not taken, it is obvious that Turkey will become a water scarce country in the very near future and will bring many negative social and economic consequences. As it can be understood from the results of future projections, the risk of drought and water scarcity awaiting our country necessitates the efficient and sustainable use of our existing water resources.

The concept of water efficiency can be defined as *"using the least amount of water in the production of a product or service"*. The water efficiency approach is based on the rational, sharing, equitable, efficient and effective use of water in all sectors, especially in drinking water, agriculture, industry and household use, in a way that protects water in terms of quantity and quality and takes into account not only the needs of humans but also the needs of all living things with ecosystem sensitivity.

With the increasing demand for water resources, changes in precipitation and temperature regimes as a result of climate change, increasing population, urbanization and pollution, the fair and balanced distribution of usable water resources among users is becoming more and more important every day. Therefore, it has become imperative to create a road map based on efficiency and optimization in order to conserve and use limited water resources through sustainable management practices.

In the vision of sustainable development set by the United Nations, *Goal 7: Ensuring Environmental Sustainability* from the Millennium Development Goals, *Goal 9: Industry, Innovation and Infrastructure* from the Sustainable Development Goals and *Goal 12: Responsible Production and Consumption* from the Sustainable Development Goals include issues such as efficient, fair and sustainable use of resources, especially water, environmentally friendly production and consumption with concern for future generations.

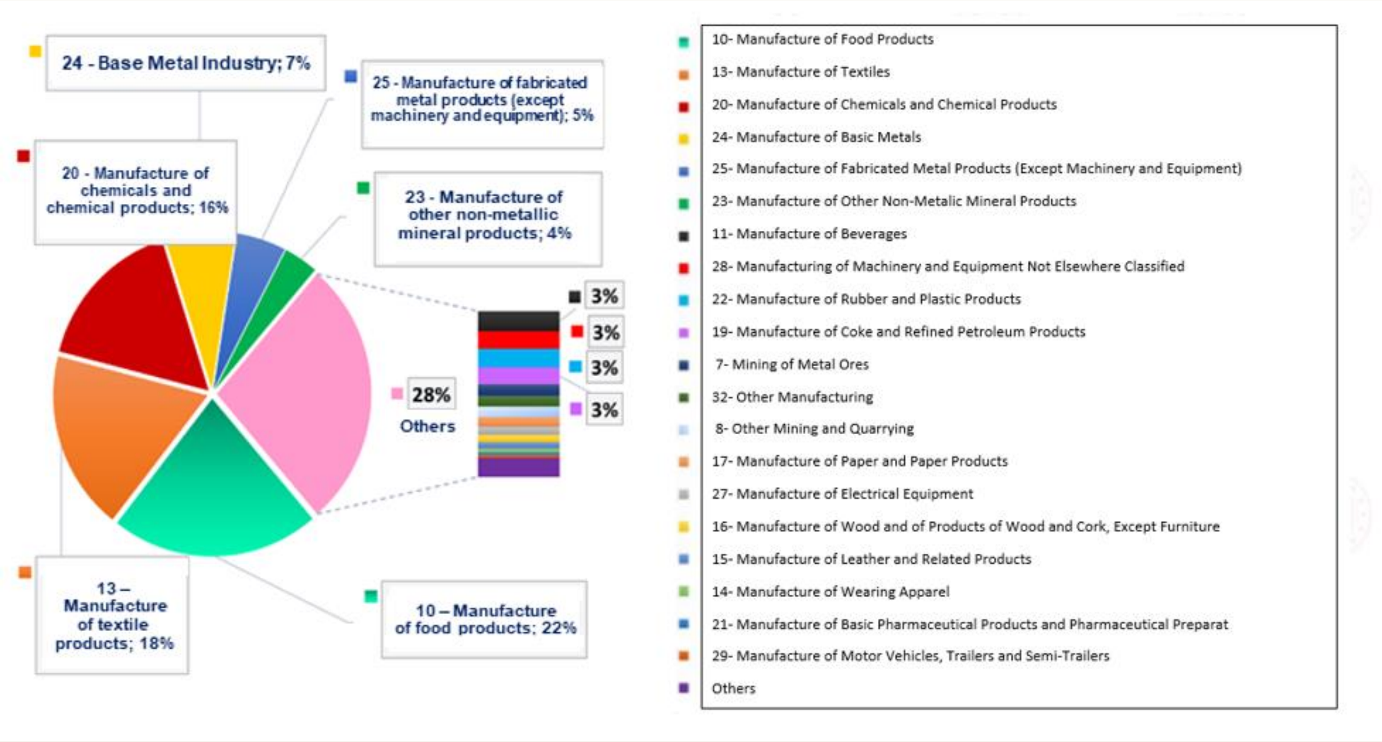
Within the scope of the European Green Deal, where member countries have agreed on goals such as implementing a clean, circular economy model with a carbon neutral target, expanding the efficient use of resources and reducing environmental impacts, actions emphasizing water and resource efficiency in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

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

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

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

As in the world, the sectors with the highest share in water consumption in our country are food, textile, chemical and basic metal sectors. Within the scope of the studies, field visits were carried out in enterprises representing 152 sub-sectors in 35 main sectors, mainly food, textile, chemical and basic metal industries, representing production areas with different capacities and diversity within the scope of NACE Codes operating in our country and with high water consumption, and data on water supply, sectoral water use, wastewater generation, recycling were obtained and information was provided on best available techniques (BAT) and sectoral reference documents (BREF) published by the European Union, water efficiency, clean production, water footprint, etc.



Sectoral distribution of water use in industry in Turkey

As a result of the studies, specific water consumption and potential savings rates for the processes of enterprises for 152 different 4-digit NACE codes with high water consumption were determined, and water efficiency guidance documents were prepared by taking into account the EU best available techniques (BAT) and other cleaner production techniques. The guidelines include 500 techniques (BATs) for water efficiency;
(i) Good Management Practices, (ii) General Measures, (iii) Measures Related to Auxiliary Processes and (iv) Sector Specific Measures.

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

2 Scope of the Study

Guidance documents prepared within the scope of water efficiency measures in industry cover the following main sectors:

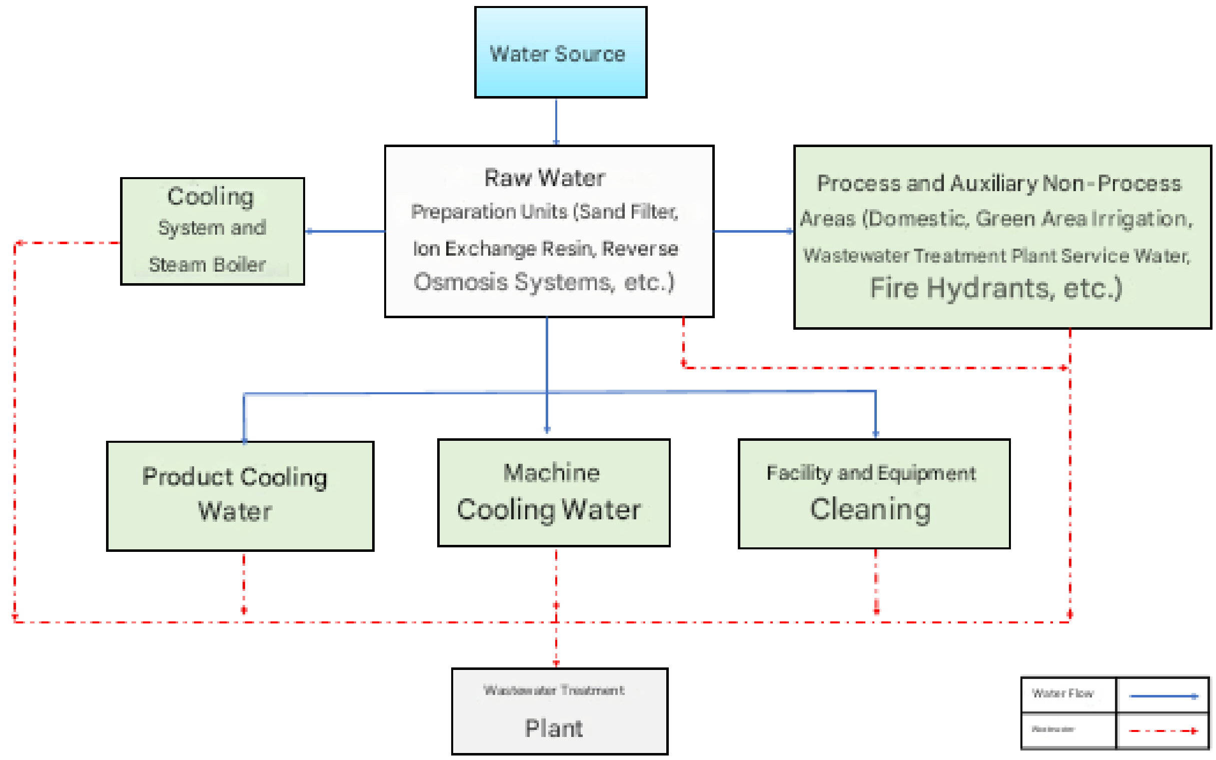
- Crop and animal production and hunting and related service activities (including sub-production area represented by 6 four-digit NACE codes)
- Fisheries and aquaculture (including sub-production area represented by 1 four-digit NACE Code)
- Coal and lignite extraction (including sub-production represented by 2 four-digit NACE codes)
- Service activities in support of mining (including sub-production area represented by 1 four-digit NACE Code)
- Metal ores mining (including the sub-production area represented by 2 four-digit NACE codes)
- Other mining and quarrying (including sub-production represented by 2 four-digit NACE codes)
- Manufacture of food products (including 22 sub-production areas represented by four-digit NACE codes)
- Manufacture of beverages (including sub-production represented by 4 four-digit NACE codes)
- Manufacture of tobacco products (including sub-production area represented by 1 four-digit NACE Code)
- Manufacture of textile products (including 9 sub-production areas represented by four-digit NACE codes)
- Manufacture of apparel (including sub-production area represented by 1 four-digit NACE Code)
- Manufacture of leather and related products (including sub-production area represented by 3 four-digit NACE codes)
- Manufacture of wood, wood products and cork products (except furniture); manufacture of articles made of thatch, straw and similar materials (including sub-production area represented by 5 four-digit NACE Codes)
- Manufacture of paper and paper products (including sub-production area represented by 3 four-digit NACE codes)
- Manufacture of coke and refined petroleum products (including sub-production area represented by 1 four-digit NACE Code)
- Manufacture of chemicals and chemical products (including 13 sub-production areas represented by four-digit NACE codes)
- Manufacture of basic pharmaceutical products and pharmaceutical ingredients (including sub-production area represented by 1 four-digit NACE Code)
- Manufacture of rubber and plastic products (including sub-production area represented by 6 four-digit NACE codes)
- Manufacture of other non-metallic mineral products (including 12 sub-production areas represented by four-digit NACE codes)
- Basic metal industry (including 11 sub-production areas represented by four-digit NACE codes)
- Manufacture of fabricated metal products (excluding machinery and equipment) (including 12 sub-production areas represented by four-digit NACE codes)
- Manufacture of computers, electronic and optical products (including sub-production area represented by 2 four-digit NACE codes)
- Electrical equipment manufacturing (including sub-production area represented by 7 four-digit NACE codes)
- Manufacture of machinery and equipment not elsewhere classified (including sub-production area represented by 8 four-digit NACE codes)
- Manufacture of motor vehicles, trailers (semi-trailers) and semi-trailers (semi-trailers) (including sub-production area represented by 3 four-digit NACE codes)
- Manufacture of other means of transportation (including the sub-production area represented by 2 four-digit NACE codes)
- Other manufacturing (including sub-production represented by 2 four-digit NACE codes)
- Installation and repair of machinery and equipment (including sub-production represented by 2 four-digit NACE codes)
- Electricity, gas, steam and ventilation system production and distribution (including sub-production area represented by 2 four-digit NACE codes)
- Waste collection, reclamation and disposal activities; recovery of materials (including sub-production represented by 1 four-digit NACE Code)
- Construction of non-building structures (including sub-production area represented by 1 four-digit NACE Code)

- Warehousing and supporting activities for transportation (including sub-production area represented by 1 four-digit NACE Code)
- Accommodation (including sub-production area represented by 1 four-digit NACE Code)
- Educational Activities (Higher Education Campuses) (including sub-production area represented by 1 four-digit NACE Code)
- Sports, leisure and recreation activities (including sub-production area represented by 1 four-digit NACE Code)

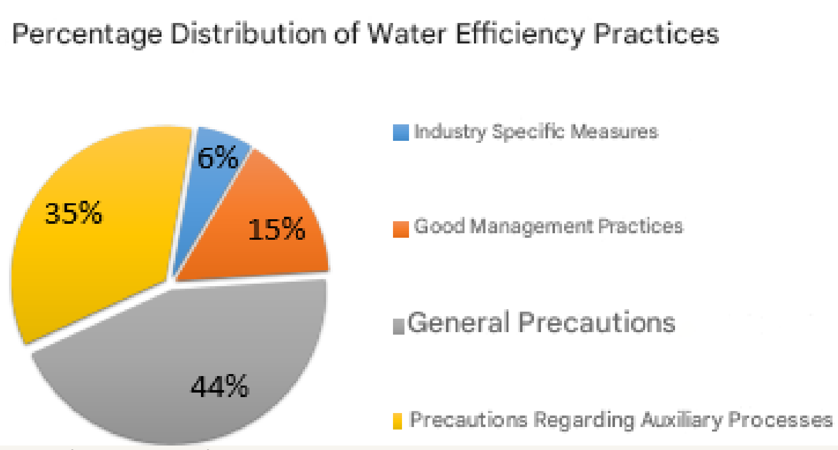
Manufacture of rubber and plastic products

Under the rubber and plastic products manufacturing sector, the sub-production branches for which guidance documents were prepared are as follows

22.11	Manufacture of inner and outer tubes; tire tread and reprocessing
22.19	Manufacture of other rubber products
22.21	Manufacture of plastic sheets, plates, tubes and profiles
22.22	Implications of packaging materials such as plastic bags, bags, sacks, boxes, carboys, bottles, spools, etc.
22.23	Manufacture of plastic construction materials
22.29	Manufacture of other plastic products



	Minimum	Maximum
Specific Water Consumption of Facilities Visited within the Scope of the Project (L/kg product)	1.04	15.6
Reference Specific Water Consumption (L/kg product)	8.6	



2.1 Inner and Outer Tire Manufacturing (NACE 22.11)

In the manufacture of inner and outer tires, tires are obtained by using natural rubber, synthetic rubber, carbon black and various chemicals together with oil as the main raw materials. The mixed inputs are heated at about 120 °C to form rubber sheets. The rubber sheets are brought to a certain width and thickness during the extrusion process. At this stage, the treads on the outer surface of the tire and the sidewall parts on the side of the tire are formed. With the help of continuously rotating rolls, steel threads and fabric threads are coated on the tire. At this stage, called the rolling process, the tire gains strength. In the so-called heel process, where steel wires are added, the coated heels are formed to serve as a frame for car rims. In the molding stage, all components and materials are placed in the molding press. The "carcass", which is the frame in which the tire's treads are located, and the "beads" and "sidewalls", which are the frame in which the wheels are fixed to the rim, are assembled. With the belt and treads installed, it is transferred to the secondary molding press. In the curing (vulcanization) stage, the tyres are placed in a fixed mould and heat and pressure are applied from inside and outside. Sulfur and other chemicals react with the tire to give it flexibility.

In plants producing various materials such as tubes, pipes, hoses, etc. from vulcanized rubber, there is no water consumption in basic production processes. However, machine and product cooling water consumption occurs in plants producing automobile tires where the vulcanization process takes place in the plant. In the production of the "tread" part of the tire, which is the rubber part of the tire that comes into contact with the ground, there is a need for product cooling water and when this water becomes contaminated, supplementary cooling water is used. There is also a need for water in steam boilers to supplement the steam used in hardening presses. Significant water consumption is also realized for filter washing, resin regeneration and membrane cleaning processes in raw water preparation units such as activated carbon filter, ion exchange resin, reverse osmosis, which are used to produce soft water for use in production processes in the sector.

The reference specific water consumption in the inner and outer tire manufacturing sector is 8.6 L/kg. The specific water consumption of the production branch analyzed within the scope of the study remains in the range of 1.04 - 15.6 L/kg. With the implementation of sector-specific techniques, good management practices, general measures and measures related to auxiliary processes, it is possible to achieve water savings of 20 - 71% in the sector.

22.11 Internal and External Tire Manufacturing NACE code, the recommended priority water efficiency implementation techniques are presented in the table below.

NACE Code	NACE Code Description		Sectoral Prioritized Best Available Techniques
22.11	Inner and outer tire manufacturing		**Sector Specific Measures**
		1.	Treatment and reuse of wastewater in emulsion styrene butadiene rubber production
		2.	Treatment and reuse of sulfate-rich rubber wastewater from concentrated latex and skim crepes
		3.	Reuse in the process by obtaining good quality water by using ozonation and batch activated sludge process which provides high removal efficiency
			Good Management Practices
		1.	Use integrated wastewater management and treatment strategy to reduce wastewater quantity and pollutant load
		2.	Establishment of an environmental management system
		3.	Preparation of water flow diagrams and mass balances for water
		4.	Preparing a water efficiency action plan to reduce water use and prevent water pollution
		5.	Providing technical trainings to staff for the reduction and optimization of water use
		6.	Good production planning to optimize water consumption
		7.	Setting 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
			Measures in the nature of General Measures
		1.	Minimizing spills and leaks
		2.	Recovery of water from rinsing solutions and reuse of recovered water in processes appropriate to its quality
		3.	Use of automatic hardware and equipment (sensors, smart hand washing systems, etc.) to save water at water usage points such as showers/toilets etc.
		4.	Use of pressure washing systems for equipment cleaning, general cleaning, etc.
		5.	Reducing water consumption by reusing filter wash water in filtration processes, reusing relatively clean cleaning water in production processes and using clean-in-place systems (CIP)
		6.	Avoiding the use of drinking water in production lines
		7.	Use of cooling water as process water in other processes
		8.	Identification and reduction of water losses
		9.	Automatic control-close valves to optimize water use

NACE Code	NACE Code Description		Sectoral Prioritized Best Available Techniques
22.11	Inner and outer tire manufacturing	10.	Production procedures are documented and used by employees to prevent water and energy waste
		11.	Reuse of pressurized filtration backwash water prior to water softening at appropriate points
		12.	Optimizing the frequency and duration of regeneration (including rinses) in water softening systems
		13.	Construction of closed storage and impermeable waste/scrap sites to prevent the transportation of toxic or hazardous chemicals for the aquatic environment
		14.	Storage and storage of substances that pose a risk to the aquatic environment (such as oils, emulsions, binders) and prevention of their mixing with wastewater after use
		15.	Where technically feasible, treating appropriate wastewater and using it as steam boiler feed water
		16.	Prevention of mixing of clean water flows with polluted water flows
		17.	Determination of wastewater flows that can be reused with or without treatment by characterizing wastewater quantities and qualities at all wastewater generation points
		18.	Use of closed loop water cycles in appropriate processes
		19.	Use of computer-aided control systems in production processes
		20.	Untreated reuse of relatively clean wastewater from washing, rinsing and equipment cleaning in production processes
		21.	Determining the scope of reuse of washing and rinsing water
		22.	Separate collection and treatment of gray water in the facility and its use in areas that do not require high water quality (green area irrigation, floor washing, etc.)
		23.	Implementing time optimization in production and organizing all processes to be completed as soon as possible
		24.	Collecting rainwater and utilizing it as an alternative water source for facility cleaning or in suitable areas
		25.	Reuse of nanofiltration (NF) or reverse osmosis (RO) concentrates with or without treatment depending on their characterization
			Precautions for Auxiliary Processes
		1	Saving water by reusing steam boiler condensate
		2.	Ensuring water savings by insulating steam and water lines (hot and cold), preventing water and steam losses in pipes, valves and connection points in the lines and monitoring them with a computer system
		3.	replacement of old equipment in the ventilation system with ion exchange resins based on the principle of reverse osmosis (systems producing demineralized water) and reuse of water

NACE Code	NACE Code Description		Sectoral Prioritized Best Available
22.11	Inner and outer tire	4.	Reuse of the liquid formed by condensation from the ventilation system
		5.	Avoiding unnecessary cooling processes by identifying processes that need wet cooling
		6.	Reducing water consumption by increasing the number of cycles in closed loop cooling systems and improving the quality of make-up water
		7.	Reduction of evaporation losses in closed loop cooling water Water
		8.	recovery with tower cooling application in systems without closed loop
		9.	Increasing the number of cycles by using corrosion and scale inhibitors in systems with closed water cycles
		10.	Prevention of flash steam losses due to boiler unloading Use of hot water
		11.	produced in the cogeneration system in heating processes
		12.	Use of cold water produced in the cogeneration system in cooling processes
		13.	Use of air cooling systems instead of water cooling in cooling systems
		14.	Installation of water softening systems for the healthy operation of cooling water recovery systems
		15.	Use of closed loop cooling system to reduce water usage
		16.	Cooling with local dry air in some periods of the year when the cooling need is low
		17.	Collecting the water generated by surface runoff with a separate collection system and using it for cooling water, process water, etc.
		18.	Reuse of energy generated from steam condenser A total

of 54 techniques have been proposed in this sector.

For Internal and External Tire Manufacturing NACE Code;

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

2.1.1 Sector Specific Measures

- ***Treatment and reuse of wastewater in emulsion styrene butadiene rubber production***

  Wastewater from emulsion styrene butadiene rubber production can be treated by biological treatment, settling ponds and wastewater skimmers and reused in processes. Wastewater skimmers are highly efficient but costly compared to other techniques. Biological treatment is a technique that can provide high efficiency at low cost (IPPC BREF, 2007).

- ***Biological treatment of sulfate-rich rubber wastewater from concentrated latex and skim crepes combined with a sulfate reduction system (treatment with photosynthetic bacteria) and reuse in processes***

  In anaerobic wastewater treatment systems, the use of sulfate by sulfate-reducing bacteria in the absence of oxygen causes the formation of H2S. In order to remove the highly toxic and corrosive hydrogen sulfide (H2S) gas, the sulfate concentration in wastewater must be reduced. A sulfate reduction reactor (SRR) is used to treat sulfate-rich wastewater. In the sulfate reduction reactor, sulfite can be converted to sulfur by partial oxidation. The sulfur oxidation level in the system varies depending on the oxygen concentration. Bacteria capable of oxidizing reduced sulfur compounds are used to remove hydrogen sulfide (H2S) from treated wastewater or gaseous systems. Sulfate-rich rubber wastewater from concentrated latex and skim crepe can be reused by biological treatment combined with a sulfate reduction system (treatment with photosynthetic bacteria) (Mohammadi & Man, 2010).

- ***Reuse in the process by obtaining good quality water by using ozonation and batch activated sludge process which provides high removal efficiency***

  In the treatment of rubber wastewater, ozonation followed by batch activated sludge process provides high efficiency of dissolved matter, suspended solids and nutrient removal and good quality water can be obtained. Biological treatment of rubber wastewater is the most efficient method for BOD removal. However, some of the non-biodegradable substances and ammonia nitrogen in rubber wastewater cannot be completely removed using biological treatment. With ozonation, refractory or poorly degradable organic materials can be converted into smaller sized by-products. In addition, ammonia can be converted to biodegradable nitrate by ozonation. The effects of different pH levels (7.4, 9.0 and 11.0), different contact times (0 - 90 minutes) and ozone doses (37.20, 56.90 and 66.44 mg O3/L O2) on wastewater were investigated. As a result of the study, it was determined that ozone dosage of 66.44 mg O3/L O2, pH of 9.0 and contact time of 30 minutes were the most suitable conditions for pollutant reduction. It was revealed that the combination of ozonation and batch activated sludge process provided higher removal efficiency for all parameters compared to other systems (Mohammadi & Man, 2010).

2.1.2 Good Management Practices

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

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

The most widely used Environmental Management Standard is ISO 14001. Alternatives include the Eco Management and Audit Scheme Directive (EMAS) (761/2001). It was developed to assess, improve and report on the environmental performance of businesses. It is one of the leading practices within the scope of eco-efficiency (cleaner production) in EU legislation and voluntary participation is provided (TUBITAK MAM, 2016; TOB, 2021). The benefits of establishing and implementing an Environmental Management System are as follows:

- Economic benefits can be achieved by improving business performance (Christopher, 1998).
- International Organization for Standardization (ISO) standards are adopted, ensuring greater compliance with global legal and regulatory requirements (Christopher, 1998).
- While minimizing the risks of penalties associated with environmental responsibilities, the amount of waste, resource consumption and operating costs are reduced (Delmas, 2009).
- The use of internationally recognized environmental standards eliminates the need for multiple registrations and certifications for businesses operating in different locations around the world (Hutchens Jr., 2017).
- Especially in recent years, the improvement of companies' internal control processes has also been emphasized by consumers. The implementation of environmental management systems provides a competitive advantage against companies that do not adopt the standard. It also contributes to the better position of organizations in international areas / markets (Potoski & Prakash, 2005).
- The above-mentioned benefits depend on many factors such as the production process, management practices, resource utilization and potential environmental impacts (TOB, 2021). Practices such as preparing annual inventory reports with similar content to an environmental management system and monitoring the quantity and quality of inputs and outputs in production processes can save 3-5% of water consumption (Öztürk, 2014). The total duration of the development and implementation phases of an EMS takes an estimated 8-12 months (ISO 14001 User Manual, 2015).

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

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

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

  On-site reuse of treated wastewater not only improves the quality of water bodies, but also reduces the demand for freshwater. It is therefore crucial to identify appropriate treatment strategies for different reuse objectives.

  In integrated industrial wastewater treatment, different aspects such as wastewater collection system, treatment process and reuse target are considered 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 the integrated wastewater management framework (Naghedi et al., 2020). The integration of Analytic Hierarchy Process (AHP) and CoCoSo techniques can be used to set priorities for industrial wastewater management processes based on multiple criteria (Adar et al., 2021).

  The implementation of integrated wastewater management strategies can reduce water consumption, wastewater quantity and pollution loads of wastewater by up to 25% on average. The potential payback period of implementation varies between 1-10 years (MoAF, 2021).

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

Industrial Wastewater Treatment Plant

- ***Providing technical trainings to staff for the reduction and optimization of water use***

  With this measure, water saving and water recovery can be achieved by increasing the training and awareness of the personnel, and water efficiency can be achieved by reducing water consumption and costs. In industrial facilities, problems related to high water use and wastewater generation may arise due to the lack of necessary technical knowledge of the personnel. For example, it is important that cooling tower operators, who represent a significant proportion of water consumption in industrial operations, are properly trained and have technical knowledge. It is also necessary for the relevant personnel to have sufficient technical knowledge in applications such as determining water quality requirements in production processes, measuring water and wastewater quantities, etc. (TOB, 2021). Therefore, it is important to train staff on water use reduction, optimization and water saving policies. Practices such as involving staff in water saving efforts, creating regular reports on water use before and after water efficiency initiatives, and sharing these reports with staff support participation and motivation in the process. The technical, economic and environmental benefits of staff training are realized in the medium or long term (TUBITAK MAM, 2016; TOB, 2021).

- ***Monitoring the water used in production processes and auxiliary processes and the wastewater generated in terms of quantity and quality and adapting this information to the environmental management system***.

  inefficiency and environmental problems can arise from input-output flows. For this reason
  The quantity 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 reduce energy consumption by 6-10%, water consumption and wastewater quantities by
  It can provide up to 25% reduction (Öztürk, 2014).

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

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

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

  In industrial production processes, planning by using the least amount of process from raw material to product is an effective practice to reduce labor costs, resource utilization costs and environmental impacts and to ensure efficiency (TUBITAK MAM, 2016; TOB, 2021). Production planning in industrial plants, taking into account the water efficiency factor, reduces water consumption and wastewater amount. Modifying production processes or combining some processes in industrial plants 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***

  It is important for water efficiency to prepare an action plan that includes short, medium and long term actions to be taken in order to reduce water-wastewater quantities and prevent water pollution in industrial facilities. At this point, determination of water needs throughout the facility and in production processes, determination of quality requirements at water use points, wastewater generation points and wastewater characterization should be carried out (TOB, 2021). At the same time, measures to be implemented to reduce water consumption, wastewater generation and pollution loads should be determined, feasibility should be made and action plans should be prepared for the short-medium-long term. In this way, water efficiency and sustainable water use in facilities are ensured (MoAF, 2021).

- ***Determination of water efficiency targets***

  The first step in achieving water efficiency in industrial facilities is to set targets (TOB, 2021). For this, first of all, a detailed water efficiency analysis should be carried out on the basis of processes. In this way, unnecessary water use, water losses, wrong practices affecting water efficiency, process losses, reusable water-wastewater sources with or without treatment, etc. can be determined. It is also extremely important to determine the water saving potential and water efficiency targets for each production process and the plant as a whole (TOB, 2021).

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

  Determining the points of water use and wastewater generation in industrial plants, establishing water-wastewater balances in production processes and auxiliary processes other than production processes constitute the basis of many good management practices in general. Establishing process profiles on a plant-wide and production process basis facilitates the identification of unnecessary water use points and high water use points, evaluation of water recovery opportunities, process modifications and determination of water losses (TOB, 2021).

2.1.3 Measures in the nature of General Measures

- ***Identification and reduction of water losses***

  Water losses occur in equipment, pumps and pipelines in industrial production processes. First of all, water losses should be identified and equipment, pumps and pipelines should be regularly maintained and kept in good condition to prevent leaks (IPPC BREF, 2003). Regular maintenance procedures should be established, paying particular attention to

  - Adding pumps, valves, level switches, pressure and flow regulators to the maintenance checklist,
  - Inspections not only of the water system, but also, in particular, of heat transfer and chemical distribution systems, broken and leaking pipes, drums, pumps and valves,
  - Regular cleaning of filters and pipelines,
  - Calibrate, routinely check and monitor measurement equipment such as chemical measuring and dispensing devices, thermometers, etc. (IPPC BREF, 2003).

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

- ***Minimization of spills and leaks***

  Both raw material and water losses can occur due to spills and leaks in enterprises. In addition, if wet cleaning methods are used to clean 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, spill and splash losses are reduced by using splash guards, flaps, drip trays, screens (IPPC BREF, 2019).

- ***Untreated reuse of relatively clean wastewater from washing, rinsing and equipment cleaning in production processes***

  In industrial plants, relatively clean wastewaters such as washing-final rinse wastewaters and filter backwash wastewaters can be reused without treatment in floor washing and garden irrigation processes that do not require high water quality, saving between 1-5% in raw water consumption. The initial investment costs required for the application are the installation of new pipelines and reserve tanks (Öztürk, 2014).

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

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

- ***Prevention of mixing of clean water flows with polluted water flows***

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

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

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

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

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

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

  Determination and characterization of wastewater generation points in industrial facilities
  It is possible to reuse various wastewater streams with or without treatment (Öztürk, 2014; TUBİTAK MAM, 2016; TOB, 2021). In this context, filter backwash waters, TO concentrates, blowdown waters, condensate waters, relatively clean washing and rinsing waters can be reused without treatment in the same/different processes and in areas that do not require high water quality (such as facility and equipment cleaning). In addition, wastewater streams that cannot be directly reused can be reused in production processes after treatment using appropriate treatment technologies.

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

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

  Water cooling systems are widely used in processes where thermal energy is intensively used and cooling is required. By using heat exchangers in cooling water return, it is possible to recover heat, prevent contamination of cooling water and save water and energy by increasing cooling water return rates (TUBITAK MAM, 2016; TOB, 2021). In addition, if cooling water is collected separately, it is often possible to use the collected water for cooling purposes or to reuse it in appropriate processes (EC, 2009). Cooling water reuse can save 2-9% of total water consumption (Greer et al., 2013). Energy consumption can be saved by up to 10% (Öztürk, 2014; TOB, 2021).

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

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

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

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

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

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

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

  In different sub-sectors of the manufacturing industry, waters with different water quality can be used for production purposes. In industrial plants, raw water from groundwater sources is generally used in production processes after treatment. However, in some cases, although it is costly, drinking water can be used directly 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 matter (DOM)) in water in production processes and form disinfectant by-products harmful to living metabolisms (Özdemir & Toröz, 2010; Oğur et al.) The use of drinking water containing residual chlorine compounds or raw water disinfected with chlorinated compounds should be avoided as much as possible. Highly oxidizing disinfection methods such as ultraviolet (UV), ultrasound (US) or ozone can be used instead of chlorine disinfection for disinfection of raw water. In order to increase the technical, economic and environmental benefits of the application, it helps to reduce unnecessary water supply and treatment costs by determining and using the water quality parameters required in each production process. With this application, it is possible to reduce water, energy and chemical costs (TUBITAK MAM, 2016).

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

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

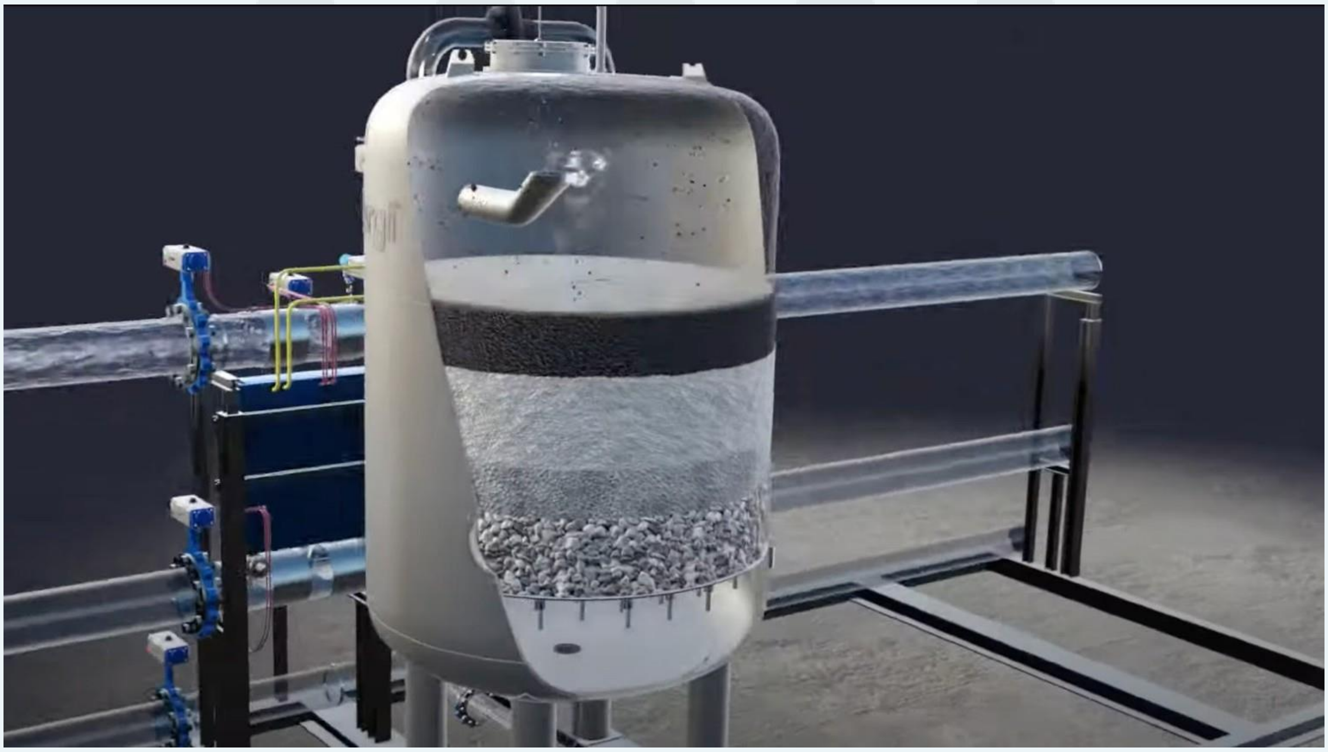
  In various examples, roof rainwater collected in industrial facilities was stored and then used inside the building and in landscape areas, resulting in 50% water savings in landscape irrigation (Yaman, 2009). Perforated stones and green areas can be preferred to increase the permeability of the ground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

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

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

  In regeneration processes, washing, regeneration and rinsing wastewaters are usually removed directly. However, if the washing and final rinse water is of raw water quality, it can be sent to raw water storage or reused in processes that do not require high water quality such as facility cleaning and green area irrigation (TOB, 2021).

  It is very important to determine the optimum regeneration frequency in regeneration systems. Although regeneration in water softening systems is adjusted according to the frequencies 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. Thus, regeneration frequencies can be optimized and excessive washing rinsing or backwashing with brine can be prevented by using online hardness sensors.



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Water Softening Systems

- ***Reuse of pressurized filtration backwash water prior to water softening at appropriate points***

  Many industrial processes require softened water with low calcium and magnesium concentrations. 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 water at appropriate points before water softening. This measure is similar in content to practices such as "Reuse of filter backwash water in filtration processes, reuse of relatively clean water in production processes, reduction of water consumption by using on-site cleaning systems".

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

  Based on the wastewater characterization and appropriate point of use, the potential for reuse of other wastewater from membrane processes (backwashing without or with chemicals, CIP cleaning, module cleaning, cleaning of chemical tanks, etc.) should be assessed.

  Nanofiltration is a membrane-based liquid separation technique with low energy consumption and low operating pressures suitable for the treatment 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 treatment depending on their characterization. Measures should be taken to reduce water consumption by reusing clean water in the production processes of filter backwash water in filtration processes and using cleaning systems (TOB, 2021).

Reverse Osmosis System

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

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

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

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

Heat recovery is also provided by the use of heat exchangers in cooling water. Generally, closed loop systems are used in plants using water cooling systems. However, cooling system blowdowns are discharged directly to the wastewater treatment plant channel. These 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 being mixed into wastewater as much as possible after storage, storage and use*** In industrial facilities, substances that pose a risk to the aquatic environment such as oils, emulsions and binders
dry cleaning techniques to prevent chemicals from mixing into wastewater streams can be used and leaks can be prevented. In this way, water resources can be protected (TUBITAK MAM, 2016).

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

Closed and impermeable waste/scrap storage sites can be constructed in industrial facilities to prevent the transportation of toxic or hazardous chemicals for the aquatic environment to receiving environments. This practice is already being implemented in our country within the scope of existing environmental regulations. Within the scope of the field studies carried out, a separate collection channel can be built in the storage areas of toxic or hazardous substances in industrial facilities to collect the leachate separately and prevent it from mixing into natural water environments.

- ***Recovery of water from rinsing solutions and reuse of recovered water in processes appropriate to its quality***

Rinsing wastewater in industrial plants is relatively clean wastewater that can be reused without treatment in floor washing and garden irrigation processes that do not require high water quality (Öztürk, 2014). Raw water consumption can be reduced with the recovery of rinse water.
Savings between 1-5% can be achieved.

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

  Since inefficient resource utilization and environmental problems in industrial facilities are directly linked to input-output flows, it is necessary to define the process inputs and outputs in the best way for production processes (TUBITAK MAM, 2016). Thus, it becomes possible to develop measures to improve resource efficiency, economic and environmental performance. The organization of input-output inventories is considered a prerequisite for continuous improvement. While such management practices require the participation of technical staff and senior management, they pay for themselves in a short time with the work of various experts (IPPC BREF, 2003). On the basis of the implementation processes, the use of measurement equipment and some routine analyzes/measurements specific to the processes are required. Utilizing computerized monitoring systems as much as possible in order to maximize the efficiency of the application increases the technical, economic and environmental benefits (TUBITAK MAM, 2016).

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Computer Aided Control System

- ***Reducing water consumption by reusing filter wash water in filtration processes, reusing relatively clean cleaning water in production processes and using clean-in-place systems (CIP)***

The wastewater from backwashing of activated carbon filters and softeners often contains only high levels of suspended solids (TSS). Backwash water, which is one of the easiest types of wastewater to recover, can be recovered by filtration with ultrafiltration plants. In this way, water savings of up to 15% can be achieved (URL - 1, 2021).

Regeneration wastewater generated after the regeneration process is soft water with high salt content and accounts for approximately 5-10% of total water consumption. Regeneration wastewater is collected in a separate tank and utilized in processes with high salt requirements, plant cleaning and domestic use. This requires a reserve tank, plumbing and a pump. By reusing regeneration wastewater, water consumption, energy consumption, wastewater quantities and salt content of wastewater are reduced by approximately 5-10% (Öztürk, 2014). The payback period varies depending on whether the regeneration wastewater is consumed in production processes, plant cleaning or domestic use. The potential payback period is estimated to be less than one year if regeneration water is reused in production processes that require high salt content (since both water and salt will be recovered). For facility and equipment cleaning and domestic uses, the payback period is estimated to be over one year (MoAF, 2021).

In Turkey, reverse osmosis (RO) concentrates are combined with other wastewater streams and discharged to the wastewater treatment plant channel. The concentrates formed in TO systems used for additional hardness removal can be used in garden irrigation, in-plant and tank-equipment cleaning (TUBITAK MAM, 2016; TOB, 2021). In addition, with the structuring of raw water quality monitoring, it is possible to feed TO concentrates back into the raw water reservoirs and reuse them by mixing (TOB, 2021).

- ***Implementing time optimization in production and organizing all processes to be completed as soon as possible***

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

- ***Production procedures are documented and used by employees to prevent water and energy waste***

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

2.1.4 Precautions for Auxiliary Processes

BATs for steam generation

- ***Ensuring water savings by insulating 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***

Steam losses may occur if steam lines are not properly designed, routine maintenance and repairs of steam lines are not carried out, mechanical problems occurring in the lines and the lines are not operated properly, steam lines and hot surfaces are not fully insulated. This situation affects both water consumption and energy consumption of the plant. Control systems with automatic control mechanisms should be used in order to ensure steam isolation and continuous monitoring of steam consumption. Depending on the reduction of steam losses, similar savings can be achieved in fuel consumption and additional soft water consumption in boilers. Since fuel consumption in steam boilers will decrease, waste gas emissions are expected to decrease at the same rate. Since the additional soft water used in steam boilers will be reduced with the application, the amount of regeneration water, the amount of salt used in regeneration and reverse osmosis concentrates will also be reduced. Full steam isolation application and automatic control mechanisms to minimize steam losses are used in many plants with high steam consumption. 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 the equipment such as pumps, valves, control knobs, pressure and flow regulators to the maintenance checklist, inspecting not only water systems but also heating and chemical dispensing systems, drums, pumps and valves, regular cleaning of filters and pipelines, regular calibration of measuring equipment (thermometers, chemical scales, dispensing/dosing systems, etc.) and inspection and cleaning of heat treatment units (including chimneys) at routinely determined periods, effective maintenance-repair, cleaning and loss control practices can reduce water consumption by %%.Regular calibration of measuring equipment (thermometers, chemical scales, dispensing/dosing systems, etc.), routine inspection and cleaning of heat treatment units (including chimneys) in specified periods, effective maintenance-repair, cleaning and loss control practices can save 1-6% in water consumption (Hasanbeigi, 2010; Öztürk, 2014; TOB, 2021).

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Industrial Steam Boilers

Saving water by reusing steam boiler condensate

When steam indirect heating techniques are used to transfer thermal energy in production processes, recovery of condensed steam (condensate) is an effective practice to reduce water consumption (IPPC BREF, 2009). Condensate recovery can reduce water consumption by 5% on average (Greer et al., 2013). Moreover, the potential payback period varies between 4-18 months (considering energy savings) (Öztürk, 2014; TUBITAK MAM, 2016).

- ***Prevention of ffaş steam losses due to boiler unloading***

  Steam boiler condensate is generally discharged from the system at atmospheric pressure through equipment outlets and steam traps. As the pressure decreases in condensate systems, some of the condensate re-evaporates and cools to the boiling point of water at atmospheric pressure. The re-evaporated condensate, called flash steam, is lost by being thrown into the atmosphere. In condensate return lines, which are usually quite long, cooling and therefore vaporization is inevitable. In order to prevent re-evaporation of condensate, 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 vapor formed as the pressure drops collects on the tank and feeds the low pressure steam system from here. The remaining hot condensate is taken from the bottom of the tank to the boiler.

- ***Reuse of energy generated from the steam condenser***

  With a simple modification to the piping system, the water supplying the water resting/decarbonization unit can be obtained from the outlet of the turbine condenser unit. This water is of sufficient temperature for the recovery/decarbonization unit. It is therefore not necessary to heat this water by means of steam produced by the heat exchanger system. Significant steam recovery can be achieved through this operation. Cooling water consumption can also be reduced (CPRAC, 2021).

BATs for cooling systems

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

  Closed loop cooling systems significantly reduce water consumption compared to open loop systems, which are more water intensive. In closed loop systems, the same amount of water is recirculated within the system, usually requiring the addition of cooling water equal to the amount of water evaporated. By optimizing cooling systems, evaporation losses can also be reduced.

- ***Reducing water consumption by increasing the number of cycles in closed loop cooling systems and improving the quality of make-up water***

  Water is used as a refrigerant in many processes such as production processes of the manufacturing industry and cooling of products. The water is recirculated through cooling tower or central cooling systems and cooling process is carried out. If an unwanted microbial growth occurs in the cooling water, it can be controlled by adding chemicals to the recirculated water (TUBITAK MAM, 2016). The number of cycles can be increased with good chemical conditioning in the recirculation process. In this way, the amount of fresh water fed to the system can be reduced and water savings can be achieved. In addition, good conditioning of the cooling make-up 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

In cases where the cooling requirement is low, it is possible to save water by cooling with dry air.

- ***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 using a fluid (gas or liquid) or dry air (IPPC BREF, 2001b; TOB, 2021). Air cooling systems consist of finned pipe elements, condenser and air fans (IPPC BREF, 2001b; TOB, 2021). Air cooling systems can 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 into a cooling tower and the water is cooled in trickling systems. However, although water-cooled systems operate in closed circuit, a significant amount of evaporation occurs. In addition, since some water is discharged as blowdown in cooling systems, water is also lost in this way (IPPC BREF, 2001b; TOB, 2021). The use of 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).

- ***Tower cooling in non-closed loop systems is the application of water reuse***

Cooling towers are divided into two as counter-flow and cross-flow according to their working principles. In counter-flow cooling towers, the air flow moves upwards while the water flows downwards, and in cross-flow cooling towers, the air flow moves horizontally while the water flows downwards. Water exposed to fresh air cools down until it reaches the cold water pool, where it is collected and sent to the plant. During these processes, some of the water evaporates. 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 must be managed effectively.

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

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Tower Type Cooling Systems

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

Cooling towers and evaporative condensers are efficient and low-cost systems that remove heat from air conditioning and industrial process cooling systems (IPPC BREF, 2001b; TOB, 2021). In these systems, more than 95% of the circulating water can be recovered (TUBITAK MAM, 2016). In cooling systems, impurities remain in the recirculated water due to the evaporation of a portion of the recirculated water, and impurity concentrations gradually increase with each cycle. Impurities that can enter the cooling system together with air can cause contamination in recirculation water (TUBITAK MAM, 2016). If impurities and contaminants are not effectively controlled, they can cause scaling and corrosion, unwanted biological growth and sludge accumulation. This can become a chronic problem leading to reduced efficiency of heat transfer surfaces and increased operating costs. In this case, it is necessary to implement a water treatment program specifically designed for the quality of the feed water supplied to the cooling system, the cooling water system construction material and the operating conditions. This may include blowdown control, control of biological growth, corrosion control, avoidance of hard water, use of sludge control chemicals, filtration and screening systems (TUBITAK MAM, 2016). Establishing and periodically implementing an effective cleaning procedure and program is also a good management practice for the protection of cooling systems. Corrosion is one of the most important problems in cooling systems. Dissolved solids (sulfate, chloride, carbonate, etc.) in the tower recirculation water, which cause corrosion as a result of the formation of limestone and deposits on the walls as the degree of hardness increases, will cause corrosion on the surface over time. In addition, the formation of deposits negatively affects heat transfer and reduces energy efficiency. In order to prevent these problems, a chemical treatment program to prevent scale and corrosion, disinfection with biological activation inhibitor biocide, chemical and mechanical cleaning of the cooling towers in use at least twice a year to remove deposits, hardness and conductivity values of the make-up water should be as low as possible (IPPC BREF, 2001; Kayabek et al., 2005). Treatment (conditioning) using an appropriate treatment system may be necessary to improve the quality of the makeup water. It is also necessary to control undesirable microbial growth (IPPC BREF, 2001b; TOB, 2021). Blowdown occurs in cooling systems as well as in steam boilers due to micro-residues and deposits in the cooling water. The deliberate draining of the cooling system to compensate for the increased concentration of solids in the cooling system is called cooling blowdown. By pre-treatment of cooling water with appropriate methods and continuous monitoring of cooling water quality, biocide usage and blowdown amounts can be reduced (TUBITAK MAM, 2016). The investment cost depends on the scale of implementation, but the payback period for the expected investment costs varies between 3 and 4 years (IPPC BREF, 2001).

- ***Collecting the water generated by surface runoff with a separate collection system and using it for cooling water, process water, etc.***

  Most industrial facilities generate wastewater from process or non-process areas. The wastewater generated can be treated and reused in appropriate places. Savings can be achieved at varying rates in various industrial plants by reusing the wastewater generated in the plant after treatment. Water generated by surface runoff can be collected with a separate collection system and used as cooling water (TOB, 2021).

Avoiding unnecessary cooling processes by identifying processes that need wet cooling

The boundaries of the plant site affect design parameters such as cooling tower height. In cases where the tower height has to be reduced, a hybrid cooling system can be applied. Hybrid cooling systems are a combination of evaporative and non-evaporative (wet and dry) cooling systems. Depending on the ambient temperature, the hybrid cooling tower can be operated as a fully wet cooling tower or as a combined wet/dry cooling tower (TUBITAK MAM, 2016). In regions where there is not enough cooling water or where water costs are high, the evaluation of dry cooling systems or hybrid cooling systems can be an effective solution to reduce the amount of cooling makeup water (TUBITAK MAM, 2016).

- ***Reduction of evaporation losses in closed loop cooling water***

Some water evaporates during the cooling of heated water in cooling systems. Therefore, in closed cycle cooling systems, cooling water is added as much as the amount of evaporated water. Evaporation losses can be prevented by optimizing cooling systems. In addition, the amount of blowdown can be reduced with applications such as treatment of make-up water added to cooling systems and prevention of biological growth in cooling systems. Within the scope of the field studies carried out, the blowdown water generated in the cooling system is generally discharged directly to the wastewater channel. By reusing cooling system blowdown water, water consumption of cooling systems can be saved up to 50%. Implementation of this measure may require the installation of new pipelines and reserve tanks (MoAF, 2021).

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

Cooling water is collected separately and used for cooling purposes or recycled in appropriate processes (EC, 2009). A water softening system is required for this system to work properly. Cooling water has suitable water quality for reuse as cleaning and irrigation water. However, since it contains some hardness in its use as cooling water, additional softening is required to prevent corrosion problems that will occur over time. These waters should be subjected to an appropriate disinfection process before being reused as cooling water or in the process. In addition, these waters can be treated with appropriate treatment techniques (membrane filtration, advanced oxidation, chemical precipitation, granular activated carbon adsorption, etc. processes) and reused not only in cooling processes but also in all production processes (TUBITAK MAM, 2016). As the hardness of the cooling water increases, limestone and deposit formation occurs on the walls. The formation of deposits negatively affects heat transfer, reducing energy efficiency and increasing energy costs. With the increase in evaporation in the system, the ion concentration and conductivity value in the water increases. In order to prevent these negativities, chemical treatment of the cooling water to prevent scale and corrosion, disinfection with a biocide that prevents biological activation, chemical and mechanical cleaning of cooling towers at least twice a year and cleaning of deposits, hardness and conductivity values should be kept as low as possible (TUBITAK MAM, 2016).

BATs for ventilation and air conditioning systems

- ***Reuse of the liquid formed by condensation from the ventilation system***
  Condensate with good water quality can be produced in the system during the aeration cycle. For example, in a plant in Spain, condensate from the aeration system with a conductivity of around 200 µS is collected in a tank and used to flush an automatic galvanizing line (MedClean, n.d.).

- ***Replacement of old equipment in the aeration system with ion exchange resins based on the principle of reverse osmosis (systems producing demineralized water) and water reuse***
  By using ion exchange resins in the aeration system, the conductivity of the final effluent is brought to a conductivity level suitable for use in equipment cleaning. For example, in a plant in Spain, by replacing the equipment in the aeration system with ion exchange resins, effluent with a conductivity of approximately 1000 µS is obtained and reused in the system (MedClean, n.d.).

BATs for cogeneration system

- ***Use of hot water produced in the cogeneration system in heating processes***
  By including cooling systems in cogeneration systems (trigeneration)
  10-30% of the efficiency losses can be converted into hot water, water vapor, cold air, hot air and water (absorption heat exchangers must be used for this). In this way, it is possible to meet a part of the energy required in processes such as cooling and drying in the plant from the waste heat in the cogeneration systems. Energy costs can be reduced by up to 40% in plants utilizing cogeneration systems (TUBITAK MAM, 2016).

- ***Utilization of cold water produced in the cogeneration system in cooling processes*** Water can be saved by utilizing cold water produced in the cogeneration system in cooling processes (TUBITAK MAM, 2016).

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