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

Water Efficiency
Campaign

Water Efficiency
Guide Documents Series

PROCESSING AND STORAGE OF POTATOES

NACE CODE: 10.31

ANKARA 2023

Ministry of Agriculture and Forestry, General Directorate of Water Management Contractor io Environmental Solutions R&D Ltd. Sti. has been prepared.

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Abbreviations

EU	European Union
SS	Suspended Solids
BREF	Best Available Techniques Reference Document
EMS	Environmental Management System
MoEUB	Republic of Turkey Ministry of Environment, Urbanization and Climate Change
NOM	Natural Organic Matter
EMAS	Eco Management and Audit Program Directive
EPA	United States Environmental Protection Agency
IPPC	Industrial Pollution Prevention and Control
ISO	International Organization for Standardization
FLOW	Best Techniques Available
NACE	Statistical Classification of Economic Activities
DGWM	General Directorate of Water Management
RO	Reverse Osmosis
MOAF	Ministry of Agriculture and Forestry of the Republic of Turkey
TurkStat	Turkish Statistical Institute
NF	Nanophilia
MF	Microfiltration
UF	Ultrafilt
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 m³, 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.

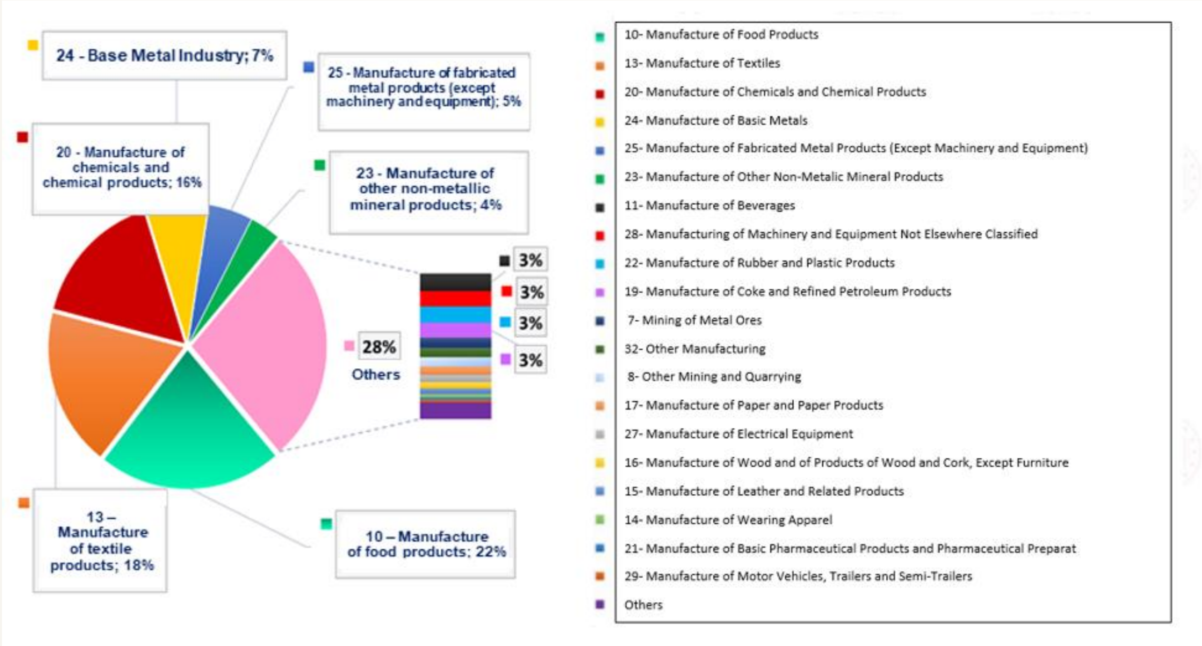
In the European Green Deal Action Plan prepared by our country within the scope of the European Green Deal, where member countries agree on goals such as implementing a clean, circular economy model with the goal of carbon neutrality, expanding the efficient use of resources and reducing environmental 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 our country

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 Water Efficiency BATs, (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)

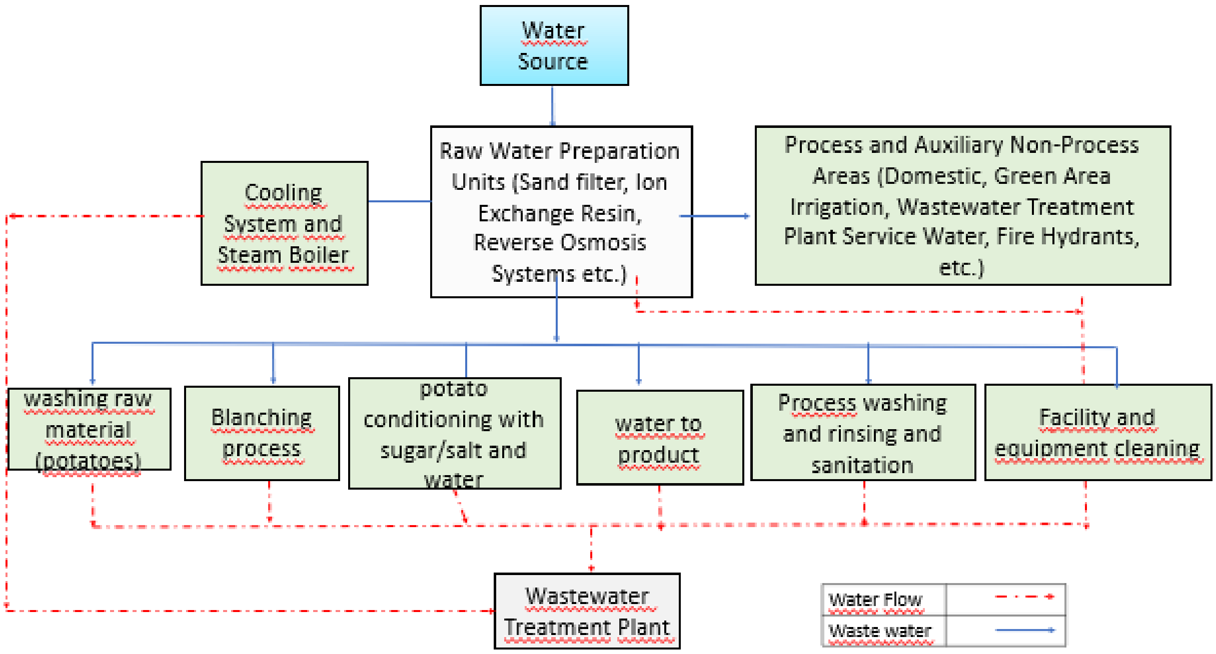
Manufacture of food products

The sub-production branches for which guide documents are prepared under the production of food products sector are as follows:

10.11	Processing and storage of meat
10.12	Processing and storage of poultry meat
10.13	Manufacture of products made from meat and poultry meat
10.20	Processing and storage of fish, shellfish and mollusks
10.31	Processing and storage of potatoes
10.32	Manufacture of vegetable and fruit juice
10.39	Processing and storage of fruits and vegetables n.e.c.
10.41	Manufacture of oils and fats
10.42	Manufacture of margarine and similar edible fats
10.51	Dairy management and cheese manufacturing
10.52	Ice cream manufacturing
10.61	Manufacture of milled cereals and vegetable products
10.62	Manufacture of starch and starchy products
10.71	Manufacture of bread, fresh patisserie products and fresh cakes
10.72	Manufacture of rusks and biscuits; Durable patisserie products and durable cake manufacturing
10.73	Manufacture of pasta, noodles, couscous and similar bakery products
10.81	Manufacture of sugar
10.82	Manufacture of cocoa, chocolate and confectionery
10.83	Processing of coffee and tea
10.84	Manufacture of spices, sauces, vinegars and other condiments
10.85	Manufacture of ready meals
10.89	Manufacture of other foodstuffs n.e.c.

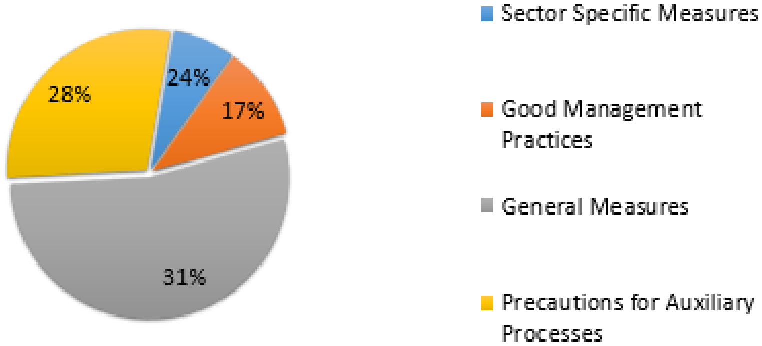
2.1. Processing and Storage of Potatoes (NACE 10.31)

Potato processing and storage sector water flow chart



	Minimum	Maksimum
Specific Water Consumption of the Facility Visited during the Project (L/kg product)	4,3	22,3
Reference Specific Water Consumption (L/kg product)	1,25	10

Percentage Distribution of Water Efficiency Practices



In potato processing and storage facilities, after the raw material is accepted to the facility, it is stored in refrigerated areas with high relative humidity. Potatoes, before peeling; It is first fed to the stone sorting machine in order to remove the stones mixed with the pile, to remove the microorganisms on their surfaces, to clean the dust-soil, mud, pesticide residues, insects and similar foreign matter residues. Here, the stones mixed into the potatoes and the heavy particles that cannot float in the water are separated and removed by centrifugal effect. Potatoes that have left the stone sorting machine are taken to the pre-washing machine. Potatoes, leaving the washing machine, are fed into the peeling machine. After the dehulling machine, it goes to the washing machine. Here, by spraying high-pressure water, both the remaining skins are completely separated from the potatoes and the peeled potatoes are effectively cleaned. Then the weeding control process is carried out. The potatoes, whose control process is completed, are cut with special knives using water pressure and brought to the desired shape and size. Cut potatoes are subjected to trimming and trimming process. Sliced fingerling potatoes are once again sorted before boiling. The purpose of the boiling process is to provide enzyme inactivation, to reduce the sugar content for a good color in the product, to reduce the oil absorption rate by forming a thin gelatin layer on the surface, to shorten the cooking and frying time of the product and to give the final product a quality structure. Drying is carried out to reduce the load on the fryer and slow down the hydrolytic degradation of the oil. The potatoes passing over the belt are exposed to hot air flow, allowing them to lose water. The potatoes, which are subjected to the drying process, are fried on a belt by passing through hot oil. In the pre-cooling process, the product from the frying is cooled slightly with air before entering the freezing. The pre-cooled potatoes go to the freezing process. The final products, whose freezing process is completed, go to the packaging machine.

In the production of potato chips, stone separation, peeling, selection and cutting, slicing, hot and cold washing, frying, salting/seasoning processes are followed by packaging.

In the processing and storage facilities of potatoes, water consumption is realized in raw material washing, boiling and conditioning processes. In addition, there are waters that are directly added to the product. In raw water preparation units such as activated carbon filters, ion exchange resins, reverse osmosis, which are used to produce the demineralized water needed in the sector, significant water consumption is also realized for filter washing, resin regeneration and membrane cleaning processes. In addition, water consumption is also realized in auxiliary units such as cooling towers and steam boilers.

The reference specific water consumption in potato processing and storage facilities is in the range of 1.25 – 10 L/kg (IPPC BREF, 2019). The specific water consumption of the production branch analyzed within the scope of the study remains in the range of 4.3 – 22.3 L/kg, and it is possible to achieve 33 – 58% water recovery in the sector with the application of sector-specific techniques, good management practices, general measures and measures related to auxiliary processes.

10.31 Processing and Storage of Potatoes The priority water efficiency implementation techniques recommended under the NACE code are shown in the table below is offered.

NACE Code	NACE Code Description		Industry-First Available Best Techniques
10.31	Processing and storage of potatoes		**Industry-Specific Measures**
		1.	Evaluation of advanced treated water in processes that require drinking water standards
		2.	Reuse of biologically treated and chlorinated water for floor cleaning
		3.	Development of unit processes that use less water
		4.	Reuse of wastewater from filling equipment (fillers)
		5.	Optimisation of the water circuit inside the factory
		6.	Purification and reuse of used water that meets the necessary hygiene standards
		7.	Reuse of water used in processes such as washing, peeling, sorting, or canning raw materials
		8.	Cleaning the harvested raw fruits and vegetables by dry cleaning methods
		9.	Reuse of scalding water and cooling water after blanching
		10.	Use of dry separation techniques to separate waste from process steps or out-of-specification products
		11.	The use of dry caustic for peeling fruits and vegetables
		12.	Starch recovery in potato processing
		13.	Reuse of process water in potato starch production
		14.	Determining water quality needs on the basis of processes and using appropriate quality water
		15.	Use of pressure washing systems in vegetable and fruit washing processes
		16.	Separation of residual materials from peeling and cutting processes
		17.	Reuse of wash water
			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 water used in production processes and auxiliary processes and the wastewater generated in terms of quantity and quality, and this information is used in the environment.

NACE Code	NACE Code Description		Industry-First Available Best Techniques
10.31	Processing and storage of potatoes		**General Water Efficiency BATs**
		1.	Minimization of spills and leaks
		2.	Recovery of water from rinsing solutions and reuse of recovered water in processes appropriate to its quality
		3.	Use of automatic equipment and equipment (sensors, smart hand washing systems, etc.) that will save water at water usage points such as showers/toilets, etc .
		4.	Use of pressure washers for equipment cleaning, general cleaning, etc.
		5.	Reuse of filter wash water in filtration processes, reuse of relatively clean cleaning water in production processes, and reduction of water consumption by using clean-in-place systems (CIP)
		6.	Avoiding the use of drinking water in production lines
		7.	Detection and reduction of water losses
		8.	Use of automatic check-off valves to optimise water use
		9.	Documentation of production procedures and use by employees to prevent waste of water and energy
		10.	Reuse of pressurized filtration backwash water prior to water softening at appropriate points
		11.	Optimising the frequency and duration of regeneration (including rinses) in water softening systems
		12.	Construction of closed storage and impermeable waste/scrap yard to prevent the transportation of toxic or hazardous chemicals for the aquatic environment
		13.	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
		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.	Determination of the scope of reuse of washing and rinsing waters
		19.	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.)

NACE Code	NACE Code Description		Industry-First Available Best Techniques
10.31	Processing and storage of potatoes	20.	Implementation of time optimization in production and arrangement of all processes to be completed as soon as possible
		21.	Collecting rainwater and evaluating it as an alternative water source in facility cleaning or in appropriate areas
		22.	Avoiding the need for rinsing between activities by using compatible chemicals in successive processes
		23.	Reuse of nanofiltration (NF) or reverse osmosis (CTR) concentrates with or without purification depending on characterization
			Precautions for Ancillary Processes
		1.	Saving water by reusing steam boiler condensate
		2.	Saving water with the insulation of 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
		3.	Reduction of water consumption in closed-loop cooling systems by increasing the number of cycles and improving the quality of the catch-up water
		4.	Reduction of evaporation losses in closed-loop cooling water
		5.	Water recovery with tower cooling application in systems that do not have a closed loop
		6.	Increasing the number of cycles by using anti-corrosion and anti-scale inhibitors in systems with a closed water loop
		7.	Prevention of flash steam losses due to boiler draining
		8.	The use of hot water produced in the cogeneration system in heating processes
		9.	Air cooling instead of water cooling in cooling systems g systems

NACE Code	NACE Code Descriptio		Industry-First Available Best Techniques
10.31	Processing of potatoes and	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.	In some periods of the year, when the need for cooling is low, cooling with local dry air
		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 steam condenser A total

of 63 techniques have been proposed in this sector.

Processing and Storage of Potatoes for NACE Code;

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

2.1.1 Industry-Specific Measures

Processing and preserving of vegetables and fruits, processing and preserving potatoes, manufacture of vegetable and fruit juice

- ***Cleaning the harvested raw fruits and vegetables by dry cleaning methods***

  In order to reduce water consumption in the water cleaning process, it is necessary to remove as much residual material as possible from raw materials and equipment beforehand. By means of compressed air, vacuum systems or screens with mesh covers, the amount of water used and the amount of wastewater generated can be reduced. A significant reduction in the pollutant load of wastewater can be achieved by separating residual materials by dry cleaning methods such as screening, brushing/abrasion, ventilation (blowing), aspiration (pulling) before contact with water (IPPC BREF, 2019).

- ***Use of pressure washing systems in vegetable and fruit washing processes***

  In high-pressure cleaning systems, water is sprayed on the surface to be cleaned at pressures ranging from 15 bar to 150 bar. High-pressure cleaners have some advantages compared to low-pressure cleaners. With the mechanical cleaning effect of the water jet, water usage is significantly reduced, and heavy dirt can be removed, resulting in a significant reduction in the use of chemicals. As a result of this application, bacterial growth is also reduced (IPPC BREF, 2019).

- ***Reuse of water used in processes such as washing, peeling, sorting, or canning raw materials***

  Wastewater with low BOD levels, which is used only for washing, peeling, sorting or canning input products, can be reused by simply filtering without full treatment (IPPC BREF, 2019).

- ***Use of dry separation techniques to separate waste from process steps or out-of-specification products***

  Sorting faulty products at the beginning of production lines; It prevents waste materials from steps such as trimming, separation, extraction or out-of-specification products (products outside the quality standards) from passing through the production line and being removed at the end of the line. Defective products that are not sorted at the beginning of the production line also cause additional losses in energy/water/auxiliary products. This problem can be avoided by manual or mechanical dry separation method (IPPC BREF, 2019).

- ***Separation of residual materials from peeling and cutting processes***

  Leftovers of classified, unprocessed or partially processed vegetables and fruits can be separated for use in the product by manual or mechanical methods or for other purposes, for reuse, recovery, recycling and disposal. These residues, which include rejected raw materials, cut parts, and out-of-specification products, can be separated by sedimentation and filtration techniques before being sent directly to disposal, reducing water use and the generation of extra wastewater (IPPC BREF, 2019).

- ***Reuse of wastewater from filling equipment (fillers)***

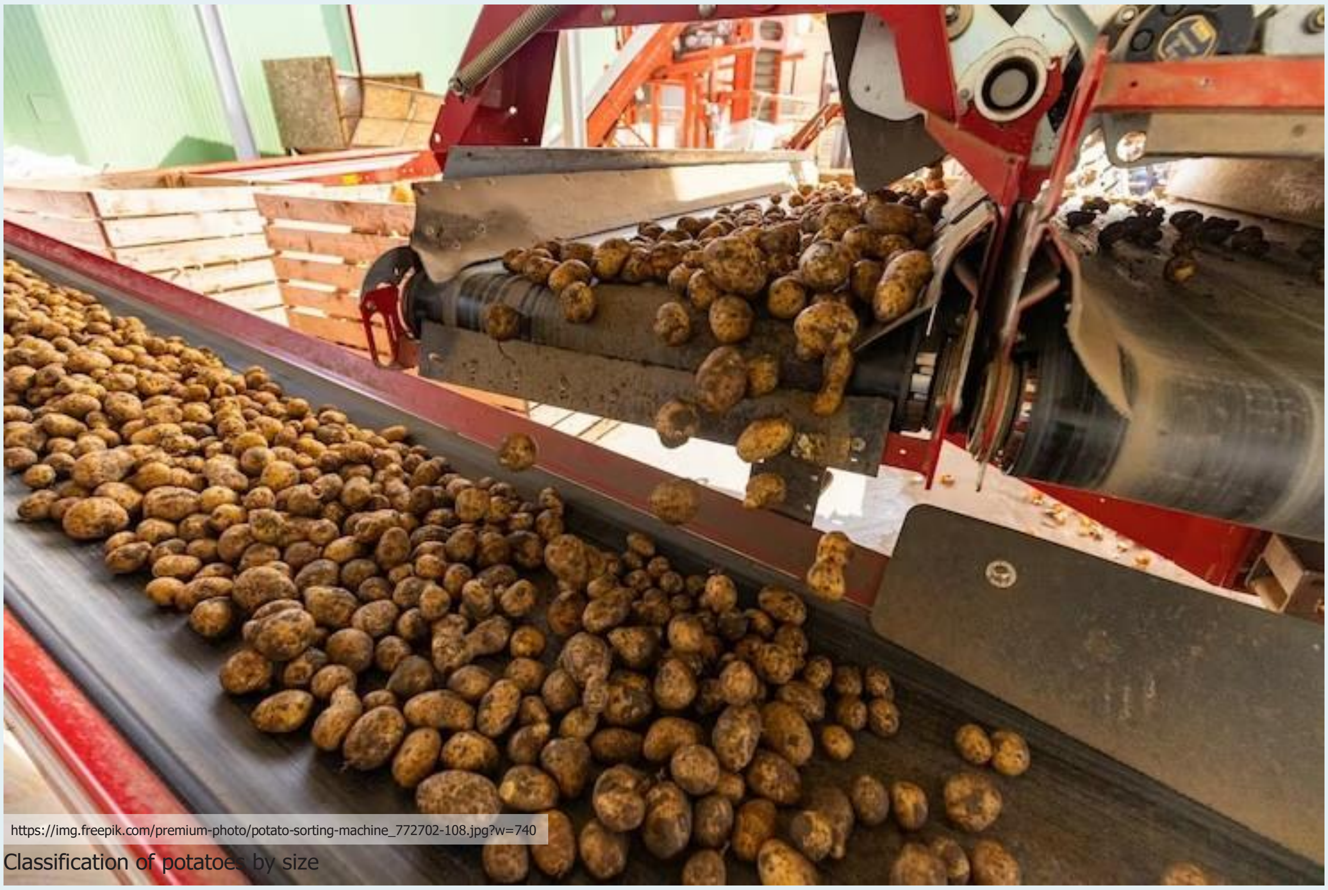
  Wastewater from filling equipment (fillers) in a fruit or vegetable juice producing facility has less pollution load than other wastewater (COD 100 mg/L) and can be reused in cooling towers after being conditioned with biocides. The addition of biocides is required for wastewater to be reused in cooling towers.

- ***Reuse of scalding water and cooling water after blanching***

  After blanching, the cooling water heated in this compartment can be fed to the preheating compartment before the blanching process and reused. Thus, both heat recovery is achieved and less water is used by circulating. In addition , the scalding water used for some fruits and vegetables can be used for pre-cleaning of freezer tunnels or washing raw materials (IPPC BREF, 2019).

- ***Reuse of wash water***

  The water resulting from the washing, cleaning of raw materials and defrosting of frozen products can then be reused as cooling water or for the process itself . Water with a low organic content, which is only used to wash inputs, can only be reused by filtering without being subjected to full treatment. The same applies to freezer defrost water.



https://img.freepik.com/premium-photo/potato-sorting-machine_772702-108.jpg?w=740

Classification of potatoes by size

- ***Reuse of biologically treated and chlorinated water in floor cleaning*** Water use can be reduced by reusing wastewater in floor cleaning and similar areas by treatment and chlorination.

- ***Evaluation of advanced treated water in processes that require drinking water standards***
After biological treatment, wastewater that has undergone reverse osmosis and UV disinfection can be used in areas that require drinking water standards. Advanced treatment is required to prevent the production of microorganisms in the food industry and to ensure hygiene conditions. The use of wastewater undergoing advanced treatment in cooking, product ingredient preparation and similar processes that require potable quality water reduces water consumption (IPPC BREF, 2019).

- ***Recovery of starch in potato processing***
Process streams and wastewater in the potato processing industry contain high concentrations of starch. This starch can be recovered in different places during the production process. Depending on its place in the production process, a distinction is made between white and gray starch. White starch is starch that has not been heated above 40°C. This starch has typical starch properties and can be used as a raw material in the paper, adhesive and bioplastics industries. Gray starch is starch that changes color after heating. This starch can be recovered before the wastewater enters the WWTP. By using recovered starch as a raw material, both economic gain is obtained and the organic matter load and operating costs of the treatment plant are reduced as it will not go to the treatment plant (IPPC BREF, 2019).

- ***Development of unit processes that use less water***
In the food industry, a large part of the water is used for washing processes. For this reason, significant savings in water consumption can be achieved by reducing the water used in washing processes (IPPC FDM BREF, 2006). In this context, washing processes using spray systems and cleaning processes such as jar and bottle washing with steam can save water in food businesses (Casani et al., 2005).

- ***Optimisation of the water circuit inside the factory***
Efficient use of water can be ensured by optimizing the water cycle in water usage areas in food enterprises. For example, in washing processes and food processing processes, losses during the transmission of water can be minimized. In addition, water losses can be reduced during the collection of wastewater that is planned to be reused without treatment within the facility and conveyed it to the appropriate process (Casani et al., 2005).

- ***The use of dry caustic for peeling fruits and vegetables***

In dry caustic peeling, it is applied to a 10% caustic solution heated to 80 – 120 °C to soften the peel of vegetables and fruits. Then the shell is removed with rubber discs or rollers. In the process of peeling fruits and vegetables, if the batch steam process or steam peeling techniques cannot be applied due to technological inadequacy, performing the peeling process with dry caustic reduces water consumption, but in the end, concentrated caustic paste emerges and this paste must be disposed of. After peeling, washing is carried out to remove the bark and cayenne caustic.Dry caustic peeling methods can greatly reduce the volume and pollutant load of wastewater compared with steam peeling and wet caustic peeling. Dry caustic peeling has lower caustic consumption than wet caustic peeling (IPPC BREF, 2019). The peeling process with caustic is shown in Figure 13.

Figure-13 Potato peeling process with caustic (URL - 4, 2010)

- ***Determining water quality needs on the basis of processes and using appropriate quality water***

By determining the water quality needs on the basis of processes, appropriate quality water can be used . In the food industry, water reuse may not be appropriate in every process. The biggest reason for this is the risk that the water to be reused does not meet the necessary hygiene standards. It may be appropriate to reuse water at points where it does not come into contact with the product. It may be possible to reuse water in the same process without treatment or after simple filtration. However, in this case, it is necessary to ensure the necessary hygiene standards (IPPC BREF, 2006).

- ***Purification and reuse of used water that meets the necessary hygiene standards***

The treatment and reuse of cooling water, cleaning wastewater, evaporation condensates, membrane concentrate water and rinsing water, which meet the necessary hygiene standards, plays an important role in ensuring water efficiency in facilities.

- ***Reuse of process water in potato starch production***

In places where starch and starch derivatives are produced from potatoes, high amounts of potato starch production wastewater are generated. The wastewater in question, the processed potato juice, which is treated by reverse osmosis, is then sent to protein extraction by coagulation together with the process water. The potato juice separated from the protein and the process water are condensed by evaporation. The resulting condensed steam is cooled and brought to the appropriate pH level and conveyed to the biological wastewater treatment plant. Part of the purified water is first passed through a sand filter, and then disinfected. The recovered water is mixed with fresh water and returned to the production process. Depending on the product requirements

A second reverse osmosis applicationcan be performed. A reduction in both freshwater consumption and wastewater volume is achieved (IPPC BREF, 2019).

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.

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

The reuse of treated wastewater 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).

Industrial Wastewater Treatment Plant

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

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

  With this measure, water saving and water recovery can be achieved by increasing the training and awareness of the personnel, and water efficiency can be achieved by reducing water consumption and costs. 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 water used in production processes and auxiliary processes and the wastewater generated in terms of quantity and quality and adapting this information to the environmental management system,*** There are resource uses in industrial facilities, and as a result of resource use,

  Inefficiency and environmental problems can be caused by input-output flows. Therefore

  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).

- ***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).

- ***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).

- ***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; It facilitates the identification of unnecessary water usage points and high water use points, the evaluation of water recovery opportunities, process modifications and the determination of water losses (TOB, 2021).

2.1.3 General Water Efficiency BATs

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

In industrial production processes, water losses occur in equipment, pumps and pipelines. First of all, water losses should be detected and leaks should be prevented by 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).

- ***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).

- ***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).

- ***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.

- ***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 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.

- ***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).

- ***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,*** Determining and characterizing wastewater generation 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).

In some industrial facilities operating in the food sector, water consumption can be reduced by 13%, wastewater amounts by 18% and COD loads of wastewater by up to 48% by recycling wastewater with or without treatment (TUBITAK MAM, 2016; TOB, 2021). In addition, the payback period required for the application was calculated as approximately 3 years (energy savings were also taken into account) (TUBITAK MAM, 2016; TOB, 2021).

- ***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).

- ***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.

- ***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.

- ***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).

- ***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).

- ***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.

- ***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).

- ***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).

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

Reverse Osmosis System

- ***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 approximately

A reduction of 5-10% is achieved (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).

- ***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".

- ***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).

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

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

- ***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).

2.1.4 Precautions for Ancillary Processes

METs for steam generation

- ***Saving water with the insulation of steam and water lines (hot and cold) and preventing water and steam losses at pipes, valves and connection points in the lines and monitoring them with a computer system*** Failure to properly design steam lines in facilities, routine maintenance of steam lines and
Failure to carry out repairs, mechanical problems occurring in the lines and the appropriate Steam losses may occur if it is not operated in the way and if the steam lines and hot surfaces are not fully insulated. 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

- ***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 flash 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).

- ***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.

- ***Reduction of water consumption in closed-loop cooling systems by increasing the number of cycles and improving the quality of the catch-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).

- ***In some periods of the year, when the need for cooling is low, cooling with local dry air***

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

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

  Industrial refrigeration systems are used to cool heated products, processes and equipment. Closed and open loop cooling systems can be used for this purpose, as well as industrial cooling systems where a fluid (gas or liquid) or dry air is used (IPPC BREF, 2001b; TOB, 2021). Air cooling systems consist of finned tube elements, condensers and air fans (IPPC BREF, 2001b; TOB, 2021). Air cooling systems can have different operating principles. In industrial air cooling systems, heated water is air-cooled in closed-loop refrigerant condensers and heat exchangers (IPPC BREF, 2001b; TOB, 2021). In water cooling systems, the heated water is taken to a cooling tower and the water is cooled in drip systems. However, although water-cooled systems operate in a closed circuit, a significant amount of evaporation occurs. In addition, since some water is blown down in cooling systems , water is lost in this way (IPPC BREF, 2001b; TOB, 2021). The use of air cooling systems instead of water in cooling systems is effective in reducing evaporation losses and also reducing the risk of contamination of cooling water (IPPC BREF, 2001b; TOB, 2021).

- ***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).

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

Cooling Systems (Chiller)

The application of tower cooling in systems that do not have a closed loop is water reuse

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

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

- ***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).

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Tower Type Cooling Systems

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

Cooling towers and evaporative condensers are efficient and cost-effective systems that remove heat from air conditioning and industrial process cooling systems (IPPC BREF, 2001b; TOB, 2021). More than 95% of the circulating water in these systems can be recovered (TUBITAK MAM, 2016). In cooling systems, 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).

METs related to the cogeneration system

- ***The use of hot water produced in the cogeneration system in heating processes***

  With the inclusion of cooling systems in cogeneration systems (trigeneration)
  It is possible to convert yield losses of 10-30% into hot water, water vapor, cold air, hot air and water (for this, it is necessary to use absorption heat exchangers). Thus, it is possible to meet some of the energy required in processes such as cooling and drying in the facility from the waste heat in the cogeneration systems. Energy costs can be reduced by up to 40% in facilities where cogeneration systems are used (TUBITAK MAM, 2016).

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