REPUBLIC OF TÜRKİYE
MINISTRY OF AGRICULTURE AND FORESTRY
GENERAL DIRECTORATE OF WATER MANAGEMENT

Water Efficiency Campaign

Water Efficiency Guidance Documents Series

IRON CASTING

NACE CODE: 24.51

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Contents

Abbreviations

AAT	Wastewater Treatment Plant
EU	Europe Union
AKM	Suspended Solids
BREF	Best Available Techniques Reference Document
EMS	Environment Management System
CSIDB	Ministry of Environment, Urbanization and Climate Change of the Republic of Türkiye
DOM	Natural Organic Matter
EMAS	Eco Management and Control Program Directive
EPA	United States Environmental Protection Agency
IPC	Industrial Pollution Prevention and Control
ISO	International Standards Organization
MET	Best Available Techniques
NACE	Statistical Classification of Economic Activities
SYGM	General Directorate of Water Management
TO	Reverse Osmosis
TOB	Ministry of Agriculture and Forestry of the Republic of Türkiye
TUIK	Turkish Statistical Institute
NF	Nanofiltration
MF	Microfiltration
WHEW	Ultrafiltration
AGE	Groundwater
YUS	Surface Water

1 Introduction

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

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

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

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

In the sustainable development vision determined by the United Nations, within the scope of Goal 7 of the Millennium Development Goals: Ensuring Environmental Sustainability, Goal 9 of the Sustainable Development Goals: Industry, Innovation and Infrastructure and Goal 12 of the Responsible Production and Consumption, issues such as efficient, equitable and sustainable use of resources, especially water, environmentally friendly production and consumption that are concerned about future generations are included.

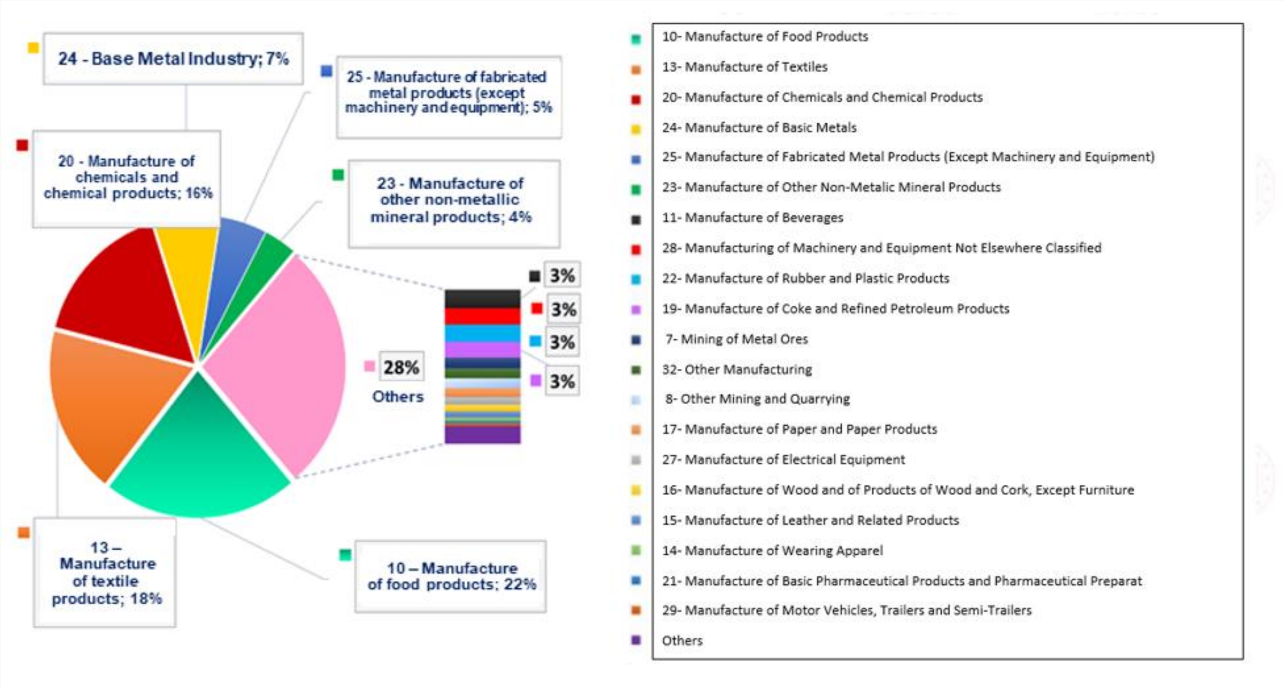
Within the scope of the European Green Deal, in which member countries have agreed on targets such as implementing a clean, circular economy model with a carbon neutral target, expanding the efficient use of resources and reducing environmental impacts, actions emphasizing water and resource efficiency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

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

The Ministry of Agriculture and Forestry, General Directorate of Water Management is carrying out studies aimed at spreading efficient practices in urban, agricultural, industrial and individual water use and increasing social awareness. Within the scope of the “Water Efficiency Strategy Document and Action Plan (2023-2033) within the Framework of Adaptation to the Changing Climate”, which entered into force with the Presidential Circular No. 2023/9, water efficiency action plans addressing all sectors and stakeholders have been prepared. A total of 12 actions have been determined for the 2023-2033 period in the Industrial Water Efficiency Action Plan, and responsible and relevant institutions have been assigned for the said actions. Within the scope of the said Action Plan; conducting studies on determining specific water use intervals and quality requirements on a sub-sector basis in the industry, organizing technical training programs and workshops on a sectoral basis and preparing water efficiency guide documents have been defined as the responsibility of the General Directorate of Water Management.

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

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



Distribution of water usage in industry on a sectoral basis in our country

As a result of the studies, specific water consumption levels and potential savings rates were determined for businesses across 152 distinct 4-digit NACE codes with high water consumption. Water efficiency guidance documents were prepared by taking into account the EU's Best Available Techniques (BAT) and other clean production techniques. These guides analyze a total of 500 BATs (Best Available Techniques) for water efficiency, categorized under four main groups: (i) Good Management Practices, (ii) General Preventive Measures, (iii) Auxiliary Process Measures, and (iv) Sector-Specific Measures.

During the project, environmental benefits, operational data, technical specifications-requirements, and applicability criteria were considered in identifying BATs for each sector. The determination of BATs was not limited to BREF documents; updated global literature data, real case analyses, innovative applications, and reports from sector representatives were also examined in detail to compile sector-specific BAT lists. For evaluating the compatibility of these BAT lists with the local industrial infrastructure and capacity in Turkey, specific BAT lists were prepared for each NACE code. These lists were prioritized based on water savings, economic savings, environmental benefits, applicability, and cross-media impact criteria, and final BAT lists were determined using these prioritization scores. Sectoral water efficiency guides were created based on NACE codes, using the final BAT lists identified by incorporating data from the water and wastewater records of the visited facilities and local dynamics highlighted by sectoral stakeholders.

2 Scope of the Study

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

- Crop and animal production, hunting, and related service activities (including 6 sub-production areas represented by 4-digit NACE codes)
- Fishing and aquaculture (including 1 sub-production area represented by a 4-digit NACE code)
- Mining of coal and lignite (including 2 sub-production areas represented by 4-digit NACE codes)
- Support services for mining (including 1 sub-production area represented by a 4-digit NACE code)
- Metal ore mining (including 2 sub-production areas represented by 4-digit NACE codes)
- Other mining and quarrying (including 2 sub-production areas represented by 4-digit NACE codes)
- Manufacture of food products (including 22 sub-production areas represented by 4-digit NACE codes)
- Manufacture of beverages (including 4 sub-production areas represented by 4-digit NACE codes)
- Manufacture of tobacco products (including 1 sub-production area represented by a 4-digit NACE code)
- Manufacture of textiles (including 9 sub-production areas represented by 4-digit NACE codes)
- Manufacture of clothing (including 1 sub-production area represented by a 4-digit NACE code)
- Manufacture of leather and related products (including 3 sub-production areas represented by 4-digit NACE codes)
- Manufacture of wood, wood products, and cork products (excluding furniture); manufacture of woven products from reed, straw, and similar materials (including 5 sub-production areas represented by 4-digit NACE codes)
- Manufacture of paper and paper products (including 3 sub-production areas represented by 4-digit NACE codes)
- Manufacture of coke and refined petroleum products (including 1 sub-production area represented by a 4-digit NACE code)
- Manufacture of chemicals and chemical products (including 13 sub-production areas represented by 4-digit NACE codes)
- Manufacture of basic pharmaceutical products and pharmaceutical preparations (including 1 sub-production area represented by a 4-digit NACE code)
- Manufacture of rubber and plastic products (including 6 sub-production areas represented by 4-digit NACE codes)
- Manufacture of other non-metallic mineral products (including 12 sub-production areas represented by 4-digit NACE codes)
- Basic metal industry (including 11 sub-production areas represented by 4-digit NACE codes)
- Manufacture of fabricated metal products (excluding machinery and equipment) (including 12 sub-production areas represented by 4-digit NACE codes)
- Manufacture of computers, electronic, and optical products (including 2 sub-production areas represented by 4-digit NACE codes)
- Manufacture of electrical equipment (including 7 sub-production areas represented by 4-digit NACE codes)
- Manufacture of machinery and equipment not elsewhere classified (including 8 sub-production areas represented by 4-digit NACE codes)
- Manufacture of motor vehicles, trailers, and semi-trailers (including 3 sub-production areas represented by 4-digit NACE codes)
- Manufacture of other transportation equipment (including 2 sub-production areas represented by 4-digit NACE codes)

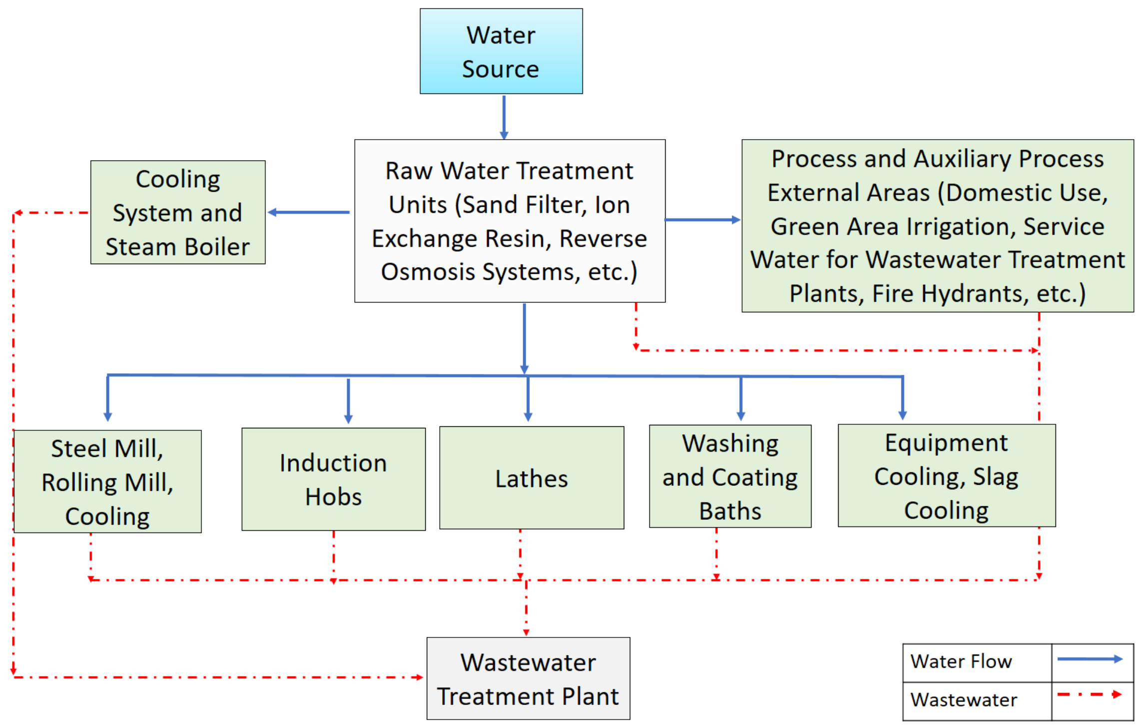
- Other manufacturing (including 2 sub-production areas represented by 4-digit NACE codes)
- Installation and repair of machinery and equipment (including 2 sub-production areas represented by 4-digit NACE codes)
- Production and distribution of electricity, gas, steam, and ventilation systems (including 2 sub-production areas represented by 4-digit NACE codes)
- Waste collection, treatment, and disposal activities; materials recovery (including 1 sub-production area represented by a 4-digit NACE code)
- Construction of non-residential buildings (including 1 sub-production area represented by a 4-digit NACE code)
- Storage and support activities for transportation (including 1 sub-production area represented by a 4-digit NACE code)
- Accommodation (including 1 sub-production area represented by a 4-digit NACE code)
- Educational activities (Higher Education Campuses) (including 1 sub-production area represented by a 4-digit NACE code)
- Sports, entertainment, and recreational activities (including 1 sub-production area represented by a 4-digit NACE code)

"Basic Metal Industry" and "Manufacture of Fabricated Metal Products (excluding machinery and equipment) "

"The sub-production branches for which guidance documents have been prepared under the sectors of "Basic Metal Industry" and "Manufacture of Fabricated Metal Products (excluding machinery and equipment)" are as follows:"
24.10 Manufacture of basic iron and steel products and ferroalloys
24.20 Manufacture of tubes, pipes, hollow profiles, and related fittings of steel
24.31 Cold drawing of bars
24.32 Cold rolling of narrow strips
24.34 Cold drawing of wire
24.41 Precious metal production
24.42 Aluminium production
24.51 Casting of iron
24.52 Casting of steel
24.53 Casting of light metals
24.54 Casting of other non-ferrous metals
25.12 Manufacture of metal doors and windows
25.21 Manufacture of central heating radiators (excluding electric radiators) and boilers for hot water
25.30 Manufacture of steam generators, except central heating hot water boilers
25.50 Forging, pressing, stamping, and roll-forming of metal; powder metallurgy
25.61 Treatment and coating of metals
25.62 Machining and shaping of metals
25.71 Manufacture of cutlery and other cutting tools
25.73 Manufacture of hand tools, tool parts, saw blades, etc.
25.92 Manufacture of light metal packaging materials
25.93 Manufacture of wire products, chains, and springs
25.94 Manufacture of fasteners and screw machine products
25.99 Manufacture of other fabricated metal products not elsewhere classified

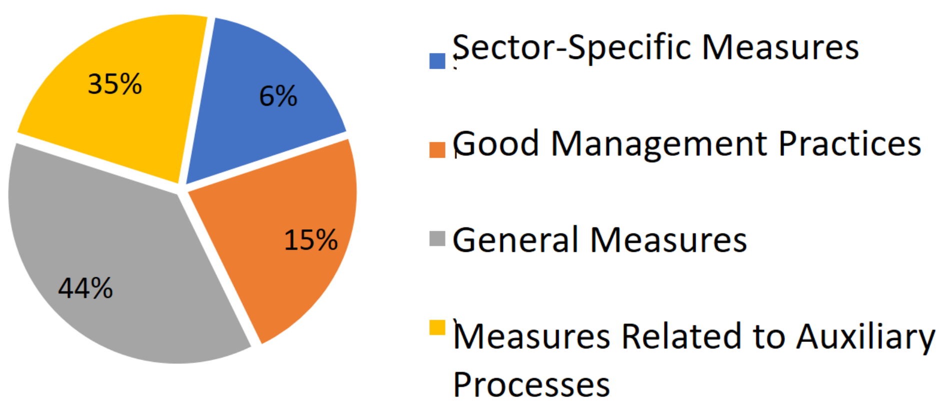
2.1 Iron Casting (NACE 24.51)

Iron Casting Industry Water Flow Diagram



	Minimum	Maximum
Facilities Visited Within the Scope of the Project Specific Water Consumption (L/kg product)	0.4	86.8
Reference Specific Water Consumption (L/kg product)	3	5

Percentage Distribution of Water Efficiency Practices



In iron casting facilities, all raw materials that directly affect the product's structure (such as additives for sand preparation, molding, core, and melting units) are procured and stored in the material warehouse. A sand mold with a gating and feeder system is prepared. If the casting requires internal surfaces, a core is also added. The sand molds and sand cores must have high strength, permeability, thermal stability, and minimal expansion. Sand from a broken mold is reused in other molds. The molten iron metal is poured into the sand mold, and after cooling and solidifying, the mold is dismantled to remove the casting. Surface cleaning is performed to remove sand from the casting surface and improve its appearance. Heat treatment is applied to the casting to enhance metallurgical properties.

In the iron casting process, water consumption also occurs in auxiliary processes such as cooling towers for induction furnaces and machine cooling. In integrated iron and steel production facilities, a large portion of the water is used for cooling purposes. Due to the high amount of cooling water needed for furnace cooling and post-casting cooling processes, the water is circulated to save on consumption. Closed-loop systems are used to prevent evaporation losses. There are also small to medium-sized foundries operating under the NACE code 24.51 Iron Casting that do not qualify as integrated production facilities. In such facilities, cooling water is used in induction casting furnaces and for cooling press machines.

In addition, water is consumed in raw water preparation units such as ion exchange resins and reverse osmosis for producing soft water used in production processes, as well as in resin regeneration and membrane cleaning. Further water consumption occurs in washing and coating baths, dust control systems, and steam boilers in auxiliary processes.

The reference specific water consumption in the iron casting sector ranges from 3 to 5 L/kg. The specific water consumption for the production branch analyzed in this study varies from 0.4 to 86.8 L/kg. By implementing sector-specific techniques, good management practices, general preventive measures, and auxiliary process measures, water savings of 20–76% are achievable in the sector.

24.51 The priority water efficiency application techniques recommended under the Iron Casting NACE code are presented in the table below.

NACE Code	NACE Code Explanation	Prioritized Sectoral Water Efficiency Techniques
24.51	Cast Iron	**Industry Specific Measures**
		1.Designing the water collection system to collect oils from leaks and using an oil interceptor for wastewater
		2.Implementation of dry processes for reuse instead of wet systems for dust removal
		3.Reducing water consumption by using water jets to cool the casting and sand
		4.Using water-cooled spray pipes that penetrate deep into the furnace shaft
		5.Optimizing bath drain frequency
		6.Implementation of dry dust removal processes that do not transfer pollution to other environments, such as wet dust removal that allows reuse instead of wet systems for dust removal.
		Good Management Practices
		1. Using an integrated wastewater management and treatment strategy to reduce wastewater volume and pollutant load
		2. Establishment of 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 usage
		6. Determining water efficiency targets
		7. Monitoring the quantity and quality of water used in production processes and auxiliary processes and the wastewater generated, and adapting this information to the environmental management system.

NACE Code	NACE Code Explanation	Prioritized Sectoral Water Efficiency Techniques
		General Precautions
		1. Minimizing spills and leaks
		2. Use of automatic equipment and hardware (sensors, smart hand washing systems, etc.) that will save water at water usage points such as showers/toilets etc.
		3. Use of pressure washing systems in equipment cleaning, general cleaning, etc.
		4. Reusing filter wash water in filtration processes, reusing relatively clean cleaning water in production processes, and reducing water consumption by using cleaning-in-place systems (CIP)
		5. Avoiding the use of drinking water in production lines
		6. Use of cooling water as process water in other processes
		7. Detection and reduction of water losses
		8. Use of automatic control-shutoff valves to optimize water usage
		9. To prevent water and energy waste, production procedures must be documented and used by employees.
		10. Reuse of pressurized filtration backwash waters before water softening at appropriate points
		11. Optimizing the frequency and duration of regeneration (including rinses) in water softening systems
		12. Establishing closed storage and impermeable waste/scrap areas to prevent the transport of toxic or hazardous chemicals to the aquatic environment.
		13. substances that pose a risk to the aquatic environment (such as oils, emulsions, binders) from being stored, stored, and mixed with wastewater after use.
		14. Where technically possible, appropriate wastewater should be treated and used as steam boiler feed water.
		15. Preventing clean water streams from mixing with dirty water streams

NACE Code	NACE Code Explanation	Prioritized Sectoral Water Efficiency Techniques
		16. Determination of wastewater streams that can be reused with or without treatment by characterizing the quantities and qualities of wastewater at all wastewater generation points.
		17. Use of closed loop water cycles in suitable processes
		18. Use of computer-aided control systems in production processes
		19. Determining the scope of reuse of washing and rinsing waters
		20. Grey water is collected and purified separately in the facility and used in areas that do not require high water quality (green area irrigation, ground washing, etc.)
		21. Implementing time optimization in production and arranging all processes to be completed in the shortest time possible.
		22. Collecting rainwater and using it as an alternative water source for facility cleaning or in suitable areas.
		23. Reuse of nanofiltration (NF) or reverse osmosis (RO) concentrates with or without purification depending on their characterization
		Precautions Regarding Auxiliary Processes
		1. Water saving by reusing steam boiler condensate
		2. Saving water by isolating steam and water lines (hot and cold), preventing water and steam losses in pipes, valves and connection points in the lines and monitoring them with a computer system.
		3. Replacing old equipment in the ventilation system with ion exchange resins (systems that produce demineralized water) based on the reverse osmosis principle and reusing water
		4. Reuse of condensate from the ventilation system
		5. Avoiding unnecessary cooling processes by determining the processes that require wet cooling.
		6. Reducing water consumption by increasing the number of cycles in closed loop cooling systems and improving the quality of makeup water
		7. Water recovery with tower cooling application in systems without closed loop

NACE Code	NACE Code Explanation	Prioritized Sectoral Water Efficiency Techniques
		8. Increasing the number of cycles by using corrosion and scale inhibitors in systems with closed water loops
		9. Preventing flash steam losses caused by boiler discharge
		10. Using air cooling systems instead of water cooling in cooling systems
		11. Installation of water softening systems for the healthy operation of cooling water recovery systems.
		12. Use of a closed loop cooling system to reduce water usage
		13. Cooling with local dry air in some periods of the year when the cooling need is low
		14. Collecting the water formed by surface runoff with a separate collection system and using it for purposes such as cooling water, process water, etc.
		15. Reducing the amount of blowdown in steam boilers by using deaerators
		16. Minimizing boiler discharge water (blowdown) in steam boilers
		17. Reuse of energy produced from steam condenser
A total of 53 techniques were proposed in this sector.		

Iron Casting NACE To your code Oriented;

(i) To the sector Unique Measures,
(ii) Good Management Applications,
(iii) General Measures And
(iv) Helper to processes related measuresseparate Titles in is given.

2.1.1 Sector-Specific Measures

- ***Implementation of dry processes for reuse instead of wet systems for dust removal***
  Both wet and dry systems are used for dust and particle removal. The main advantage of using dry systems is that the dust is captured in dry form. In addition, no other pollution is transferred to the environment as in wet systems (IPPC BREF, 2005a).

- ***Reducing water consumption by using water jets to cool the casting and sand***
  In foundries, water consumption can be reduced by using air fans or rotary drum coolers instead of water cooling systems to cool the casting and the sand in the molds (IPPC BREF, 2005a).

- ***Optimizing Bath Drain Frequency***
  In water-based surface treatment processes, implementing counterflow and multiple cascade rinsing, along with regular conductivity monitoring in the final rinse tank, can help regulate bath drain frequency. By regularly monitoring conductivity, unnecessary bath draining can be prevented, resulting in water savings.

- ***Designing the water collection system to collect oils from leaks and using an oil interceptor for wastewater***
  Oil interceptors are used for wastewater from permanent mold foundries. The hydraulic systems of die casting machines can potentially leak oil and hydraulic oil. The water collection system should be designed to collect the oil resulting from leaks. The resulting wastewater can be treated and water pollution can be prevented by using oil interceptors (IPPC BREF, 2005a).

- ***Using water-cooled spray pipes that penetrate deep into the furnace shaft***

  In the iron casting industry, the amount of water used for cooling the molds after casting can be reduced by placing spray pipes in a way that cools a large part of the furnace shaft (IPPC BREF, 2005a).

Use of cooling water in iron and steel production

2.1.2 Good Management Applications

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

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

The most widely used Environmental Management Standard is ISO 14001. Among its alternatives, there is the Eco Management and Audit Program Directive (EMAS) (761/2001). It was developed for the assessment, improvement and reporting of the environmental performance of businesses. It is one of the leading applications within the scope of eco-efficiency (cleaner production) in EU legislation and participation is provided voluntarily (TUBITAK MAM, 2016; TOB, 2021) . The benefits of establishing and implementing an Environmental Management System are as follows:

- Economic benefits can be obtained by improving business performance (Christopher, 1998) .
- By adopting International Standards Organization (ISO) standards, greater compliance with global legal and regulatory requirements is achieved (Christopher, 1998) .
- While the risks of penalties related to environmental liabilities are minimized, 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 internal control processes of companies has also been considered important by consumers. The implementation of environmental management systems provides a competitive advantage against companies that do not adopt the standard. It also contributes to the institutions' better position in international areas/markets (Potoski & Prakash, 2005) .

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

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

- ***Using an integrated wastewater management and treatment strategy to reduce wastewater volume and pollutant load***

A wastewater management should be based on a holistic approach from wastewater generation to final disposal and includes functional elements such as composition, collection, treatment including sludge disposal and reuse. The selection of 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 in the facility not only improves the quality of water bodies but also reduces the demand for fresh water. Therefore, it is very important to determine appropriate treatment strategies for different reuse targets.

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

25% in water consumption, wastewater amount and wastewater pollution loads can be achieved. The potential payback period of the application varies between 1 and 10 years (TOB, 2021) .

Industrial Wastewater Treatment Plant

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

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

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

There are resource uses in industrial facilities, and inefficiency and environmental problems resulting from resource use can arise from input-output flows. For this reason, the amount and quality of water and wastewater used in production processes and auxiliary processes must be monitored (TUBİTAK MAM, 2016; TOB, 2021) . Process-based quantity and quality monitoring, together with other good management practices (personnel training, establishment of an environmental management system, etc.), can provide reductions of up to 6% -10% in energy consumption and 25% in water consumption and wastewater amounts (Öztürk, 2014) .

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

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

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

  In order to reduce the amount of water and wastewater in industrial facilities and to prevent water pollution, it is important to prepare an action plan that includes short, medium and long-term actions in terms of water efficiency. 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 generation points and wastewater characterization should be carried out (TOB, 2021) . At the same time, it is necessary to determine the measures to be implemented to reduce water consumption, wastewater generation and pollution loads, to conduct feasibility studies and to prepare action plans for the short-medium-long term. In this way, water efficiency and sustainable water use are ensured in the facilities (TOB, 2021) .

- ***Determining water efficiency targets***

  The first step in ensuring water efficiency in industrial facilities is to determine targets (TOB, 2021) . For this purpose, a detailed water efficiency analysis must be carried out on a process basis. In this way, unnecessary water use, water losses, incorrect applications affecting water efficiency, process losses, water that can be reused with or without treatment, etc. can be determined. It is also extremely important to determine water saving potential and water efficiency targets for each production process and the facility in general (TOB, 2021) .

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

  Determining water usage and wastewater generation points in industrial facilities, creating water-wastewater equivalences in production processes and auxiliary processes outside of production processes generally form the basis of many good management practices. Creating process profiles throughout the facility and on the basis of production processes facilitates the determination of unnecessary water usage points and high water usage points, the evaluation of water recovery opportunities, process modifications and water losses (TOB, 2021) .

2.1.3 General Preventive Measures

- ***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 determined and leaks should be prevented by regularly maintaining equipment, pumps and pipelines and keeping them in good condition (IPPC BREF, 2003) . Regular maintenance procedures should be established and attention should be paid to the following issues in particular:

- Adding pumps, valves, level switches, pressure and flow regulators to the maintenance checklist,
- Conducting inspections not only on the water system, but also specifically on 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 devices, thermometers, etc. (IPPC BREF, 2003) .

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

- ***2Minimizing spills and leaks***

Spills and leaks in businesses can cause both raw material and water losses. In addition, if wet cleaning methods are used to clean spilled areas, water consumption, wastewater amounts and pollution loads of wastewater may increase (TOB, 2021) . In order to reduce raw material and product losses, spillage and splash losses are reduced by using splash guards, wings, drip trays and sieves (IPPC BREF, 2019) .

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

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

- ***Preventing clean water streams from mixing with dirty water streams***

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

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

  By determining and characterizing wastewater generation points in industrial facilities, it is possible to reuse various wastewater streams with or without treatment (Öztürk, 2014; TUBİTAK MAM, 2016; TOB, 2021) . In this context, filter backwash water, RO 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 facility and equipment cleaning). Apart from this, it is possible to reuse wastewater streams that cannot be directly reused in production processes after being treated using appropriate treatment technologies.

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

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

  Water cooling systems are widely used in processes where thermal energy is used intensively and cooling is required. It is possible to save water and energy by using heat exchangers in cooling water return, preventing the pollution of cooling water and increasing cooling water return rates (TUBITAK MAM, 2016; TOB, 2021) . In addition, if cooling waters are collected separately, it is generally possible to use the collected water for cooling purposes or to re-evaluate it in appropriate processes (EC, 2009) . Reusing cooling water can save 2% to 9% of total water consumption (Greer, Keane, Lin, & James, 2013) . Savings of up to 10% can be achieved in energy consumption (Öztürk, 2014; TOB, 2021) .

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

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

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

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

- ***Use of automatic control-shutoff valves to optimize water usage***

  Monitoring and controlling water consumption using flow control devices, meters and computer-aided monitoring systems provides significant 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 counters throughout the facility and specifically for production processes, to use automatic shut-off valves and shut-off valves in continuously operating machines, and to develop monitoring-control mechanisms according to water consumption and certain quality parameters using computer-aided systems (TUBITAK MAM, 2016) . With this application, it is possible to achieve savings of up to 20-30 % in water consumption on a process basis (DEPA, 2002; LCPC, 2010; IPPC BREF, 2003) . By monitoring and controlling water consumption on a process basis, 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, usually obtained from underground water sources, is used in production processes after being purified. However, in some cases, drinking water can be used directly, although it is costly in production processes, or raw water is evaluated in production processes after being disinfected with chlorinated compounds. These waters containing residual chlorine can react with organic compounds (natural organic substances (DOM)) in water during production processes and form disinfectant by-products that are harmful to living metabolisms (Özdemir & Toröz, 2010; Oğur, Tekbaş, & Hasde, 2004; 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. Instead of chlorine disinfection in the disinfection of raw water, disinfection methods with high oxidation capacity such as ultraviolet (UV), ultrasound (US) or ozone can be used. In order to increase the technical, economic and environmental benefits to be provided by the application, determining and using the water quality parameters required in each production process helps to reduce unnecessary water supply and treatment costs. It is possible to reduce water, energy and chemical costs with this application (TUBITAK MAM, 2016) .

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

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

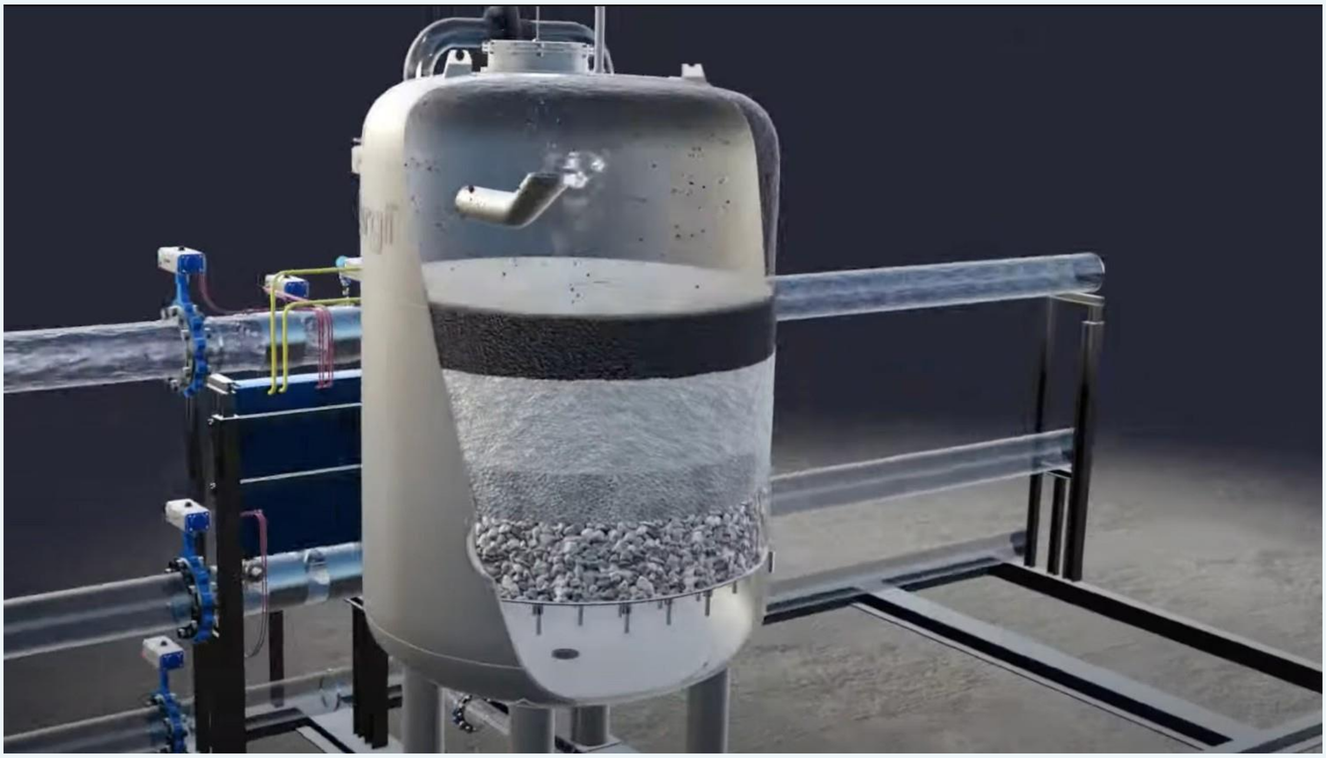
  50% water savings were achieved in landscape irrigation by storing roof rainwater collected in industrial facilities and using it inside the building and in landscape areas (Yaman, 2009) . In order to increase the permeability of the ground and to ensure that rainwater passes into the soil and is absorbed in the field, perforated stones and green areas can be preferred (Yaman, 2009) . Rainwater collected on building roofs can be used for car washing and garden watering. After use, 95% of the collected water can be recovered and reused through biological treatment (Şahin, 2010).

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

Cationic ion exchange resins, one of the most commonly used methods for softening raw water in industrial facilities, are routinely regenerated. In regeneration, the resin is pre-washed using raw water, regenerated with salt water and final rinsed. Regeneration periods are determined depending on the hardness of the water. If the hardness is high, regeneration should be done more frequently in water softening systems.

In regeneration processes, washing, regeneration and rinsing wastewater is usually directly removed. 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) .

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



Water Softening Systems

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

  Many industrial processes require softened water with low calcium and magnesium concentrations. With water softening systems, calcium, magnesium and some other metal cations in hard water are removed from the water and soft water is obtained.

  Savings are achieved by reusing the pressurized filtration backwash water at appropriate points before water softening. This measure is similar in content to practices such as "Reusing filter backwash water in filtration processes, relatively cleaning water in production processes, reducing water consumption by using on-site cleaning systems".

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

  According to the wastewater characterization and appropriate usage points, the reuse potential of other wastewaters originating from membrane processes (backwashing without or with 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 suitable for the purification of well water and surface water. Reverse osmosis is also a membrane-based liquid separation technique and can separate smaller substances than nanofiltration. (Akgul, 2016) .

  Savings are achieved by reusing nanofiltration or reverse osmosis concentrates with or without purification depending on their characterization. In filtration processes, measures should be taken to reuse clean water in the production processes of filter backwash water and to reduce water consumption by using cleaning systems. (TOB, 2021) .should be taken (TOB, 2021).

Reverse Osmosis System

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

  Refrigerants are generally chemical compounds with certain thermodynamic properties that cool the substances to be cooled by taking heat from them and affecting the performance of the cooling process (Kuprasertwong, ve diğerleri, 2021).

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

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

  Heat recovery is also achieved by using heat exchangers in cooling water. Closed loop systems are generally used in facilities where water cooling systems are used. However, cooling system blowdowns are removed by being given directly to the wastewater treatment plant channel. These removed blowdown waters can be reused in suitable production processes.

- ***Substances that pose a risk to the aquatic environment (such as oils, emulsions, binders) from being stored, stored, and mixed 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 into wastewater streams (TUBITAK MAM, 2016) .

- ***Establishing closed storage and impermeable waste/scrap areas to prevent the transport of toxic or hazardous chemicals to the aquatic environment.***

  In industrial facilities, closed and impermeable waste/scrap storage areas can be built to prevent the transfer of toxic or hazardous chemicals to the recipient environment for the aquatic environment. This practice is currently implemented within the scope of current environmental regulations in our country. Within the scope of the field studies carried out, a separate collection channel can be built for toxic or hazardous substance storage areas in industrial facilities, and the leakage water in question can be collected separately and prevented from mixing with natural water environments.

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

  Since inefficient resource use and environmental problems in industrial facilities are directly related to input-output flows, it is necessary to define the process inputs and outputs in the best way possible, especially in production processes. (TUBITAK MAM, 2016) . Thus, it becomes possible to develop measures to increase resource efficiency, economic and environmental performance. The organization of input-output inventories is considered a prerequisite for continuous improvement. While such management practices require the participation of technical personnel and senior management, they quickly pay for themselves with the work of various experts. (IPPC BREF, 2003) . The use of measurement equipment and some routine analyses/measurements specific to the processes are required based on the application processes. In order to obtain the highest level of efficiency from the application, the use of computerized monitoring systems as much as possible increases the technical, economic and environmental benefits to be obtained. (TUBITAK MAM, 2016) .

Computer Aided Control System

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

Wastewater resulting from backwashing of activated carbon filters and softening devices mostly contains only high levels of suspended solids (SS). Backwash water, which is one of the easiest wastewater types to recover, can be recycled by filtering with ultrafiltration facilities. In this way, water savings of up to 15% are achieved (URL - 1, 2021) .

The regeneration wastewater formed after the regeneration process is soft water with high salt content and constitutes approximately 5-10% of the total water consumption . Regeneration wastewater is collected in a separate tank and used in processes requiring high salt, facility cleaning and domestic use. A reserve tank, water installation and pump are needed for this. By reusing regeneration wastewater, a reduction of approximately 5-10% is achieved in water consumption, energy consumption, wastewater amounts and salt content of wastewater (Öztürk, 2014) . The payback period varies depending on whether regeneration water is consumed in production processes, facility cleaning, and domestic purposes. In case of reuse of regeneration water in production processes requiring high salt (since both water and salt will be recovered), the potential payback period is estimated to be less than one year. In facility and equipment cleaning and domestic uses, the payback period is estimated to be over one year (TOB, 2021) .

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

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

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

- ***Grey water is collected and purified separately in the facility and used in areas that do not require high water quality (green area irrigation, ground washing, etc.)***

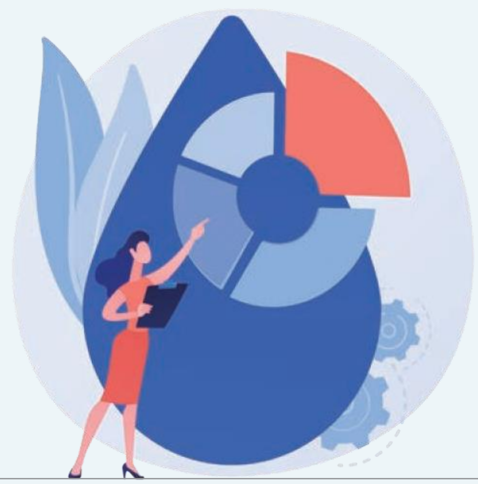
Wastewater generated in industrial facilities is not only industrial wastewater originating from production processes, but also includes wastewater originating from showers, sinks, kitchens, etc. Wastewater generated from showers, sinks, kitchens, etc. is called grey water. Water savings can be achieved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

- ***To prevent water and energy waste, production procedures must be documented and used by employees.***

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

- ***Production and organization of all processes to be completed in the shortest time possible.***

  In industrial production processes, planning the process from raw material to product by using the least amount of processes is an effective practice to reduce labor costs, resource usage costs and environmental impacts and to ensure efficiency. In this context, it may be necessary to review 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, inefficiencies and design errors in basic production processes, production processes may need to be renewed. Therefore, in this case, the resource usage required for the production of a unit amount of product and the amount of waste, emissions and solid waste generated increase. Time optimization in production processes is an effective application (TUBITAK MAM, 2016) .



2.1.4 Precautions Regarding Auxiliary Processes

BATs for steam generation

- ***Saving water by isolating steam and water lines (hot and cold), preventing water and steam losses in pipes, valves and connection points in the lines and monitoring them with a computer system.***

In case of improper design of steam lines in facilities, failure to perform routine maintenance and repair of steam lines, mechanical problems in lines and improper operation of lines, and failure to fully insulate steam lines and hot surfaces, steam losses may occur. This situation affects both water consumption and energy consumption of the facility. Automatic control mechanism control systems should be used in order to perform steam insulation and continuously monitor steam consumption. Similar savings can be achieved in fuel consumption and additional soft water consumption in boilers depending on the reduction of steam losses. Since fuel consumption in steam boilers will decrease, it is expected that waste gas emissions will decrease at the same rate. Since the additional soft water used in steam boilers will decrease with the application, the amount of regeneration water, the amount of salt used in regeneration and reverse osmosis concentrates will also decrease. Automatic control mechanisms are used in many facilities where intensive steam consumption is experienced for full steam insulation application and minimizing steam losses. With the configuration of the application, fuel savings of 2-4% are achieved in steam boilers.

In order to prevent losses in production processes; adding the most important parts of equipment such as pumps, valves, adjustment knobs, pressure, flow regulators to the maintenance checklist, checking not only water systems but also heating and chemical distribution systems, drums, pumps and valves, cleaning filters and pipelines regularly, regular calibration of measurement equipment (thermometers, chemical scales, distribution/dosing systems, etc.) and routine inspection and cleaning of heat treatment units (including chimneys) at specified periods, effective maintenance-repair, cleaning and loss control practices can save 1-6% in water consumption (Hasanbeigi, 2010; Öztürk, 2014; TOB, 2021) .

Industrial Steam Boilers

- ***Water saving by reusing steam boiler condensate***

When indirect heating techniques with steam are used to transfer thermal energy in production processes, recovery of the condensed steam (condensate) is an effective application in terms of reducing water consumption (IPPC BREF, 2009) . By recycling condensate water, an average of 5% reduction in water consumption can be achieved (Greer, Keane, Lin, & James, 2013) . In addition, the potential payback period varies between 4 and 18 months (taking energy savings into account) (Öztürk, 2014; TUBİTAK MAM, 2016) .

- ***Preventing flash steam losses caused by boiler discharge***

The steam boiler condensate is usually discharged from the system at atmospheric pressure from the equipment outlets and steam trap outlets. As the pressure in condensate systems decreases, some of the condensate re-vaporizes and cools to the boiling point of water at atmospheric pressure. The re-vaporized condensate, called flash steam, is lost by being discharged into the atmosphere. Cooling and therefore evaporation are inevitable in condensate return lines, which are usually quite long. In order to prevent the condensate from re-vaporizing, it can be saved 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 top of the tank and feeds the low-pressure steam system from here. The remaining hot condensate is taken from the bottom of the tank to the boiler.

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

Boiler blowdown refers to the water spent from a boiler to prevent the condensation of pollutants during the continuous evaporation of steam. Boiler blowdown can be reduced by 50% with condensate recovery (IPPC BREF, 2009) .

In automatic systems, the blowdowns in the boilers are continuously monitored and the system is re-analyzed with the water taken after the blowdown. In the analysis, data such as dissolved and undissolved particles in the water and water density are processed. If the density for the boiler is above the system limits, the blowdown process is repeated. The system should be automated and the optimum blowdown frequency should be determined. When the blowdown frequency is reduced, the amount of wastewater decreases. The energy used for cooling this wastewater and cooling water are saved (IPPC BREF, 2009) . By optimizing the steam boiler blowdown process, operating costs are reduced by providing savings in boiler water consumption, waste costs, conditioning and heating.

- ***Reuse of energy produced from steam condenser***

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

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

  Free oxygen dissolved in the feed water of steam boilers and the make-up water of hot water boilers and carbon dioxide formed by the disintegration of carbonates in boilers can cause corrosion in the form of pores, rust and melting in steam boilers, steam-using devices and especially in installations. The effects of these gases increase as the fresh feed water ratio and system operating pressure increase. If these dissolved gases are not removed from the boiler feed water, the useful life of the systems in question is shortened and corrosion and various deformations may occur. These gases also cause excessive corrosion in carbon dioxide coils, steam devices and condensate pipes . Boiler feed waters must be passed through a deaerator to be purified from dissolved gases such as oxygen and carbon dioxide. Deaerator systems are mechanical systems that allow dissolved gases to be evaporated from the water by supplying air to the water with a fan. Dissolved gas removal can be increased by increasing the water and air contact surface in the deaerator system. In this way, corrosion formation is reduced and boiler efficiency is increased (TUBITAK MAM, 2016; TOB, 2021) .

BATs for cooling systems

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

  Closed loop cooling systems significantly reduce water consumption compared to open loop systems with more intensive water usage. In closed loop systems, the same water is recirculated in the system, while the amount of cooling water that evaporates usually needs to be added. Evaporation losses can also be reduced by optimizing cooling systems.

Cooling Systems (Chiller)

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

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

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

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

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

  Industrial cooling systems are used to cool heated products, processes and equipment. For this purpose, closed and open circuit cooling systems can be used, as well as industrial cooling systems where a fluid (gas or liquid) or dry air is used (IPPC BREF, 2001b; TOB, 2021) . Air cooling systems consist of finned tube elements, condensers and air fans (IPPC BREF, 2001b; TOB, 2021) . Air cooling systems may have different operating principles. In industrial air cooling systems, heated water is cooled with air in closed circuit cooling condensers and heat exchangers (IPPC BREF, 2001b; TOB, 2021) . In water cooling systems, heated water is taken to a cooling tower and the water is cooled in drip systems . However, although water-cooled systems operate in closed circuit, a significant amount of evaporation occurs. In addition, since some water is thrown out as blowdown 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 in reducing the risk of contamination of the cooling water (IPPC BREF, 2001b; TOB, 2021) .

- ***Water recovery with tower cooling application in systems without closed loop***

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

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

Tower Type Cooling Systems

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

  Cooling towers and evaporative condensers are effective and low-cost systems that remove heat from air conditioning and industrial process cooling systems (IPPC BREF, 2001b; TOB, 2021) . More than 95% of the water circulating in these systems can be recovered. (TUBITAK MAM, 2016) . In cooling systems, impurities remain in the recirculation water due to the principle of evaporation of a portion of the recirculation water and impurity concentrations gradually increase in each cycle. Impurities that can be included in the cooling system together with air can cause contamination in recirculation water (TUBITAK MAM, 2016) . If impurities and contaminants are not effectively controlled, they can cause scale and corrosion formation, unwanted biological growth and sludge accumulation. This can become a chronic problem that causes the efficiency of heat transfer surfaces to decrease and operating costs to increase. In this case, a specially designed water treatment program should be implemented in terms of the quality of the feed water given to the cooling system, the cooling water system construction material and operating conditions. In this context; blowdown control, biological growth control, corrosion control, avoiding the use of hard water, using sludge control chemicals, and using filtration and screening 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 tower recirculation water, as the degree of hardness increases, the formation of limestone and deposits on the walls, resulting in the formation of dissolved solids (sulphate, chloride, carbonate, etc.) that cause corrosion will cause surface wear over time. In addition, the formation of deposits negatively affects heat transfer and reduces energy efficiency. In order to prevent these negativities, a chemical conditioning program that prevents lime and corrosion should be implemented, disinfection should be carried out with biocides that prevent biological activation, cooling towers in use should be subjected to chemical and mechanical cleaning at least twice a year to clean the deposits, and the hardness and conductivity values of the makeup water should be as low as possible (IPPC BREF, 2001b; Kayabek, Yıldırım, & İnce, 2005). In order to increase the quality of the makeup water, it may be necessary to treat (condition) it using a suitable treatment system. In addition, unwanted microbial growth should be kept under control. (IPPC BREF, 2001b; TOB, 2021) . Blowdown occurs in cooling systems as well as in steam boilers due to micro-residues and sediments in the cooling water. The deliberate draining of the cooling system to balance the increasing density of solids in the cooling system is called cooling blowdown. Pre-treatment of cooling waters with appropriate methods and continuous monitoring of cooling water quality can reduce biocide usage and blowdown amounts (TUBİTAK MAM, 2016). Although the investment cost depends on the scale of the application, the expected payback period in investment expenses varies between 3 and 4 years (IPPC BREF, 2001b).

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

  The boundaries of the facility site affect design parameters such as cooling tower height. In cases where it is necessary to reduce the tower height, a hybrid cooling system can be applied. Hybrid cooling systems are a combination of evaporative and non-evaporative (wet and dry) cooling systems. A hybrid cooling tower can be operated as a completely wet cooling tower or as a combined wet/dry cooling tower, depending on the ambient temperature (TUBİTAK 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 make-up water (TUBİTAK MAM, 2016).

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

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

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

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

BAT for ventilation and air conditioning systems

- ***Reuse of condensate from the ventilation system***

  During the ventilation cycle, condensate with good water quality can be produced in the system. For example, in a plant in Spain, condensate with a conductivity of approximately 200 µS from the ventilation system is collected in a tank and used to wash the automatic galvanizing line (MedClean, nd) .

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

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

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