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MINISTRY OF AGRICULTURE AND FORESTRY
GENERAL DIRECTORATE OF WATER MANAGEMENT

Water Efficiency Campaign

Water Efficiency Guide Documents Series

MANUFACTURE OF OTHER ORGANIC BASIC CHEMICALS

NACE CODE: 20.14

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Abbreviations

WWTP	Wastewater Treatment Plant
EU	European Union
SSM	Suspended Solid Matter
BREF	Best Available Techniques Reference Document
EMS	Environmental Management System
MoEUU	Republic of Turkey Ministry of Environment, Urbanization and Climate Change
NOM	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
BAT	Best Available Technique
NACE	Statistical Classification of Economic Activities
GDWM	General Directorate of Water Management
RO	Reverse Osmosis
TOB	Republic of Turkey Ministry of Agriculture and Forestry
TUIK	Turkish Statistical Institute
NF	Nanofiltration
MF	Microfiltration
UF	Ultrafiltration
GW	Groundwater
SW	Surface Water

1Introduction

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

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

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

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

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

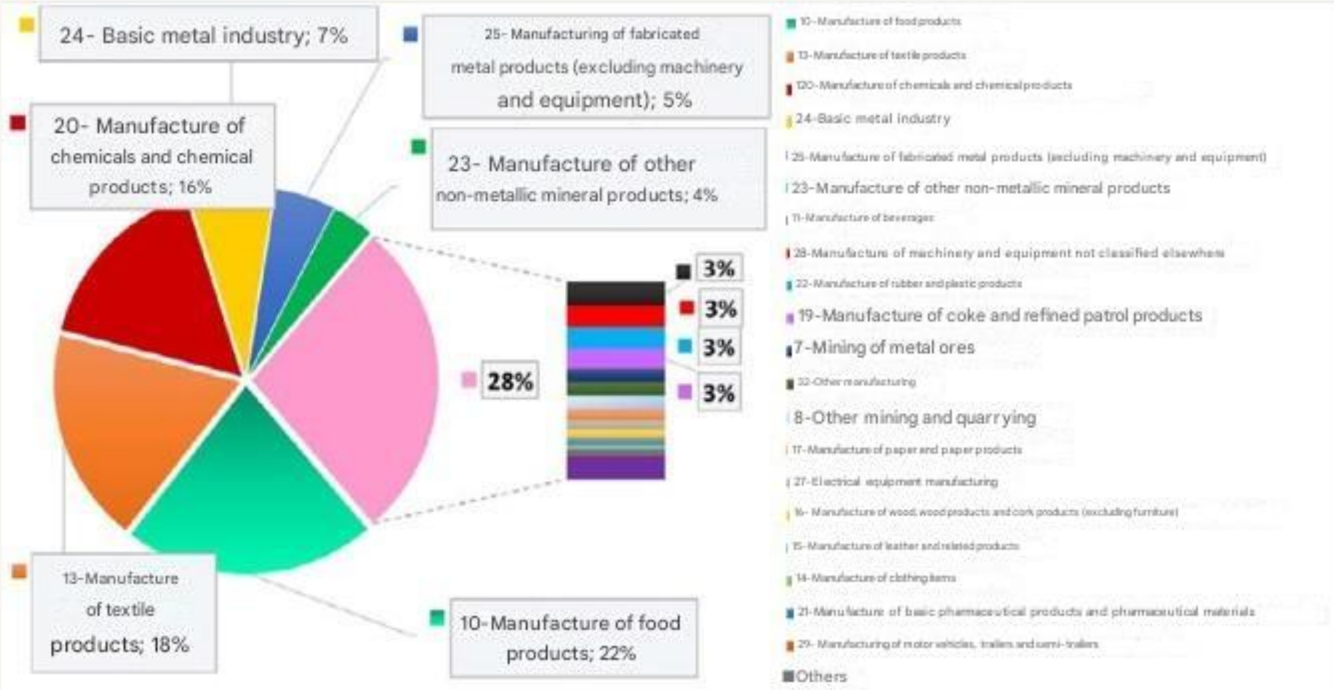
In the European Green Deal Action Plan prepared by our country within the scope of the European Green Deal, where member countries agree on goals such as implementing a clean, circular economy model with the goal of carbon neutrality, expanding the efficient use of resources and reducing environmental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

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

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

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

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



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

As a result of the studies, specific water consumption and potential savings rates for the processes of the enterprises were determined for 152 different 4-digit NACE codes with high water consumption, and water efficiency guidance documents were prepared by taking into account the EU best available techniques (MET) and other cleaner production techniques. The guidelines include 500 techniques for water efficiency (MET); It has been examined under 4 main groups: (i) Good Management Practices, (ii) General 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 account during the determination of METs for each sector. In the determination of METs, BREF documents were not limited to the METs, but also different data sources such as current literature data, real case studies, innovative practices, and reports of sector representatives on a global scale were examined in detail and sectoral MET lists were created. In order to evaluate the suitability of the MET lists created for the local industrial infrastructure and capacity of our country, the MET lists prepared specifically for each NACE code were prioritized by the enterprises by scoring them on the criteria of water saving, economic saving, environmental benefit, applicability, cross-media impact, and the final MET lists were determined using the scoring results. Sectoral water efficiency guidelines have been created on the basis of the NACE code based on the water and wastewater data of the facilities visited within the scope of the project and the final MET lists highlighted by the sectoral stakeholders and determined by taking into account the local dynamics specific to our country.

2 Scope of the Study

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

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

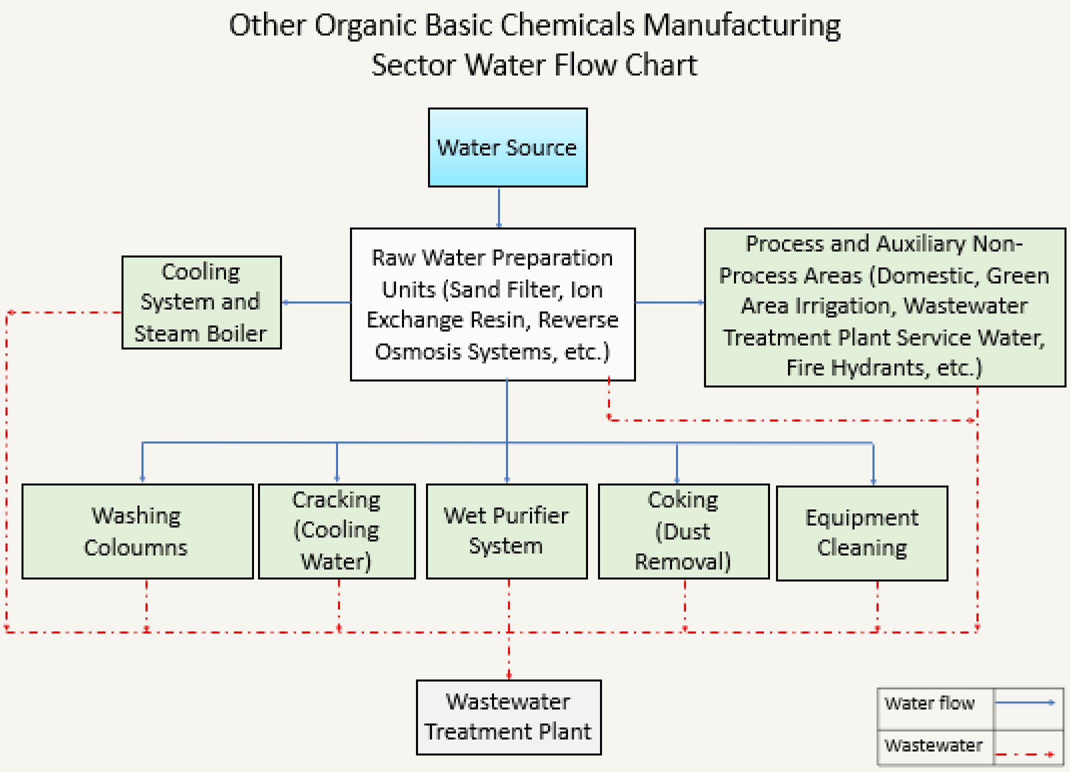
- Waste collection, remediation and disposal activities; recovery of materials (including 1 sub-production area represented by a four-digit NACE Code)
- Construction of non-building structures (including 1 sub-production area represented by a four-digit NACE Code)
- Storage and supporting activities for transportation (including 1 sub-production area represented by a four-digit NACE Code)
- Accommodation (including 1 sub-production area represented by a four-digit NACE Code)
- Educational Activities (Higher Education Campuses) (including 1 sub-production area represented by a four-digit NACE Code)
- Sports, entertainment and recreational activities (including 1 sub-production area represented by a four-digit NACE Code)

Manufacture of chemicals and chemical products

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

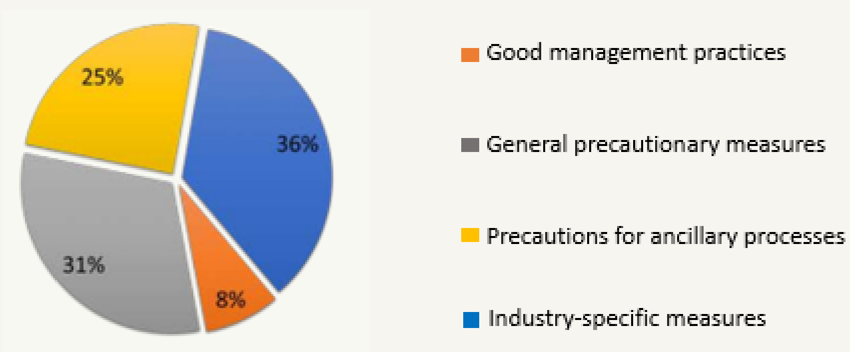
20.11	Manufacture of industrial gases
20.12	Manufacture of dyestuffs and pigments
20.13	Manufacture of other inorganic basic chemicals
20.14	Manufacture of other organic basic chemicals
20.15	Manufacture of chemical fertilizers and nitrogen compounds
20.16	Manufacture of plastic raw materials in primary form
20.17	Manufacture of synthetic rubber in primary form
20.20	Manufacture of pesticides and other agro-chemical products
20.30	Manufacture of paints, varnishes and similar coating agents, printing ink and putty
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 n.e.c.
20.60	Manufacture of man-made or man-made fibers

2.1 Manufacture of Other Organic Basic Chemicals (NACE 20.14)



	Minimum	Maximum
Specific Water Consumption of the Facilities Visited within the Scope of the Project (L/kg product)	0,2	4,3
Reference Specific Water Consumption (L/kg product)	1	4

Percentage Distribution of Water Efficiency Applications



20.14 The Manufacture of Other Organic Basic Chemicals sector includes the activities that make up the petrochemical industry together with the 20.16 Manufacture of Plastic Raw Materials in Primary Form sector. In the manufacture of other organic basic chemicals, basic raw materials are usually procured from abroad. The compliance of the supplied raw materials with the acceptance conditions is tested and taken to the relevant tanks. Depending on the type of final product to be produced, raw materials are taken to evaporation heat exchangers. The product, which reaches the gaseous form, is then transmitted to the absorption columns. Here, it is aimed to obtain the final product by making additions (water, chemicals, etc.) in accordance with the production procedure. The final product obtained is taken into the product tanks. The final products kept in the tanks are sampled before they are shipped to the market, analyzed in the laboratory and checked whether they are suitable for the product spectrum. In addition, it can be used in concentration and stripping units according to the desired final product. The final product obtained is packaged in accordance with the shipment and made ready for sale.

In the manufacture of other organic basic chemicals, water is consumed in the basic production processes of chemicals such as hydrocarbons, aldehydes, ketones and synthetic glycerin. In order to produce the desired chemical product, dilution steam is used in the washing columns, and water consumption is realized in order to obtain the steam. Water consumption is realized in wet purifier systems for the removal of acidic gases from flue gas emissions. High-pressure water is used for dust removal to remove the coke accumulated in the coking units. Direct contact water cooling systems are used to reduce the temperature of the gases broken down in the cracking process. 20.14 Not all facilities operating under the NACE code may have the processes listed. Depending on the type of chemical product produced, differences can be observed in the processes. However, distillation columns and cracking units are frequently used in the relevant sector.

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 for the production of soft water for use in production processes in the sector. In addition, water consumption occurs in auxiliary units such as cooling towers and steam boilers.

In the manufacturing sector of other organic basic chemicals, the reference specific water consumption is in the range of 1 - 4 L/kg. The specific water consumption of the production branch analyzed within the scope of the study is 0.2 – 4.3 L/kg. It is possible to achieve 31-46% water recovery in the sector with the application of sector-specific techniques, good management practices, general precautionary measures and measures related to auxiliary processes.

20.14 Manufacture of Other Organic Basic Chemicals The priority water efficiency implementation techniques recommended under the NACE code are presented in the table below.

NACE Code	NACE Code Description		Prioritized Sectoral Water Efficiency Techniques
20.14	Manufacture of other organic basic chemicals		**Industry-Specific Measures**
		1.	Preferring dry solvents or reusing aqueous solvents with closed-loop systems
		2.	Separate collection of wastewater from processes where aromatic hydrocarbons are processed from other wastewater to facilitate the recovery of raw materials and products
		3.	The use of mechanical pumps in closed-loop operations in the production of aromatic chemicals, the reduction of the amount of blowdown and/or the use of dry-running pumps
		4.	Separation of organic phases and aqueous phases to prevent undissolved organic substances from mixing with wastewater
		5.	Reuse of process water from used acid recovery unit and nitration unit
		6.	Reducing wastewater generation from ethylbenzene dehydrogenation and ensuring maximum recovery of organic compounds
		7.	Reuse of cleaning water from ethylene oxide plant in the production of ethylene glycol
		8.	Concentrating aqueous streams by distillation technique for the recovery of glycols or partial reuse of water in ethylene oxide and ethylene glycol plants
		9.	Conversion of formaldehyde into a less hazardous substance
		10.	Increasing the use of amine washing, a regenerative solvent for the removal of acid gases
		11.	Recovery of hydrocarbons by stripping method
		12.	Selection of the optimum catalyst to increase resource efficiency
		13.	Recovery and reuse of organic solvents to improve resource efficiency
		14.	Feeding low-sulfur raw materials in the cracking process
		15.	Carrying out the regeneration of the spent acid from the nitration reaction using an appropriate combination of "evaporation/distillation - stripping and condensation" in such a way that the water and organic content are recovered for reuse
		16.	Return of nitric acid and sulfuric acid waters to the process for direct reuse or material recovery
		17.	Reduction of catalyst particles using fixed bed reactor design for oxychlorination
		18.	Pre-treatment of wastewater containing organic peroxide using hydrolysis before biological treatment without mixing with other wastewater
		19.	Use of high concentration nitric acid (HNO3) to increase process efficiency, reduce wastewater amount and pollutant load
		20.	Evaluation of stripping wastewater as process water or boiler feed water using advanced treatment techniques

NACE Code	NACE Code Description		Prioritized Sectoral Water Efficiency Techniques
20.14	Manufacture of other organic basic chemicals	21.	Reducing catalyst losses and preventing them from mixing with wastewater
		22.	Recycling organic material and recycling water into the process for reuse
		23.	Using aqueous type ring vacuum pumps
		24.	Circulation of aqueous streams from processes such as cleaning, spilling and condensation to adjust the formaldehyde product concentration
		25.	Reuse of water from washing, rinsing and equipment cleaning
			Good Management Practices
		1.	Using an integrated wastewater management and treatment strategy to reduce the amount of wastewater and the pollutant load
		2.	Establishment of an environmental management system
		3.	Preparation of water flow diagrams and mass balances for water
		4.	Preparation of a water efficiency action plan to reduce water use and prevent water pollution
		5.	Providing technical training to personnel for the reduction and optimization of water use
		6.	Good production planning to optimize water consumption
		7.	Setting water efficiency targets
		8.	Monitoring the amount and quality of the water used in production processes and auxiliary processes and the wastewater generated and adapting this information to the environmental management system
			General Precautionary Measures
		1.	Minimization of spills and leaks
		2.	Use of automatic equipment and equipment (sensors, smart hand washing systems, etc.) that will save water at water usage points such as showers/toilets, etc.
		3.	Use of pressure washers for equipment cleaning, general cleaning, etc.
		4.	Reuse of filter wash water in filtration processes, reuse of relatively clean cleaning water in production processes, and reduction of water consumption by using clean-in-place systems (CIP)
		5.	Avoiding the use of drinking water in production lines
		6.	Detection and reduction of water losses
		7.	Use of automatic check-off valves to optimise water use
		8.	Documentation of production procedures and use by employees to prevent waste of water and energy
		9.	Reuse of pressurized filtration backwash water prior to water softening at appropriate points

NACE Code	NACE Code Description		Prioritized Sectoral Water Efficiency Techniques
20.14	Manufacture of other organic basic chemicals	10.	Optimising the frequency and duration of regeneration (including rinses) in water softening systems
		11.	Construction of closed storage and impermeable waste/scrap yard to prevent the transportation of toxic or hazardous chemicals for the aquatic environment
		12.	Storage, storage and prevention of substances that pose a risk in the aquatic environment (such as oils, emulsions, binders) and mixing with wastewater after use
		13.	Where technically feasible, suitable wastewater is treated and used as steam boiler feed water
		14.	Prevention of mixing of clean water streams with dirty water streams
		15.	Characterizing the amount and quality of wastewater at all wastewater formation points and determining the wastewater flows that can be reused with or without treatment
		16.	Use of closed-loop water cycles in appropriate processes
		17.	Use of computer-aided control systems in production processes
		18.	Untreated reuse of relatively clean wastewater from washing, rinsing and equipment cleaning in production processes
		19.	Determination of the scope of reuse of washing and rinsing waters
		20.	Separate collection and treatment of gray water in the facility and in areas that do not require high water quality (green area irrigation, floor, floor washing, etc.) Use
		21.	Implementation of time optimization in production and arrangement of all processes to be completed as soon as possible
		22.	Collecting rainwater and evaluating it as an alternative water source in facility cleaning or in appropriate areas
		23.	Avoiding the need for rinsing between activities by using compatible chemicals in successive processes
		24.	Depending on the characterization of nanofiltration (NF) or reverse osmosis (TO) concentrates, repetition with or without treatment Use

NACE Kodu	NACE Code Description	Prioritized Sectoral Water Efficiency Techniques
20.14	Manufacture of other organic basic chemicals	**Precautions for Ancillary Processes**
		1. Saving water by reusing steam boiler condensate
		2. Water saving through isolation of steam and water lines (hot and cold) providing, preventing water and steam losses at pipes, valves and connection points in the lines and monitoring them with a computer system
		3. To the principle of reverse osmosis of old equipment in the ventilation system replacement by ion exchange resins (systems that produce demineralized water) and reuse of water
		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. Reduction of water consumption in closed-loop cooling systems by increasing the number of cycles and improving the quality of the catch-up water
		7. Reduction of evaporation losses in closed-loop cooling water
		8. Increasing the number of cycles by using anti-corrosion and anti-scale inhibitors in systems with a closed water loop
		9. Prevention of flash steam losses due to boiler draining
		10. Installation of water softening systems for the healthy operation of cooling water recovery systems
		11. Use of a closed-loop refrigeration system to reduce water use
		12. Collecting the water generated by surface runoff with a separate collection system and using it for cooling water, process water, etc.
		13. Reducing the amount of blowdown by using deaerators in steam boilers
		14. Minimizing boiler discharge water (blowdown) in steam boilers
		15. Reuse of energy generated from the steam condenser

A total of 72 techniques have been proposed in this sector.

Manufacture of Other Organic Basic Chemicals
NACE Code;

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

2.1.1 Industry-Specific Measures

- ***Selection of the optimum catalyst to increase resource efficiency***

  The selection of catalysts should consider the optimum balance between the following factors in order to increase resource efficiency and wastewater recovery potential:
- Activity of the catalyst
- Selectivity of the catalyst
- Life of the catalyst
- Less toxic metal use

  With the use of less toxic metals, the potential for wastewater recovery also increases.

- ***Recovery and reuse of organic solvents to improve resource efficiency***

  In the production of all organic basic chemicals, organic solvents used in processes are recovered by using appropriate techniques such as distillation and liquid phase separation. For recovery , purification is carried out using distillation, adsorption, stripping or filtration processes when necessary, and the organic solvent is returned to the treatment (IPPC BREF, 2017b).

- ***Recycling organic material and recycling water into the process for reuse***

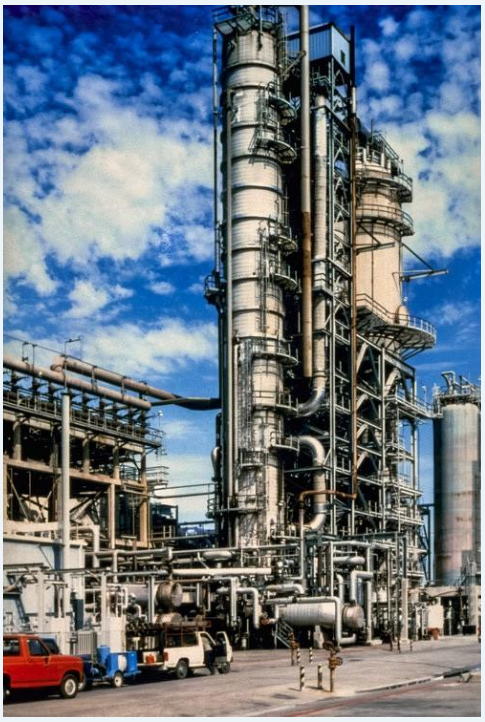
  Water recovery can be achieved by converting aqueous streams from water-type ring vacuum pumps or steam injectors back into the process for recovering organic material and reusing water (IPPC BREF, 2017b).

- ***Reuse of water from washing, rinsing and equipment cleaning***

  In this technique, multiple use and recirculation of water is aimed for the production of all organic basic chemicals. Water recovery can be achieved by reusing water from washing, rinsing, and equipment cleaning in a process such as countercurrent multi-stage washing of the organic phase (IPPC BREF, 2017b).

- ***Feeding low-sulfur raw materials in the cracking process***

  In petrochemical and olefin production, it is aimed to reduce the amount of sulfur in wastewater by using raw materials with low sulfur content or free from sulfur in the cracking process. The need to add sulfur to reduce coke formation, known as an undesirable side reaction, may limit the feasibility of the technique (IPPC BREF, 2017b).



Cracking Unit in the Chemical Industry

- ***Increasing the use of amine washing, a regenerative solvent for the removal of acid gases***

  In petrochemical and olefin production, the amount of sulfur in the wastewater is reduced by washing the cracked gases with a solvent such as regenerative amine to reduce the load on the downstream caustic scrubber, which is used in the disposal of gases such as hydrogen sulfide (IPPC BREF, 2017b). With the reduction of the amount of sulfur in the wastewater, the wastewater recovery potential also increases.

- ***Preferring dry solvents or reusing aqueous solvents with closed-loop systems***

  By using dry solvents, it is possible to reduce the amount of aromatic compounds and wastewater generated in aromatic extraction units. On the other hand, it is also possible to reduce the amount of aromatic compounds and wastewater in aromatic extraction units and the amount of aromatic compounds contained in wastewater by reusing aqueous solvents using closed-loop systems. Dry or wet solvents can be used for aromatic extraction. By using dry solvents, the amount of wastewater can be zeroed or a very low amount of wastewater is generated. If wet solvents are preferred, water can be recovered and reused by using a closed-loop recovery system (IPPC BREF, 2017b).

- ***The use of mechanical pumps in closed-loop operations in the production of aromatic chemicals, the reduction of the amount of blowdown and/or the use of dry-running pumps***

  In the production of aromatic hydrocarbons, the use of mechanical pumping systems in closed-loop processes, keeping the blowdown water low or using dry-running pumps reduce the amount of wastewater and its organic load (IPPC BREF, 2017b).

- ***Separate collection of wastewater from processes where aromatic hydrocarbons are processed from other wastewater to facilitate the recovery of raw materials and products***

  The separate collection of aqueous wastes from aromatic facilities from wastewater from other sources facilitates the recovery of raw materials and products. Applicability for existing facilities can be limited to site-specific drainage systems (IPPC BREF, 2017b).

- ***Recovery of hydrocarbons by stripping method***

  With the stripping method, volatile compounds are removed from the aqueous phase by a gas phase (e.g. steam, nitrogen or air) passed through the liquid. The resulting concentrate is recovered for reuse (e.g. by condensation) or disposed of. Removal efficiency can also be improved by increasing the temperature or reducing the pressure (IPPC BREF, 2017b).

- ***Evaluation of stripping wastewater as process water or boiler feed water using advanced treatment techniques***

  Stripping wastewater can be treated and reused with advanced treatment techniques up to the quality of the intended use of process water or boiler feed water . In this way, the amount of wastewater and water consumption can be reduced (IPPC BREF, 2017b).

- ***Reducing wastewater generation from ethylbenzene dehydrogenation and ensuring maximum recovery of organic compounds***

  In the production of ethylbenzene and styrene monomers, the mixing of organic material into the aqueous phases can be prevented, the amount of wastewater can be reduced and organic compounds can be recovered with appropriate techniques.

  With the optimized liquid phase separation technique , the separation of undissolved organic material and aqueous phases can be achieved by using the appropriate design and operation method (e.g. sufficient residence time, phase boundary detection and control). With the vapor separation technique, volatile compounds are removed from the aqueous phase by a gas phase (e.g. steam, nitrogen or air) passed through the liquid and recovered for reuse (e.g. by condensation) or disposed of. With the adsorption technique, the separation of aqueous phases and organics can be achieved by keeping the compounds in the wastewater on a solid surface (typically activated carbon) (IPPC BREF, 2017b).

- ***Pre-treatment of wastewater containing organic peroxide using hydrolysis before biological treatment without mixing with other wastewater***

  Hydrolysis is the chemical reaction in which organic or inorganic compounds react with water to convert those that are typically non-biodegradable into biodegradable or toxic ones into non-toxic compounds. To activate the reaction, hydrolysis is carried out at an elevated temperature and pressure (thermolysis) or by adding strong alkalis or acids or using an effective catalyst.

  In order to reduce the concentration of organic peroxides from the oxidation unit in the wastewater and to protect the biological wastewater treatment plant, wastewater containing organic peroxides is subjected to thermal treatment under high pH and temperature conditions. In addition, organic peroxides can also be decomposed using catalysts into compounds that are not ecotoxic and are more easily biodegradable (e.g. methanol and formic acid). This decomposition reaction can lead to the formation of hydrogen gas and the use of extra energy (IPPC BREF, 2017b).

- ***Circulation of aqueous streams from processes such as cleaning, spilling and condensation to adjust the formaldehyde product concentration***

  In formaldehyde production, aqueous streams from processes such as cleaning, spillage, and condensation are recirculated into the process to adjust the formaldehyde product concentration (IPPC BREF, 2017b).

Distillation Column in Chemical Industry

http://www.metamuhendislik.com.tr/images/phocagallery/distilasyon/thumbs/phoca_thumb_l_Bulgariaa.jpg

- ***Reuse of cleaning water from ethylene oxide plant in the production of ethylene glycol***

  In the production of ethylene oxide and ethylene glycol, the purge streams from the ethylene oxide plant are not discharged as wastewater, but are sent to the ethylene glycol process. The extent to which the purged water can be reused in the ethylene glycol process depends on the ethylene glycol product quality (IPPC BREF, 2017b).

- ***Concentrating aqueous streams by distillation technique for the recovery of glycols or partial reuse of water in ethylene oxide and ethylene glycol plants***

  Distillation is a distillation technique used to separate compounds with different boiling points through partial evaporation and re-condensation. This technique is based on the recovery or disposal of glycols in ethylene oxide and ethylene glycol plants (e.g. disposal by incineration instead of wastewater discharge) and concentrating aqueous streams for partial reuse/recovery of water. In this way, wastewater concentration and resource use can be reduced.

  While the distillation technique reduces disposal costs and economic benefits are obtained from the recovered glycols . The technique also reduces the high TOC (Total Organic Carbon)/COD (Chemical Oxygen Demand) load. At low concentrations, glycols are readily biodegradable (IPPC BREF, 2017b).

- ***Use of high concentration nitric acid (HNO3) to increase process efficiency, reduce wastewater amount and pollutant load***

  In the production of toluene diisocyanate and methylene diphenyl diisocyanate, high concentrations (e.g. approx. 99%) nitric acid (HNO3) is used (IPPC BREF, 2017b).

- ***A suitable "evaporation/distillation" of the spent acid regeneration from the nitration reaction - stripping and thickening" combination, in such a way that water and organic content are recovered for reuse***

  By using an appropriate combination of evaporation/distillation, stripping and condensation, water and organic content can be recovered for reuse by regeneration of the acid spent in the nitration reaction (IPPC BREF, 2017b).

- ***Reuse of process water from used acid recovery unit and nitration unit***

  Water consumption can be reduced by reusing process water from the used acid recovery unit and nitration unit in dinitrotoluene leaching (IPPC BREF, 2017b).

- ***Return of nitric acid and sulfuric acid waters to the process for direct reuse or material recovery***

  Nitric and sulfuric acid are removed from the organic phase using water. Pickled water can be returned directly to the process to reuse or recover materials (IPPC BREF, 2017b).

- ***Reduction of catalyst particles using fixed bed reactor design for oxychlorination***

  In the production of ethylene dichloride and vinyl chloride monomers, the catalyst particles present in the overhead gaseous stream are reduced by using a fixed-bed reactor in the oxychlorination reaction design. The technique reduces the leaching of PCDD/F compounds (Polychlorinated dibenzo-dioxins and furans) and copper resulting from the oxychlorination process into the water. However, the feasibility of the technique does not apply to existing facilities using fluidized bed design (IPPC BREF, 2017b). With the reduction of the amount of copper in wastewater, the potential for wastewater recovery also increases.

- ***Reducing catalyst losses and preventing them from mixing with wastewater***

  By using a cyclone or a dry catalyst filtration system in the production of ethylene dichloride and vinyl chloride monomers, catalyst losses in the reactor and thus their discharge into wastewater can also be reduced. This technique is only applicable to plants that use a fluidized bed design (IPPC BREF, 2017b). With the reduction of the amount of ethylene dichloride and vinyl chloride in wastewater, the potential for wastewater recovery also increases.

- ***Separation of organic phases and aqueous phases to prevent undissolved organic substances from mixing with wastewater***

  In order to prevent the mixing of undissolved organic substances into wastewater, the separation of organic phases and aqueous phases from each other under appropriate design and appropriate operating conditions (sufficient holding time, phase limit detection and control) increases the recovery of hydrocarbons and ensures the reuse of extinguishing water. Hydrocarbons recovered from extinguishing water from the primary separation stage can be recovered or used as raw materials in other chemical processes. In the recovery of organics; Efficiency can be increased through the use of steam, gas stripping or re-boiling. The treated extinguishing water is reused in the dilution steam production system. To prevent salt accumulation in the system, extinguishing water discharge current can be supplied in the direction of flow of the final wastewater treatment system (IPPC BREF, 2017b).

- ***Conversion of formaldehyde into a less hazardous substance***

  Due to its formaldehyde content, it adversely affects the performance of wastewater treatment plants. Formaldehyde can be converted into a less dangerous substance by methods such as oxidation or the addition of sodium sulfite. With the application of this technique, the amount of wastewater supplied to the wastewater treatment plant and the organic load can be reduced. Thus, the recovery potential of wastewater increases.

- ***Using aqueous type ring vacuum pumps***

  The amount of wastewater can be reduced by using aqueous-type ring vacuum pumps and circulating the sealing fluid of the pump. The water used as the pump's sealing fluid can be recirculated into the pump housing through a closed loop with small drains, reducing wastewater generation. The technique is used to prevent or reduce the emissions of organic compounds from vacuum systems to air and water (IPPC BREF, 2017b).

2.1.2 Good Management Practices

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

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

The most widely used Environmental Management Standard is ISO 14001. Alternatives include the Eco Management and Audit Programme Directive (EMAS) (761/2001). It has been developed for the evaluation, improvement and reporting of the environmental performance of enterprises. It is one of the leading practices within the scope of eco-efficiency (cleaner production) in EU legislation and participation is provided voluntarily (TUBITAK MAM, 2016; TOB, 2021). The benefits of establishing and implementing an Environmental Management System are as follows:

- Economic benefits can be achieved by improving business performance (Christopher, 1998).
- International Organization for Standardization (ISO) standards are adopted, resulting in greater compliance with global legal and regulatory requirements (Christopher, 1998).
- While the penalty risks related to environmental responsibilities are minimized, the amount of waste, resource consumption and operating costs are reduced (Delmas, 2009).
- The use of internationally accepted environmental standards eliminates the need for multiple registrations and certifications for businesses operating in different locations around the world (Hutchens Jr., 2017).
- Especially in recent years, the improvement of the internal control processes of companies is also important to consumers. The implementation of environmental management systems provides a competitive advantage over companies that do not adopt the standard. It also contributes to the better position of institutions in international areas/markets (Potoski & Prakash, 2005).

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

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

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

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. Due to the fact that the personnel do not have the necessary technical knowledge in industrial facilities, problems may arise with the use of high amounts of water and wastewater formation. 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. In applications such as determining water quality requirements in production processes, measuring water and wastewater amounts, etc., it is necessary for the relevant personnel to have sufficient technical knowledge (TOB, 2021). For this reason, it is important to provide training to staff on water use reduction, optimization and water saving policies. Practices such as involving personnel in water conservation studies, creating regular reports on water usage amounts before and after water efficiency initiatives, and sharing these reports with personnel support participation and motivation in the process. The technical, economic and environmental benefits to be obtained through personnel training give results in the medium or long term (TUBITAK MAM, 2016; TOB, 2021).

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

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

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

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

- ***Setting water efficiency targets***

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

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

  Determination of water use and wastewater generation points in industrial facilities, creation of water-wastewater balances in production processes and auxiliary processes other than production processes are the basis of many good management practices in general. Creation of process profiles throughout the plant and on the basis of production processes facilitates the identification of unnecessary water use points and high water use points, the evaluation of water recovery opportunities, process modifications and the determination of water losses (TOB, 2021).

- ***Using an integrated wastewater management and treatment strategy to reduce the amount of wastewater and the pollutant load***

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

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

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

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

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

  In terms of water efficiency, it is important to prepare an action plan that includes what to do in the short, medium and long term in order to reduce the amount of water-wastewater in industrial facilities and to prevent water pollution. At this point, water needs should be determined throughout the facility and in production processes, quality requirements should be determined at water usage points, wastewater formation points and wastewater characterization should be done (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 make feasibility and to prepare action plans for the short-medium-long term. In this way, water efficiency and sustainable water use are ensured in facilities (TOB, 2021).

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

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

2.1.3 General Water Efficiency BATs

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

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

- Adding pumps, valves, level switches, pressure and flow regulators to the maintenance checklist ,
- Carrying out inspections not only in the water system, but also especially for heat transfer and chemical distribution systems, broken and leaking pipes, barrels, pumps and valves,
- regular cleaning of filters and pipelines,
- Calibrating, routinely checking and monitoring measuring equipment such as chemical measuring and dispensing instruments, 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).

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

In industrial facilities, relatively clean wastewater, especially washing-final rinsing wastewater and filter backwash wastewater, can be recycled 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 consist of the establishment of new pipelines and reserved tanks (Öztürk, 2014).

- ***Where technically feasible, suitable wastewater is treated and used as steam boiler feed water***

Although it is difficult to apply 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; TUBITAK MAM, 2016). The initial investment cost required for the application is the treatment system to be used. Considering the amount of water to be recycled, the amount of economic savings, the applied unit water-wastewater costs, and the operation and maintenance costs of the treatment system, the payback periods vary (TOB, 2021). Membrane systems (a combination of ultrafiltration (UF), nanofiltration (NF) and reverse osmosis (CTR) systems can be used for recovery. For example, in some industrial facilities, it is possible to treat the cooling system blowdown water and reuse it as process water (TOB, 2021).

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

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

- ***Determination of wastewater flows that can be reused with or without treatment by characterizing the amount and quality of wastewater at all wastewater formation points*** By determining and characterizing wastewater formation points in industrial facilities, it is possible to reuse various wastewater streams with or without treatment (Öztürk, 2014; TUBITAK MAM, 2016; TOB, 2021). In this context, filter backwash water, CTR concentrates, blowdown water, condensate water, relatively clean washing and rinsing water can be reused without treatment in the same/different processes and in areas that do not require high water quality (such as plant and equipment cleaning). Apart from this, it is possible to reuse wastewater streams that cannot be reused directly in production processes after they are treated using appropriate treatment technologies.

  Membrane filtration processes are an integral part of many wastewater reuse systems. Nanofiltration (NF) and Reverse osmosis (CTR) filtration systems are used for industrial wastewater recovery. Microfiltration (MF) and ultrafiltration (UF) are often used for the pretreatment of water before it goes to the NF or CTR process (Singh et al., 2014).

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

  Both raw material and water losses can be experienced due to spills and leaks in enterprises. In addition, if wet cleaning methods are used to clean the spilled areas, there may be increases in water consumption, wastewater amounts and pollution loads of wastewater (TOB, 2021). In order to reduce raw material and product losses, spillage and splash losses are reduced by using anti-splashes, fins, drip trays, sieves (IPPC BREF, 2019).

- ***Determination of the scope of reuse of washing and rinsing waters***

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

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

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

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

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

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

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

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

- ***Avoiding 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 with each other and undergo 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 course 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, there may be an increase in the chemical loads carried by the wastewater. These negative effects can be minimized by ensuring that the washing water containing solvents used in the washing and rinsing processes is reused.

  It is possible to save 25-50% of water by reusing washing water. Reserved 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 many times until it loses its properties.

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

  According to wastewater characterization and appropriate points of use, the reuse potentials of other wastewater resulting from membrane processes (backwash without or with the use of chemicals, CIP cleaning, module cleaning, cleaning of chemical tanks, etc.) should be evaluated.

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

  Depending on the characterization of nanofiltration or reverse osmosis concentrates, savings are achieved by reusing them with or without treatment. Measures should be taken to reuse clean water in the production processes of filter backwash water in filtration processes and to reduce water consumption by using cleaning systems (TOB, 2021).

Reverse Osmosis System

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

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

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

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

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

- ***Storage, storage and prevention of substances that pose a risk in the aquatic environment (such as oils, emulsions, binders) and mixing with wastewater after use***

  In industrial facilities, water recovery is achieved by using dry cleaning techniques and preventing leaks in order to prevent chemicals that pose a risk to the aquatic environment such as oils, emulsions and binders from mixing with wastewater streams (TUBITAK MAM, 2016).

Water Softening Systems

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

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

  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 water at appropriate points before water softening. This measure is similar in content to applications such as "Reuse of filter backwash water in filtration processes, relatively cleaning water in production processes, and reducing water consumption by using in-situ cleaning systems".

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

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

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

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

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

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

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

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

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

- ***Implementation of time optimization in production and arrangement of all processes to be completed as soon as possible***

In industrial production processes, planning the process from raw material to product transformation using the least process is an effective practice to reduce labor costs, resource use costs and environmental impacts and to ensure efficiency. In this context, it may be necessary to review the production processes and revise them to use the least number of process steps (TUBITAK MAM, 2016). In cases where the desired product quality cannot be achieved due to some inadequacies, inefficiency and design errors in basic production processes, production processes may need to be renewed. Therefore, in this case, the use of resources required in the manufacture of the 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).

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

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

Computer Aided Control System

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

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

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

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

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

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

  Wastewater from backwashes of activated carbon filters and softening devices often contains only a high percentage of suspended solids (AKM). Backwash water, which is one of the easiest wastewater types to recycle, can be recovered by filtering with ultrafiltration plants. In this way, water savings of up to 15% 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. It is ensured that regeneration wastewater is collected in a separate tank and evaluated in processes with high salt requirements, facility cleaning and domestic use. For this, a reserved tank, plumbing and pump are needed. With the reuse of regeneration wastewater, water consumption, energy consumption, wastewater amounts and salt content of wastewater are reduced by approximately 5-10% (Öztürk, 2014). The payback period varies according to the consumption of regeneration water in production processes, facility cleaning and domestic use. It is estimated that if regeneration water is reused in production processes that require high salt (since both water and salt will be recovered), the potential payback period will be less than one year. It is estimated that the payback period will be over one year for facility and equipment cleaning and domestic uses (TOB, 2021).

  In our country, reverse osmosis (CTR) concentrates are combined with other wastewater streams and given to the wastewater treatment plant channel. The concentrates formed in the CTR 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 re-evaluate CTR concentrates by feeding them back into raw water reservoirs and mixing them (TOB, 2021).

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

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

2.1.4 Precautions for Ancillary Processes

- ***Saving water 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 the steam lines are not properly designed in the facilities, routine maintenance and repairs of the steam lines are not carried out, mechanical problems that occur in the lines and the lines are not operated properly, and full insulation of the steam lines and hot surfaces is not made. This affects both the water consumption and energy consumption of the facility. It is necessary to use control systems with automatic control mechanisms in order to make steam insulations and to monitor steam consumption continuously. Due to 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 use of 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 are also reduced. Automatic control mechanisms for full vapor insulation application and minimization of steam losses are used in many facilities with heavy steam consumption. With the configuration of the application, 2-4% fuel savings 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, inspecting not only water systems but also heating and chemical distribution systems, drums, pumps and valves, regular cleaning of filters and pipelines, 1-6% savings in water consumption can be achieved with regular calibration of measuring equipment (thermometers, chemical scales, dispensing/dosing systems, etc.) and routine inspection and cleaning of heat treatment units (including chimneys) at specified periods, effective maintenance-repair, cleaning and loss control practices (Hasanbeigi, 2010; Ozturk, 2014; TOB, 2021).

Industrial Steam Boilers

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- ***Saving water by reusing steam boiler condensate***

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

- ***Prevention of frisk steam losses due to boiler draining***

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

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

  Boiler blowdown refers to the water consumed 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 constantly monitored and the system is re-analyzed together 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 frequency of blowdowns is reduced, the amount of wastewater decreases. This saves energy and cooling water used to cool wastewater (IPPC BREF, 2009). By optimizing the steam boiler blowdown process, operating costs are reduced by saving boiler water consumption, waste costs, conditioning and heating.

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

  By applying a simple modification to the piping system, the water that feeds the water resting/decarbonization unit can be obtained from the outlet of the turbine condenser unit. This water has sufficient temperature for the resting/decarbonization unit. Therefore, this water does not need to be heated by means of steam generated by the heat exchanger system. Thanks to this work, significant steam gain can be achieved. In addition, cooling water consumption can be reduced (CPRAC, 2021).

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

  In most industrial facilities, wastewater is generated from process-sourced or non-process-based areas. The resulting wastewater 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. Water generated by surface runoff can be collected with a separate collection system and used as cooling water (TOB, 2021).

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

Free oxygen dissolved in steam boilers, feed water and hot water boilers, and carbon dioxide formed by the breakdown of carbonates in boilers can cause corrosion in the form of pores and rusting and melting in steam boilers, devices using steam and especially in installations. The effects of these gases increase as the proportion of fresh feed water and the operating pressure of the system increases. If these dissolved gases are not removed from the boiler feed water, the useful life of these systems is shortened, corrosion and various deformations may occur. These gases also cause excessive corrosion in carbon dioxide coils, steam appliances and condensate pipes. Boiler feed water must be purified from dissolved gases such as oxygen and carbon dioxide by passing through the deaerator. Deaeration systems are mechanical systems that allow dissolved gases to be evaporated from the water by giving air to the water with a fan. Dissolved deaeration 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 for refrigeration systems

- ***Use of a closed-loop refrigeration system to reduce water use***

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

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

Water is used as a refrigerant in many processes such as the production processes of the manufacturing industry and the cooling of products. Water is recirculated through a cooling tower or central cooling systems and the cooling process is carried out. 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 good chemical conditioning. In this way, water can be saved by reducing the amount of fresh water fed into the system. In addition, good conditioning of the cooling completion water can also increase the number of cycles (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 it is necessary to reduce the tower height, a hybrid cooling system can be applied. Hybrid refrigeration systems are a combination of evaporative and non-evaporative (wet and dry) refrigeration systems. Depending on the ambient temperature, the hybrid cooling tower can be operated as a completely wet cooling tower or as a combined wet/dry cooling tower (TUBITAK MAM, 2016). In regions where there is not enough cooling water or in cases 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 supplement water (TUBITAK MAM, 2016).

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

Cooling towers and evaporative condensers, air conditioning and industrial process cooling systems effective and low-cost systems that remove the heat from the outgoing (IPPC BREF, 2001b; TOB, 2021). More than 95% of the circulating water in these systems can be recovered (TUBITAK MAM, 2016). In cooling systems, impurities remain in the recirculation water due to the fact that some of the recirculation water is worked on the basis of evaporation, and the impurity concentrations gradually increase in each cycle. Impurities that can be included in the cooling system together with the air can cause contamination in the recirculation water (TUBITAK MAM, 2016). If impurities and contaminants are not effectively controlled, they can cause the formation of boilerstone and corrosion, unwanted biological growth and sludge accumulation. This can become a chronic problem that leads to a decrease in the efficiency of heat transfer surfaces and an increase in operating costs. In this case, it is necessary to implement a water treatment program specially designed in terms of the quality of the feed water supplied to the cooling system, the cooling water system building material and operating conditions. In this context; blowdown control, biological growth control, corrosion control, avoiding the use of hard water, using sludge control chemicals, using filtration and sieve systems may be appropriate (TUBITAK MAM, 2016). In addition, the establishment and periodic implementation of an effective cleaning procedure and program is a good management practice in terms of protecting cooling systems. Corrosion is one of the most important problems in cooling systems. In the tower recirculation water, as the degree of hardness increases, dissolved solids (sulfate, chloride, carbonate, etc.) that cause corrosion as a result of the formation of limestone and deposits on the walls will cause abrasion on the surface over time. In addition, the formation of deposits negatively affects heat transfer and reduces energy efficiency. In order to prevent these negativities, it is necessary to implement a lime and corrosion preventive chemical conditioning program, to disinfect with biocide that prevents biological activation, to clean the sediments by subjecting the cooling towers in use to chemical and mechanical cleaning at least twice a year, and to keep the hardness and conductivity values of the reinforcement water as low as possible (IPPC BREF, 2001; Kayabek et al., 2005). In order to improve the quality of the supplementary water, it may be necessary to treat (condition) it using an appropriate treatment system. In addition, unwanted microbial growth needs to be kept under control (IPPC BREF, 2001b; TOB, 2021). Due to micro-residues and deposits in the cooling water, blowdown occurs in cooling systems as well as in steam boilers. Deliberate draining of the cooling system to bring the increased density of solids in the cooling system to balance is called cooling blowdown. It is possible to reduce the use of biocides and blowdown amounts by pre-treating cooling water with appropriate methods and continuous monitoring of cooling water quality (TUBITAK MAM, 2016). Although the investment cost depends on the scale of the application, the payback period in expected investment expenses varies between 3 and 4 years (IPPC BREF, 2001).

https://www.chiller.com.tr/wp-content/uploads/2018/04/chiller-sogutma-kapasitesi-hesabi.jpg

- ***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 reused in appropriate processes (EC, 2009). In order for this system to work properly, a water softening system is required. It has suitable water quality in terms of cooling water, cleaning and reuse as irrigation water. However, due to the fact that it contains some hardness in its use as cooling water, an additional softening is required in order to prevent corrosion problems that will occur over time. Cooling water or before it can be reused in the process, these waters must be properly disinfected. In addition, it is possible to reuse the water in question not only in cooling processes but also in all production processes by treating it with appropriate treatment techniques (membrane filtration, advanced oxidation, chemical precipitation, granular activated carbon adsorption, etc.) (TUBITAK MAM, 2016). As the hardness of the cooling water increases, limestone and debris formation occurs on the walls. Deposit formation 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, it is necessary to apply lime and anti-corrosion chemical conditioning to the cooling water, to disinfect with a biocide that prevents biological activation, to subject the cooling towers to chemical and mechanical cleaning at least twice a year, to clean the sediments, and to keep the hardness and conductivity values as low as possible (TUBITAK MAM, 2016).

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

  Some water evaporates during the cooling of the heated water in the cooling systems. Therefore, in closed-loop cooling systems, cooling water is added as much as the amount of evaporated water. Evaporation losses can be avoided by optimizing cooling systems. In addition, a reduction in the amount of blowdown can be achieved with applications such as the treatment of completion water added to cooling systems and the prevention of biological growth in cooling systems. Within the scope of the field studies carried out, the blowdown water formed in the cooling system is generally removed by giving it directly to the wastewater channel. By reusing the cooling system blowdown water, up to 50% of the water consumption of the cooling systems can be saved. To implement this measure, it may be necessary to install new pipelines and reserved tanks. (TOB, 2021).

METs for ventilation and air conditioning systems

- ***Reuse of the liquid formed by condensation from the ventilation system***

  During the aeration cycle, condensate with good water quality can be produced in the system. 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 to flush the 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 that produce demineralized water) and reuse*** of water Conductivity of the final effluent using ion exchange resins in the aeration system
  It is brought to a conductivity level suitable for use for equipment cleaning. Example
  In a facility in Spain, effluent with a conductivity value of approximately 1000 μS is obtained by replacing the equipment in the ventilation system with ion exchange resins and reused in the system (MedClean, n.d.).

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