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MINISTRY OF AGRICULTURE AND FORESTRY
GENERAL DIRECTORATE OF WATER MANAGEMENT

Water Efficiency Campaign

Water Efficiency
Guide Documents Series

SUGAR MANUFACTURING

NACE CODE: 10.81

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Abbreviations

WWT	Wastewater Treatment Plant
EU	European Union
SS	Suspended Solids
BREF	Best Available Techniques Reference Document
EMS	Environmental Management System
MoEUCC	Ministry of Environment, Urbanization and Climate Change of the Republic of Türkiye
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 Techniques
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 Türkiye
TSI	Turkish Statistical Institute
NF	Nanofiltration
MF	Microfiltration
UF	Ultrafiltration
GW	Groundwater
SW	Surface Water

1 Introduction

Our country is located in the Mediterranean basin, where the effects of global climate change are 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 century.

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.

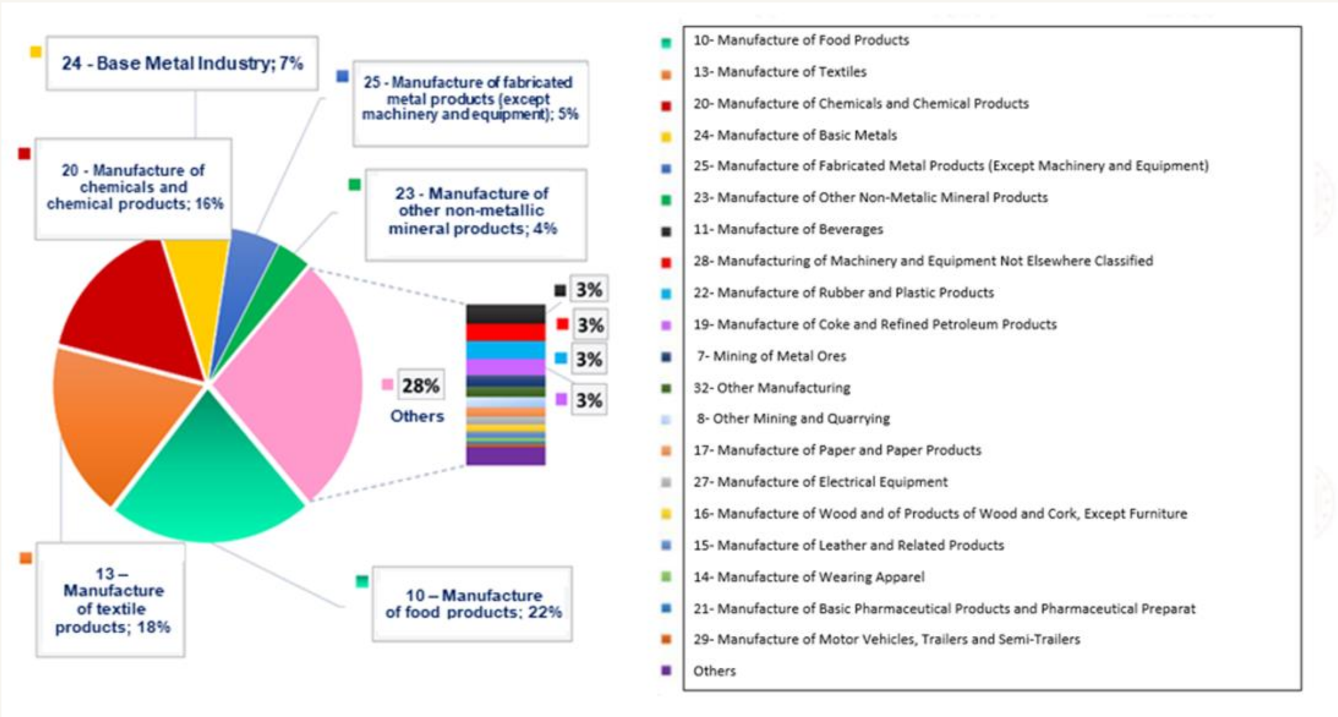
In the European Green Deal Action Plan prepared by our country within the scope of the European Green Deal, where member countries agree on goals such as implementing a clean, circular economy model with the goal of carbon neutrality, expanding the efficient use of resources and reducing environmental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

The "Industrial Emissions Directive (IED)", 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) 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, BAT are the most effective implementation techniques for a high level of environmental protection. In accordance with the Directive, Reference Documents (BREF) have been prepared for each sector, in which the BATs are explained in detail. In BREF documents, BAT 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. 2023/9*** Water 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 (BAT) 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 (BAT) and other cleaner production techniques. The guidelines include 500 techniques for water efficiency (WE);
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 BAT for each sector. In the determination of BAT, BREF documents were not limited to the BATs, 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 BAT lists were created. In order to evaluate the suitability of the BAT lists created for the local industrial infrastructure and capacity of our country, the BAT lists prepared specifically for each NACE code were prioritized by the enterprises by scoring them on the criteria of water saving, economic saving, environmental benefit, applicability, cross-media impact, and the final BAT 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 BAT 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)

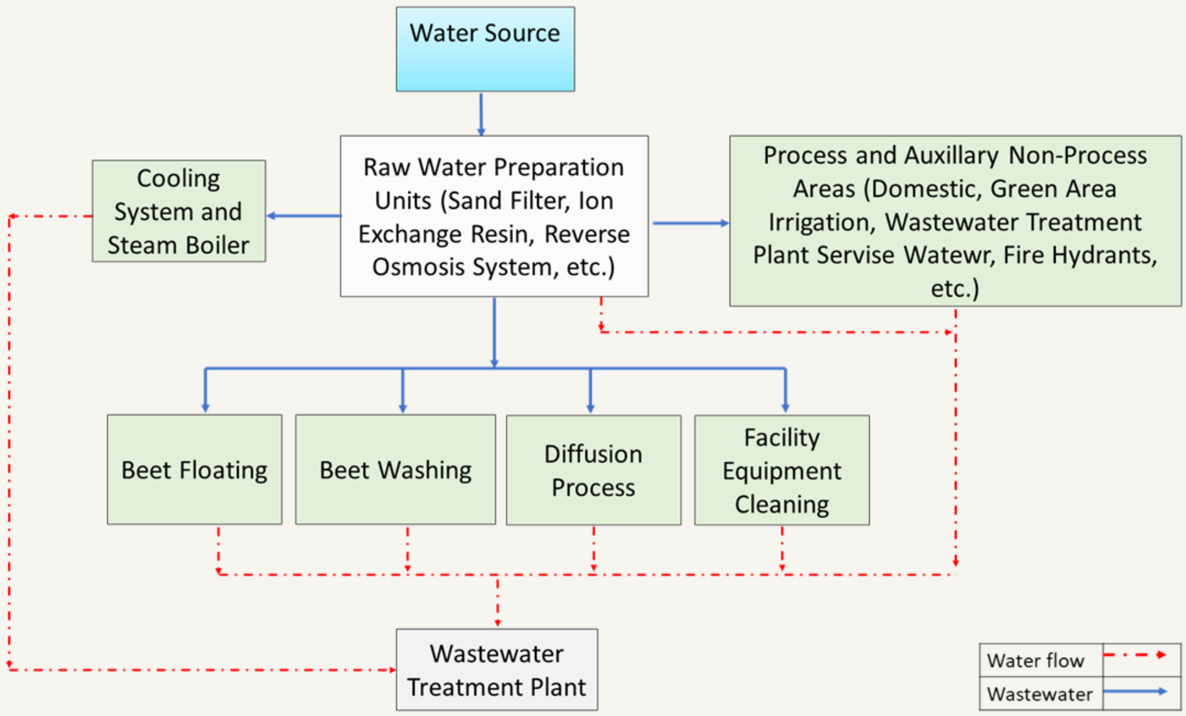
Manufacture of food products

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.

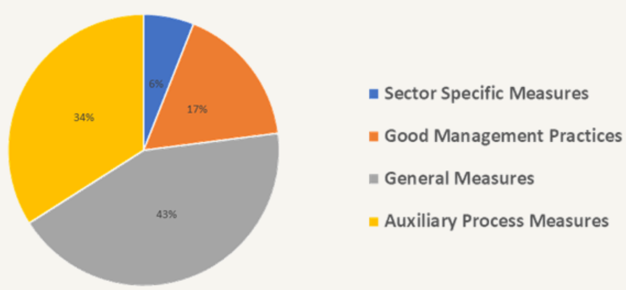
2.1 Sugar Manufacturing (NACE 10.81)

Water Flow Diagram of Sugar Manufacturing Industry



	Minimum	Maximum
Spesific Water Consumption of Facilities Visited within the Scope of The Project (L/kg product)	0,16	7,25
Reference Spesific Water Consumption (L/kg product)	0,23	1,5

Percentage Distrubition of Water Efficiency Practices



Beets, which are the raw material of sugar production, are supplied to the factory by dry methods or by floating with water in beet flotation channels. After the soil separation, the beets are taken to the beet washing unit. The water used in the beet flotation and washing units is used again in the beet washing unit after being separated from the sludge in the settling pool (Brükner pool). The beet washing process consists of pre-washing, main washing and final rinsing stages. The beetroot, which is cleaned with pressurized water in the final washing section, is shredded in the mincing unit and then transferred to the diffusion boiling system. In the boiling vat, the beet chops are mixed with syrup and transferred to the tower. Sugar is extracted with water according to the countercurrent principle. The pulp desugared from the diffusion tower is separated. After the pulp is squeezed in the presses, the pulp is sent to the drying plant. The syrup taken from under the diffusion tower is given to the boiling vat. The syrup is sent to the raw syrup treatment system (liming process) to remove the non-sugar substances in it. Milk of lime and carbon dioxide gas are used in the purification of raw syrup. The raw syrup taken from the boiling vat is passed through the heaters. Then, it is passed through liming vats, carbonation tanks and filters to obtain aqueous syrup. The aqueous syrup is sent to the cascade evaporator system to be thickened. The resulting dark syrup is filtered in the refinery and crystallized in cylinder boilers. While the crystals in the centrifuged porridge remain in the cylinder by taking the crystal sugar porridge to the coolers, the syrup passes to the body area in the outer layer. The sugar crystals, the syrup part of which is separated, are washed by spraying water and steam and dried in the drying unit. Cube sugar is obtained by pressing and drying crystal sugar in molds, and powdered sugar is obtained by grinding it in a mill.

If the raw material supply to the factory is carried out by beet flotation, a high amount of water is consumed in the sugar purchase process. However, in many sugar factories, beets are taken to the plant by dry methods. One of the most important areas of water consumption in the sector is the washing of beets. The water used in the washing and cleaning processes can be reused.

Basic production processes such as diffusion, syrup thickening and crystallization require significant amounts of heat in the facilities. The heat and electrical energy used in the production processes are produced in the boiler and turbine room. In sugar factories, there are boilers that produce pressurized superheated steam. In order to obtain the steam needed in the facility, significant amounts of feed water are required in steam boilers.

In sugar factories, a significant amount of evaporation takes place in processes such as thickening of syrup . The water, which is 75-78% in the beet, evaporates in the syrup thickening process and the steam collected from the process is sent to the condensers. The syrup vapor called brude is condensed again in condensers and these waters are reused as cooling water in the process.

Water is consumed for cooling water purposes in auxiliary facilities in sugar factories. There is a need for cooling water such as pump bed cooling, machine cooling, condenser cooling water, mechanical circuit cooling water and turbine cooling water in the facilities. In addition, significant water consumption is realized for filter washing, resin regeneration and membrane cleaning processes in raw water preparation units such as activated carbon filters, ion exchange resins, reverse osmosis, which are used in soft water production in the sector.

The reference specific water consumption in sugar manufacturing is in the range of 0.23 – 1.5 L/kg. The specific water consumption of the production branch analyzed within the scope of the study is in the range of 0.16 – 7.25 L/kg. It is possible to achieve 20-41% water recovery in the sector with the implementation of sector-specific techniques, good management practices, general precautionary measures and measures related to auxiliary processes.

10.81 Sugar Manufacturing Priority water efficiency implementation techniques recommended under the NACE code are presented in the table below.

NACE Code	NACE Code Description		Sector- Priority Best Available Techniques
10.81	Manufacture of sugar		**Sector-Specific Measures**
		1.	The use of purified water in sugar production for beet flotation and washing
		2.	The use of condensate water in sugar production for beet flotation and washing
		3.	Reuse of pump packing water in sugar production
		4.	Reuse of reverse osmosis concentrates and sand filter backwash water in appropriate processes in sugar production
			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.	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 washing water in filtration processes, reuse of relatively clean cleaning water in production processes, and Reducing water consumption by using clean-in-place systems (CIP)

NACE Code	NACE Code Description	Sector- Priority Best Available Techniques
10.81	Manufacture of sugar	6. Avoiding the use of drinking water in production lines
		7. Use of cooling water as process water in other processes
		8. Detection and reduction of water losses
		9. Use of automatic check-off valves to optimise water use
		10. Documentation of production procedures and use by employees to prevent waste of water and energy
		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. 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
		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. Between activities using compatible chemicals in successive processes Prevention of the need for rinsing

NACE Code	NACE Code Description		Sector - Priority Best Available Techniques
10.81	Manufacture of sugar		**Precautions for Ancillary Processes**
		1.	Saving water by reusing steam boiler condensate Water saving through isolation of steam and water lines (hot and cold)
		2.	and prevention of water and steam losses in pipes, valves and connection points in the lines and monitoring them with a computer system
		3.	Avoiding unnecessary cooling processes by identifying processes that need wet cooling
		4.	Reduction of water consumption in closed-loop cooling systems by increasing the number of cycles and improving the quality of the catch-up water
		5.	Reduction of evaporation losses in closed-loop cooling water With tower cooling application in systems that do not have a closed loop
		6.	Water recovery
		7.	Increasing the number of cycles by using anti-corrosion and anti-scale inhibitors in systems with a closed water loop
		8.	Prevention of flash steam losses due to boiler draining In processes for heating the hot water produced in the cogeneration system Use
		9. 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.	Collecting the water generated by surface runoff with a separate collection system and using it for cooling water, process water, etc.
		14.	Reducing the amount of blowdown by using deaerators in steam boilers
		15.	Minimizing boiler discharge water (blowdown) in steam boilers
		16.	Reuse of energy generated from the steam condenser
Total of 50 techniques have been proposed in this sector.			

Sugar Manufacturing
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.**

2.1.1Sector-Specific Measures

- ***The use of purified water in sugar production for beet flotation and washing***

  Some of the water supplied to the sugar production facilities is used for washing (removing soil and other impurities) and transporting raw beets. At this point, although there is no high water quality requirement, treated wastewater and relatively clean wastewater generated in production processes can be reused. In addition, a closed or semi-open loop system can be created to ensure the reuse of beet washing and flotation waters. In this way, water savings of 15-35% in total water consumption can be achieved (MoAF, 2021).

- ***The use of condensate water in sugar production for beet flotation and washing***

  In sugar production, water is used to wash (remove soil and other impurities) and transport raw beets . However, there is no need for high-quality water in beet washing and flotation processes. For this reason, relatively clean and appropriate quality wastewater generated in the facility can be reused in beet washing and flotation processes. With this technique, water savings of up to 10% can be achieved on average (MoAF, 2021).

- ***Reuse of pump packing water in sugar production***

  Shaft seals are used in many equipment such as valves, pumps, etc. These seals may differ according to the fluid, pressure and temperature in the area where they are used. In order to prevent or control the leakage of the transferred fluid from the gap between the pump body and the rotating shaft, a soft seal is used to prevent air from being sucked from the outside. With the soft seal, packing fluid can be used to cool the shaft and shaft seal heated as a result of the friction of the shaft. The most preferred method is to cool and lubricate the shaft seal with the fluid pressed by the pump. Pressurized clean water or liquid supplied from another source should be used as packing fluid instead of the liquid pressed directly by the pump. Water savings ranging from 0.5-2% in facilities, especially with the recovery of pump seal water (MoAF, 2021).

- ***Reuse of reverse osmosis concentrates and sand filter backwash water in appropriate processes in sugar production***

  Since the need for steam is high in sugar factories, the need for softened water for steam boilers is high. Reverse osmosis systems are used in facilities, especially in steam boilers, for additional hardness removal from softened raw water. If reverse osmosis systems are well operated, 20-25% of the softened water is disposed of as concentrated. The resulting concentrates can be used in sugar factories for in-plant cleaning, tank and equipment cleaning or green area irrigation (MoAF, 2021).

Sugar Beet Washing Unit

Beet Intake Unit with Dry Method

Shredded Sugar Beets

Sugar Factory Production Process

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; MoAF, 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 (MoAF, 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 (MoAF, 2021).

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

Industrial Wastewater Treatment Plant

- ***Providing technical 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 (MoAF, 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; MoAF, 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 that occur as a result of resource use 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; MoAF, 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; MoAF, 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 (MoAF, 2021).

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

  It is important for water efficiency to prepare an action plan that includes 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, determining the water needs throughout the facility and in the production processes, water quality requirements should be determined at the points of use, wastewater formation points and wastewater characterization should be done (MoAF, 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 (MoAF, 2021).

- ***Setting water efficiency targets***

  The first step in achieving water efficiency in industrial facilities is to set targets (MoAF, 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 (MoAF, 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 (MoAF, 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 (MoAF, 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).

- ***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).

- ***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 .

- ***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 (MoAF, 2021).Membrane systems (a combination of ultrafiltration (UF), nanofiltration (NF) and reverse osmosis (RO) systems can be used for recovery. For example, in some industrial facilities, it is possible to treat the cooling system blowdown water and reuse it as process water (MoAF, 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; MOAF, 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; MOAF, 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).

- ***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.

- ***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.

- ***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.*** Wastewater of different characters is formed in industrial facilities. For this reason, by determining and characterizing wastewater formation points, various wastewater streams are treated or it can be reused without treatment (Öztürk E., 2014; TUBITAK MAM, 2016; (MoAF, 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, wastewater streams that cannot be reused directly can be reused in production processes after being treated using appropriate treatment technologies.

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

  In some industrial facilities operating in the food sector, reductions of up to 13% in water consumption, 18% in wastewater quantities and up to 48% in COD loads of wastewater can be achieved by reusing wastewater with or without treatment. (TUBITAK MAM, 2016; MoAF, 2021). In addition, the initial investment cost required for the application was calculated as 100,000 TL and the payback period was calculated as approximately 3 years (energy savings were also taken into account) (TUBITAK MAM, 2016; MoAF, 2021). In the textile industry, water savings of 30-70% can be achieved by reusing washing and rinsing water without treatment (USEPA, 2008; LCPC, 2010; MoAF, 2021). In addition, in a clean production study carried out in the textile industry, in total water consumption with treatment/untreated reuse applications of appropriate wastewater streams.
  It has been reported that reductions in the range of 29-55% and in the range of 42-53% in the pollution loads of composite wastewater will be achieved (Öztürk E., 2014). In another textile mill engaged in textile finishing-dyeing, water consumption is carried out by reusing wastewater with or without treatment.
  It has been reported that reductions can be achieved between 46-50%, wastewater amounts between 48-56% and COD load of wastewater between 16-20% (Öztürk E., 2014).

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

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

- ***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.

- ***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). In raw water consumption with the recovery of rinse water Savings of 1-5% can be achieved.

- ***Avoid 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 can mix and undergo a chemical reaction, they are considered incompatible.

  Various chemicals are used in industrial facilities to increase the efficiency of washing and rinsing. 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.

  Water savings of 25-50% can be achieved by reusing washing water. Reserved tanks and new pipelines may be needed for the application. In some cases, the washing solution is kept directly in the system and can be used repeatedly until it loses its properties. The investment costs required for both cases can be variable. However, the initial investment cost of the applications can be between 5,000-30,000 TL.

- ***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).

- ***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 (SS). 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 (MoAF, 2021).

  In our country, reverse osmosis (RO) concentrates are combined with other wastewater streams and given to the wastewater treatment plant channel. The concentrates formed in the RO systems used for additional hardness removal can be used in garden irrigation, in-plant and tank-equipment cleaning (TUBITAK MAM, 2016; MoAF, 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 (MoAF, 2021).

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Computer Aided Control System

- ***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; MoAF, 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; MoAF, 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; MoAF, 2021).

- ***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).

2.1.4 Precautions for Auxiliary Processes

BATs for steam generation

- ***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***

Failure to properly design steam lines in facilities, failure to perform routine maintenance and repairs of steam lines, mechanical problems occurring in the lines and
Steam losses may occur if it is not operated properly and full insulation of steam lines and hot surfaces is not made. This affects both the water consumption and energy consumption of the facility. In areas with vapor insulation deficiencies, it is necessary to use analyzers and control systems with automatic control mechanisms in order to insulate and continuously monitor steam consumption. 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, reductions in the amount of regeneration water, the amount of salt used in regeneration and reverse osmosis concentrates can also be achieved. 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, fuel savings of 2-4% can be 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 E., 2014; MoAF, 2021).

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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***

  When steam indirect heating techniques are used to transmit thermal energy in production processes, it is an effective practice to reduce water consumption by ensuring the return of condensed steam (condensate) as much as possible (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) (TUBITAK MAM, 2016; Ozturk E. , 2014).

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

  A boiler blowdown is water that is deliberately wasted from a boiler to prevent the condensation of impurities during the continuous evaporation of steam. Minimizing the blowdown rate reduces energy losses. Because the blowdown temperature is blown by the blowdown of the steam produced in the boiler

  It is directly related. Boiler blowdown can be reduced by 50% with condensate recovery (IPPC BREF, 2009).

  In automated systems, the blowdowns in the boilers are constantly monitored and the system is re-analyzed together with the water taken after the blowdown. In this analysis, data such as dissolved and undissolved particles in the water and water density are processed together with the newly taken water. 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. The energy or cooling water used to cool this waste is saved (IPPC BREF, 2009). Optimising the steam boiler blowdown process reduces operating costs by saving boiler water consumption, waste costs, conditioning and heating.

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

  With a simple modification to the piping system, the water that feeds the water resting/decarbonization unit can now be obtained from the outlet of the turbine condenser unit. This water has a sufficient temperature to be used directly by the water resting/carbon removal unit. Therefore, this water does not need to be heated by means of steam generated by the heat exchanger system. Thanks to this work, a large amount of steam can be saved and cooling water consumption is reduced (CPRAC, 2021).

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

  Carbon dioxide gases formed by the breakdown of carbonates in boilers with free oxygen dissolved in steam boilers, feed water and hot water boilers; It 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 the boiler feed water is not purified from these dissolved gases, the useful life of these systems is shortened, corrosion and various deformations may occur. In addition, carbon dioxide causes excessive corrosion in coils, steam devices and condensate pipes. It is necessary to purify the boiler feed water from dissolved gases such as oxygen and carbon dioxide by passing it through a 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. The unit cost of a vacuum deaerator with a capacity of approximately 2,000 L/hour varies between 2,200-10,000 USD (TUBITAK MAM, 2016; MoAF, 2021).

BATs for refrigeration systems

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

  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, applications such as purification of completion water added to cooling systems and prevention of biological growth in cooling systems can also reduce the amount of blowdowns. Within the scope of the field studies carried out, the blowdown water generated in the cooling system is not used back and is removed by giving it directly to the wastewater channel. Water consumption in cooling systems by reusing cooling system blowdown water

  Savings of up to 50% can be achieved. The initial investment costs required for this application may include the installation of new pipelines and reserved tanks. In this case, it can be predicted that the required initial investment cost will vary between 5,000-20,000 TL (MoAF, 2021).

- ***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, the amount of fresh water fed into the system will also be reduced and savings in water consumption can be achieved. In addition, the number of cycles can be increased by good conditioning of the cooling completion water (MoAF, 2021).

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

  In cases where the need for cooling is low, it will be advantageous to establish a system that can save water by cooling with dry air.

- ***Water recovery with tower cooling application in systems that do not have a closed loop***

  Water cooling towers are divided into two as counter-flow and cross-flow towers according to their working principles. In counterflow water cooling towers, air moves from bottom to top while water percolates from top to bottom. In cross-flow water cooling towers, the airflow is horizontal as the water descends from top to bottom. In recent years, counter-flow towers have been preferred. In forced-draft counter-flow type water cooling towers, the water heated from the facility is sprayed homogeneously from top to bottom to the entire section of the tower with the help of a specially manufactured water distribution system and sprinklers. The sprayed water masses are broken up by filtering through the tower embankments. The air with the humidity of the external environment is sucked from the bottom up through the fillings with the help of the motor fan group. The water that meets the air on the filling cooling surface cools down by giving heat to the air and a small part of it evaporates. The cooled water is collected in the cold water pool of the tower and sent to the operation. As a result of the evaporation of water, the air whose humidity increases (close to the saturation rate) is thrown into the atmosphere through the fan chimney located at the top of the tower. According to the principles of thermodynamics; Approximately 540 calories of energy are absorbed from the system in order for each gram of evaporated water to perform the phase (state) change. With this approach; For every 6 ºC cooling of the water circulating in the system, approximately 0.9% of the water flow must evaporate, this is called water cooling tower evaporation loss (URL - 3, 2021).


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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; MoAF, 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 may be necessary to implement a water treatment program specially designed in terms of the quality of the feed water supplied to the cooling system, the building material of the cooling water system and the 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 can be provided (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. The main factors that can cause corrosion and scale formation in the system are closely related to the quality of the feed water. As the pH value of the water used in the cooling tower decreases ($pH<7$), the amount of corrosion increases in the metal parts, and as the pH increases ($pH>9$), the amount of corrosion increases in the copper parts. In the tower recirculation water, limestone and debris formation may occur on the walls as the degree of hardness increases. In this case, dissolved solids that cause corrosion such as sulfate, chloride, carbonate will cause corrosion in metals over time. In addition, the formation of deposits adversely affects heat transfer, reduces energy efficiency and increases energy costs. With the increase in evaporation in the system, the ion concentration and conductivity value in the water increase (TUBITAK MAM, 2016). The increase in conductivity increases in parallel with the total salinity and accelerates the formation of corrosion (Kayabek et al., 2005). In order to prevent these negativities, a chemical conditioning program that prevents lime and corrosion should be made during the operation of the cooling tower water, disinfection should be carried out with a biocide that prevents biological activation, the cooling towers in use should be subjected to chemical and mechanical cleaning at least twice a year and the sediments should be cleaned, and the hardness and conductivity values of the reinforcement water should be 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; MOAF, 2021). Due to the micro-residues and sediments in the cooling water, blowdown is made in cooling systems as well as in steam boilers. In addition, biocides are used to prevent unwanted microbial growth in cooling systems (TUBITAK MAM, 2016). For many reasons, it is more attractive to use open circuit systems. Regardless of the cooling system, water circulation or climate, biological activity does not continue under restricted nutrient conditions. Therefore, all treatment processes should aim to reduce biological growth by removing undissolved nutrients from the cooling water cycle.

For an effective treatment process, the dead volume of the cooling water system (or the volume in the cycle) is important. It is a fact that the dead volume is treated with a filter and then chlorinated continuously at small levels. This can be done by installing a continuous sand filter on the side stream, which breaks down undissolved food and also filters out transient microorganisms and other undissolved nutrients. Thus, less chlorine requirement and more condensation cycles may be possible. This technique can be developed by creating an active biology in a sand filter with a high concentration of micro-organisms, called side-stream biofiltration. In order to maintain active biology, sand filters are eliminated at high concentrations of biocide (chlorine) in the cooling water loop, because high density breaks down the biology in the sand filter and reduces its effect. As soon as the effect of chlorine in the cooling water decreases, the passage through the sand filter is allowed again. In practice, the cooling water only needs to pass once or twice a day. The occurrence of the reduction is based on the optimal combination of flow, biocide use and side-stream filtration. In order for the cooling system to function properly, the cooling water must be treated against equipment corrosion, micro and macro pollution. Deliberate draining of the cooling system to bring the increased density of solids in the cooling system to balance is called cooling blowdown. By pre-treating cooling water with appropriate methods and continuous monitoring of cooling water quality, biocide use and blowdown amounts can be reduced. It can be applied to existing cooling systems by increasing the filter capacity (TUBITAK MAM, 2016). The investment cost depends on the scale of the application. Chlorination operating costs can be reduced by around 85%. The payback period in expected capital expenses is between 3 and 4 years (IPPC BREF, 2001).

- ***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 with and without evaporation (wet and dry) is a combination of cooling 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).

- ***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. These wastewaters, which are formed with different characters, can be treated and reused in appropriate places. With the reuse of the process wastewater streams generated in the facility after treatment, savings and benefits 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 for cooling water (MoAF, 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, applications such as purification of completion water added to cooling systems and prevention of biological growth in cooling systems can also reduce the amount of blowdowns. Within the scope of the field studies carried out, the blowdown water generated in the cooling system is generally not used back and is 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. The initial investment costs required for this application may include the installation of new pipelines and reserved tanks. In this case, it can be predicted that the required initial investment cost will vary between 5,000-20,000 TL (MoAF, 2021).

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

  If the cooling water is collected separately, it is often possible to use the collected water for cooling purposes or to reuse it in appropriate processes (EC, 2009). In order for this system to work properly, a water softening system is needed. 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, additional softening will give better results 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 degree of hardness of the cooling water increases, limestone and deposits are formed 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).

BATs 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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