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MINISTRY OF AGRICULTURE AND FORESTRY GENERAL DIRECTORATE OF WATER MANAGEMENT

Water Efficiency Campaign

Water Efficiency Guide Document Series

STEEL CASTING

NACE CODE: 24.52

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Abbreviations

WTP	Wastewater Treatment Plant
EU	European Union
SSM	Suspended Solid Matter
BREF	Best Available Techniques Reference Document
EMS	Environmental Management System
MoEUCC	Republic of Turkey Ministry of Environment, Urbanization and Climate Change
NOM	Natural Organic Matter
EMAS	Eco Management and Audit Program Directive
EPA	United States Environmental Protection Agency
IPPC	Industrial Pollution Prevention and Control
ISO	International Organization for Standardization
BAT	Best Available Techniques
NACE	Statistical Classification of Economic Activities
GSWM	General Directorate of Water Management
RO	Reverse Osmosis
MAF	Ministry of Agriculture and Forestry of the Republic of Turkey
TurkStat	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 strongly felt, and it is considered among the regions that will be most affected by the adverse impacts of climate change. Projections about how our water resources in the basins may be impacted by climate change in the future indicate that these resources could decrease by up to 25% within the next century.

As of 2022, the annual per capita availability of usable water in Turkey is 1,313 m^3, but with increasing human pressures and the impacts of climate change, this figure is expected to fall below 1,000 m^3 per capita after 2030. Without necessary measures, it is evident that Turkey will soon face water scarcity, bringing numerous social and economic negative consequences. As indicated by future projections, the risks of drought and water scarcity facing our country make it essential to use our current water resources efficiently and sustainably.

The concept of water efficiency can be defined as "the minimal use of water in the production of a product or service." The water efficiency approach emphasizes the prudent, inclusive, equitable, efficient, and effective use of water in all sectors, particularly for drinking water, agriculture, industry, and household usage, taking into account not only human needs but also ecosystem sensitivity to meet the needs of all living beings by conserving water in terms of both quantity and quality.

The increasing demand for water resources, changes in precipitation and temperature patterns due to climate change, rising population, urbanization, and pollution, as well as the need to distribute available water resources fairly and equitably among users, are gaining importance every day. Therefore, it has become essential to establish a roadmap based on efficiency and optimization to protect and use these limited water resources through sustainable management practices.

In the sustainable development vision established by the United Nations, Millennium Development Goal 7: Ensure Environmental Sustainability, along with Sustainable Development Goals 9: Industry, Innovation, and Infrastructure, and 12: Responsible Production and Consumption, emphasize efficient, equitable, and sustainable use of resources—especially water—eco-friendly production, and consumption practices that consider the welfare of future generations.

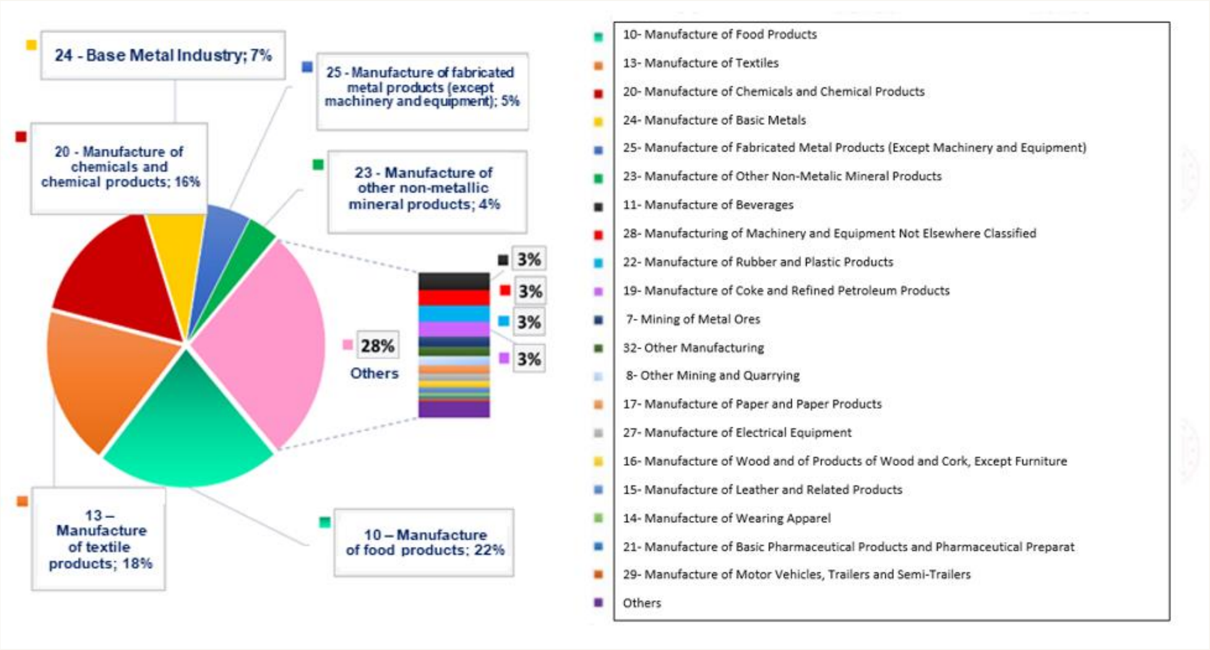
With the target of achieving carbon neutrality, the European Green Deal aims to implement a clean, circular economy model, promoting efficient use of resources and reducing environmental impacts—objectives agreed upon by member countries. In line with this, Turkey's European Green Deal Action Plan outlines actions focused on water and resource efficiency in various sectors, primarily industry, and in both production and consumption.

The "Industrial Emissions Directive (IED)," one of the most important components of the European Union’s environmental legislation in terms of industry, contains measures aimed at controlling, preventing, or reducing emissions/discharges from industrial activities into air, water, and soil through an integrated approach. The directive presents Best Available Techniques (BAT) to systematically implement clean production processes and to address practical challenges. BAT are the most effective application techniques for high-level environmental protection, considering both costs and benefits. According to the directive, detailed sector-specific BAT Reference Documents (BAT-BREF) have been prepared. These BREF documents present BAT within a general framework, covering good management practices, general technical measures, chemical use and management, techniques for various production processes, wastewater management, emission management, and waste management.

The Ministry of Agriculture and Forestry, through the Directorate General of Water Management, is conducting studies to promote efficient practices in urban, agricultural, industrial, and individual water usage and to raise societal awareness. Under Presidential Decree No. 2023/9, the "Water Efficiency Strategy Document and Action Plan (2023-2033) within the Framework of Adaptation to Changing Climate" was enacted, preparing water efficiency action plans targeting all sectors and stakeholders. The Industrial Water Efficiency Action Plan for 2023-2033 includes a total of 12 actions with designated responsible and relevant institutions. Under this Action Plan, the Directorate General of Water Management is tasked with conducting studies to define specific water usage ranges and quality requirements by sub-sector in industry, organizing sector-specific technical training programs and workshops, and preparing water efficiency guide documents.

On the other hand, the "Industrial Water Use Efficiency Project by NACE Codes," conducted by the Ministry of Agriculture and Forestry's Directorate General of Water Management, has identified sector-specific best techniques unique to our country to improve water efficiency in industry. As a result of this work, sectoral guide documents and action plans classified by NACE codes have been prepared, including recommended measures to enhance water use efficiency in high-water-consuming sectors in Turkey.

Similar to global trends, the sectors with the highest share of water consumption in Turkey are food, textiles, chemicals, and primary metals. Within the scope of these studies, field visits were conducted in facilities representing different capacities and a variety of production areas across 35 main sectors and 152 sub-sectors, including food, textiles, chemicals, and primary metals, which have high water consumption according to NACE Codes. During these visits, data on water supply, sectoral water uses, wastewater generation, and recycling were collected, and information on existing best available techniques (BAT), sectoral reference documents (BREF), water efficiency, clean production, water footprint, and related topics published by the European Union was provided.



The distribution of water usage by sector in industry in our country

As a result of the studies, specific water consumption rates and potential savings for the processes of enterprises under 152 different four-digit NACE codes with high water consumption have been determined. Water efficiency guide documents have been prepared, considering the EU's Best Available Techniques (BAT) and other clean production techniques. The guides include 500 techniques for water efficiency (BAT), categorized into four main groups: (i) Good Management Practices, (ii) General Preventive Measures, (iii) Auxiliary Process Measures, and (iv) Sector-Specific Measures.

During the determination of BATs for each sector within the project, criteria such as environmental benefits, operational data, technical specifications, requirements, and applicability were considered. The BAT determination was not limited to BREF documents but also incorporated global, up-to-date literature, real case analyses, innovative practices, and reports from sector representatives to create sectoral BAT lists. To assess the suitability of these BAT lists for the local industrial infrastructure and capacity, each NACE-specific BAT list was prioritized by enterprises, scoring them based on criteria like water savings, economic savings, environmental benefits, applicability, and cross-media impact. The final BAT lists were determined using these scores. Based on water and wastewater data collected from visited facilities and final BAT lists shaped by sectoral stakeholders and local dynamics specific to Turkey, sectoral water efficiency guides by NACE code have been created.

2 Scope of the Study

The guide documents prepared under industrial water efficiency measures include the following main sectors:

- Fishing and aquaculture (including 1 sub-production area represented by a four-digit NACE code)
- Mining of coal and lignite (including 2 sub-production areas represented by four-digit NACE codes)
- Support activities for mining (including 1 sub-production area represented by a four-digit NACE code)
- Mining of metal ores (including 2 sub-production areas represented by four-digit NACE codes)
- Other mining and quarrying (including 2 sub-production areas represented by four-digit NACE codes)
- Manufacture of food products (including 22 sub-production areas represented by four-digit NACE codes)
- Manufacture of beverages (including 4 sub-production areas represented by four-digit NACE codes)
- 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 four-digit NACE codes)
- Manufacture of wearing 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 four-digit NACE codes)
- Manufacture of wood, wood products, and cork products (excluding furniture); manufacture of articles made from straw, reeds, and similar materials (including 5 sub-production areas represented by four-digit NACE codes)
- Manufacture of paper and paper products (including 3 sub-production areas represented by four-digit NACE codes)
- 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 four-digit NACE codes)
- Manufacture of basic pharmaceutical products and pharmaceutical preparations (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 four-digit NACE codes)
- Manufacture of other non-metallic mineral products (including 12 sub-production areas represented by four-digit NACE codes)
- Basic metal industry (including 11 sub-production areas represented by four-digit NACE codes)
- Manufacture of fabricated metal products (except machinery and equipment) (including 12 sub-production areas represented by four-digit NACE codes)
- Manufacture of computers, electronics, and optical products (including 2 sub-production areas represented by four-digit NACE codes)
- Manufacture of electrical equipment (including 7 sub-production areas represented by four-digit NACE codes)
- Manufacture of machinery and equipment not elsewhere classified (including 8 sub-production areas represented by four-digit NACE codes)
- Manufacture of motor vehicles, trailers, and semi-trailers (including 3 sub-production areas represented by four-digit NACE codes)
- Manufacture of other transport equipment (including 2 sub-production areas represented by four-digit NACE codes)
- Other manufacturing (including 2 sub-production areas represented by four-digit NACE codes)
- Installation and repair of machinery and equipment (including 2 sub-production areas represented by four-digit NACE codes)
- Production and distribution of electricity, gas, steam, and air conditioning systems (including 2 sub-production areas represented by four-digit NACE codes)
- Waste collection, treatment, and disposal activities; recovery of materials (including 1 sub-production area represented by a four-digit NACE code)
- Construction of buildings other than dwellings (including 1 sub-production area represented by a four-digit NACE code)

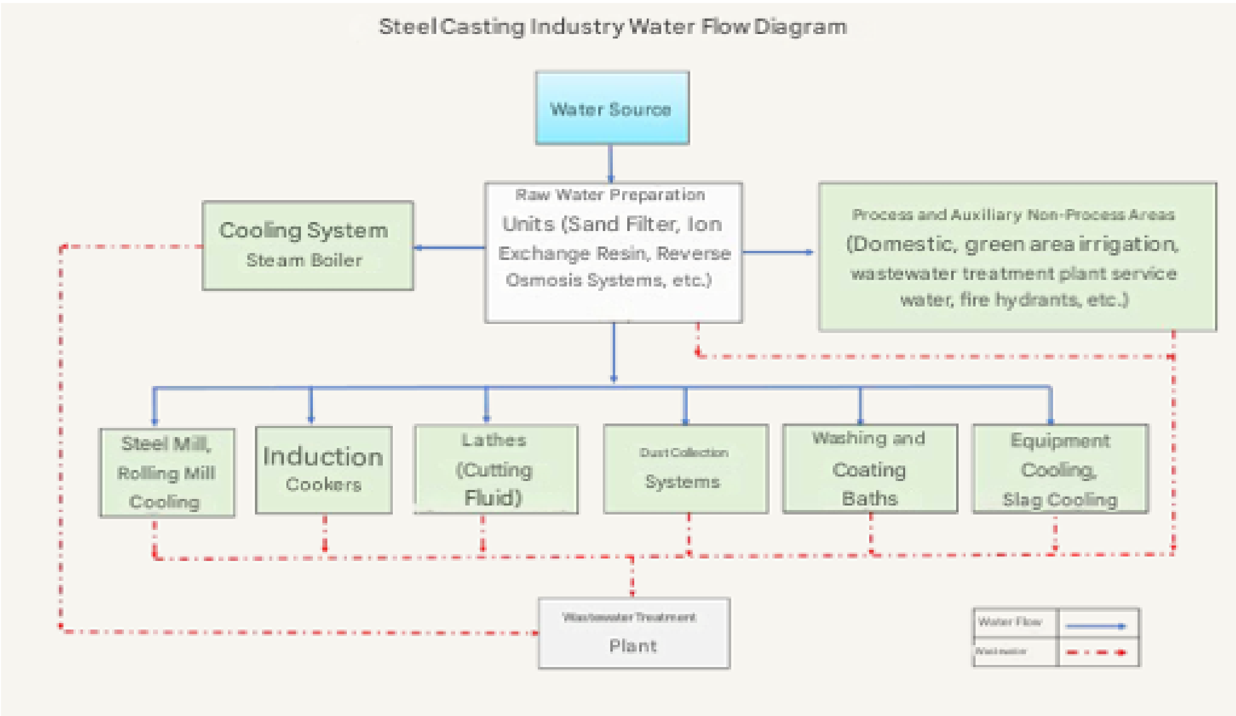
- Storage and supporting activities for transportation (including 1 sub-production area represented by a four-digit NACE code)
- Accommodation (including 1 sub-production area represented by a four-digit NACE code)
- Educational activities (Higher Education Campuses) (including 1 sub-production area represented by a four-digit NACE code)
- Sports activities, entertainment, and recreation activities (including 1 sub-production area represented by a four-digit NACE code)

Basic Metal Industry and Manufacture of Fabricated Metal Products (excluding Machinery and Equipment)

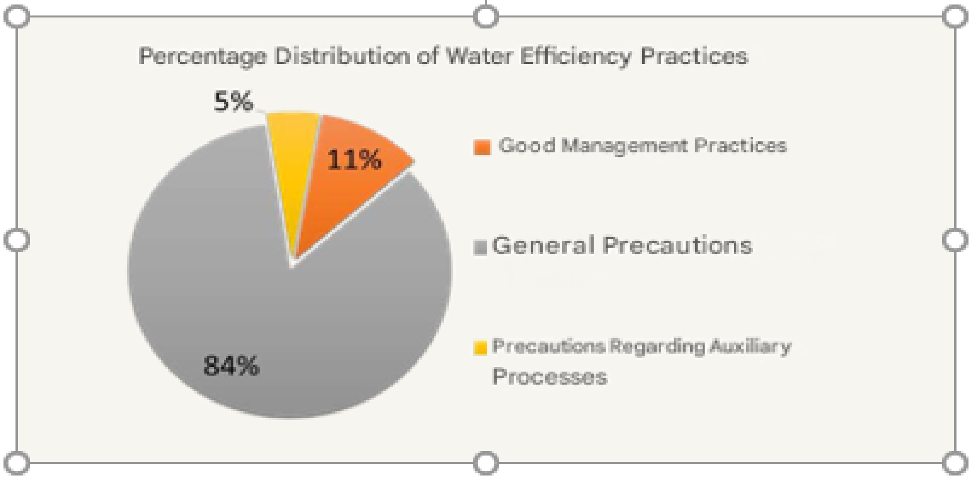
The sub-production branches for which guide documents have been prepared under the sectors of Basic Metal Industry and Manufacture of Fabricated Metal Products (excluding Machinery and Equipment) are as follows:

24.10	Manufacture of basic iron and steel products and ferroalloys
24.20	Manufacture of steel tubes, pipes, hollow profiles, and similar fittings
24.31	Cold drawing of bars
24.32	Cold rolling of narrow strips
24.34	Cold drawing of wires
24.41	Production of precious metals
24.42	Aluminum production
24.51	Iron casting
24.52	Steel casting
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 hot water boilers
25.30	Manufacture of steam generators, excluding central heating hot water boilers
25.50	Forging, pressing, stamping, and rolling of metals; powder metallurgy
25.61	Processing 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, machine tool ends, saw blades, etc.
25.92	Manufacture of lightweight packaging materials from metal
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 classified elsewhere

2.1 Steel Casting (NACE 24.52)



	Minimum	Maximum
Specific Water Consumption of Facilities Visited within the Project Scope (L/unit of product)	0,06	1,29
Reference Specific Water Consumption (L/kg of product)	3	5



In steel foundries, all raw materials that directly affect the product's structure (such as sand preparation, molding, core making, and melting unit additives) are first procured and stored in the material warehouse. A sand mold is prepared, including a sprue and feeding system. If inner surfaces are required in the casting, cores are also added. The strength, permeability, thermal stability, and expansion rate of the sand molds and cores must be high. Sand from damaged molds is reused in other molds. Molten iron metal is poured into the sand mold. After the metal cools and solidifies, the mold is broken 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 castings to enhance metallurgical processes.

In the steel casting process, water consumption also occurs in auxiliary processes such as the induction furnace cooling tower and machine cooling. In integrated iron and steel production facilities, the majority of the water used is for cooling purposes. Due to the substantial amount of cooling water used in cooling furnaces and after casting, water is reused by circulating it to promote conservation. Closed-loop systems are employed to prevent evaporation losses. There are also small to medium-sized foundries operating under the 24.52 Steel Casting NACE code that cannot be classified as integrated steel production facilities. These facilities also use cooling water in induction casting furnaces. Water is also used for cooling press machines.

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

In the steel casting sector, the reference specific water consumption ranges from 3 to 5 liters per kilogram. The specific water consumption of the production branch analyzed in the study is between 0.06 and 1.29 liters per kilogram. By implementing good management practices, general preventive measures, and measures related to auxiliary processes, it is possible to achieve water savings of 32% to 52% in the sector.

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

NACE Code	NACE Code Description		Prioritized Sectoral Water Efficiency Techniques
24.52	Steel Casting		**Good Management Practices**
		1	Utilizing an integrated wastewater management and treatment strategy to reduce the volume of wastewater and pollutant load.
		2	Conducting effective production planning to optimize water consumption.
			General Precautionary Measures
		1	Minimizing spills and leaks.
		2	Recovering water from rinsing solutions and reusing it in processes that are suitable for the reclaimed water quality.
		3	Using automatic devices and equipment (sensors, smart handwashing systems, etc.) at water usage points such as showers and toilets to promote water conservation.
		4	Reusing filter wash water in filtration processes, recycling relatively clean wash waters in production processes, and employing onsite cleaning systems (CIP) to reduce water consumption.
		5	Avoiding the use of drinking water in production lines.
		6	Detecting and reducing water losses.
		7	Utilizing automatic control and shut-off valves to optimize water usage.
		8	Reusing backwash waters from pressure filtration prior to water softening at appropriate points.
		9	Implementing closed storage and impermeable waste/scrap sites to prevent the transportation of toxic or hazardous chemicals in aquatic environments.
		10	Preventing the storage, handling, and post-use wastewater mixing of substances (such as oils, emulsions, and binders) that pose risks in aquatic environments.
		11	Preventing the mixing of clean water flows with contaminated water flows.
		12	Identifying wastewater flows that can be reused, either treated or untreated, by characterizing the quantity and quality of wastewater at all points of generation.
		13	Employing closed-loop water circulation systems in suitable processes.

NACE Code	NACE Code Description		Prioritized Sectoral Water Efficiency Techniques
24.52	Steel Casting	14	Reuse of relatively clean wastewater resulting from washing, rinsing, and equipment cleaning without treatment.
		15	Separate collection and treatment of gray water in the facility, using it in areas that do not require high water quality (e.g., irrigation of green areas, floor cleaning, etc.).
		16	Implementation of time optimization in production, organizing all processes to be completed in the shortest possible time.
		17	Collection of rainwater for use as an alternative water source in facility cleaning or appropriate areas.
		18	Reuse of nanofiltration (NF) or reverse osmosis (RO) concentrates based on their characterization, either treated or untreated.
			Measures Related to Auxiliary Processes
		1.	Increasing the cycle count by using corrosion and scale inhibitors in systems with closed water loops.

A total of 21 techniques have been proposed in this sector.

For the Steel Casting NACE Code, the following are provided under separate headings:

(i) Good Management Practices,
(ii) General Measures, and
(iii) Measures Related to Auxiliary Processes.

2.1.1 Good Management Practices

- ***Using integrated wastewater management and treatment strategies to reduce the amount of wastewater and pollutant load:***

Wastewater management should adopt a holistic approach that encompasses functional elements such as composition, collection, treatment including sludge disposal, and reuse, from the production of wastewater to its final disposal. The selection of appropriate treatment technologies for industrial wastewater depends on integrated factors such as land availability, desired quality of treated water, 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 freshwater. Therefore, it is crucial to determine suitable treatment strategies for different reuse targets.

In integrated industrial wastewater treatment, different aspects such as the wastewater collection system, treatment process, and reuse goals are evaluated together (Naghedi et al., 2020). The SWOT method (strengths, weaknesses, opportunities, and threats), PESTEL method (political, economic, social, technological, environmental, and legal factors), and decision trees can be combined with expert opinions to establish an integrated wastewater management framework (Naghedi et al., 2020). The integration of Analytic Hierarchy Process (AHP) and Combined Compromise Solution (CoCoSo) techniques can be used to determine priorities based on multiple criteria for industrial wastewater management processes (Adar et al., 2021).

The implementation of integrated wastewater management strategies can lead to an average reduction of up to 25% in water consumption, wastewater amounts, and pollutant loads in wastewater. The potential payback period for this implementation ranges from 1 to 10 years (TOB, 2021).

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

Industrial Wastewater Treatment Plant

- ***Optimizing Production Planning to Reduce Water Consumption***

Planning the production process in industrial manufacturing to minimize the number of processes involved in converting raw materials into products is an effective practice for reducing labor costs, resource usage costs, environmental impacts, and increasing efficiency (TUBİTAK MAM, 2016; TOB, 2021). When production planning in industrial facilities takes water efficiency into account, it helps to reduce both water consumption and wastewater generation. Modifying production processes or combining certain processes in industrial facilities provides significant benefits in terms of water efficiency and time management (TOB, 2021).

2.1.2 General Measures-Type Precautions

- ***Detection and Reduction of Water Losses***

Water losses occur in equipment, pumps, and pipelines during industrial production processes. First and foremost, water losses should be detected, and regular maintenance of equipment, pumps, and pipelines should be conducted to keep them in good condition and prevent leaks (IPPC BREF, 2003). Regular maintenance procedures should pay special attention to the following points:

- Inclusion of pumps, valves, level switches, pressure and flow regulators in the maintenance checklist.

- Inspections not only in the water system but also specifically in heat transfer and chemical distribution systems, broken and leaking pipes, barrels, pumps, and valves.

- Regular cleaning of filters and pipelines.

- Calibration of measurement equipment such as chemical measurement and distribution devices, thermometers, etc., along with routine checks and monitoring at designated intervals (IPPC BREF, 2003).

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

- ***Minimizing Spills and Leaks***

Spills and leaks occurring in operations can lead to both raw material and water losses. Additionally, if wet cleaning methods are used to clean areas where spills have occurred, there can be increases in water consumption, wastewater amounts, and the pollutant loads of the wastewater (TOB, 2021). To reduce losses of raw materials and products, measures such as splash guards, skirts, drip trays, and screens are utilized to minimize spills and splashes (IPPC BREF, 2019).

- ***Establishing Closed Storage and Impermeable Waste/ Scrap Areas to Prevent the Transfer of Toxic or Hazardous Chemicals to Aquatic Environments***

In industrial facilities, closed and impermeable waste/scrap storage areas can be created to prevent the transfer of toxic or hazardous chemicals to receiving environments. This practice is already implemented under current environmental regulations in our country. Through field studies conducted, separate collection channels can be constructed in industrial facilities for the storage areas of toxic or hazardous substances, allowing for the separate collection of spill waters and preventing them from mixing with natural water environments.

- ***Recovery of Water from Rinsing Solutions and Reuse of Recovered Water in an Appropriate Process***

In industrial facilities, rinsing wastewater is relatively clean wastewater that can be reused without treatment in processes such as floor washing and garden irrigation, which do not require high water quality (Öztürk E., 2014). This reuse can lead to a 1-5% reduction in raw water consumption. The initial investment costs for this application include the installation of new pipelines and the creation of reserve tanks. The estimated initial investment cost can range from 1,000 to 5,000 TL.

- ***Utilizing Collected Rainwater as an Alternative Water Source for Facility Cleaning or Other Suitable Areas***

  In today's world, where water resources are dwindling, rainwater harvesting is especially preferred in regions with low rainfall. Various technologies and systems exist for rainwater collection and distribution. Storage tank systems, infiltration into the ground, surface collection, and filtration systems are utilized. If the rainwater collected through special drainage systems meets the required quality standards, it can be used for production processes, garden irrigation, cleaning tanks and equipment, surface cleaning, etc. (Tanık et al., 2015).

  In various examples, rainwater collected from rooftops in industrial facilities has been stored and used within the building and in landscaping areas, achieving a 50% water savings in landscape irrigation (Yaman, 2009). To enhance soil permeability and facilitate the infiltration and absorption of rainwater into the ground, perforated stones and green areas can be preferred (Yaman, 2009). Rainwater collected from building roofs can be used for vehicle washing and garden irrigation. After use, the collected water can be biologically treated and recovered for reuse at a rate of 95% (Şahin, 2010).

- ***Avoiding the Use of Drinking Water in Production Lines***

  In the various subsectors of the manufacturing industry, water of different qualities can be used according to production needs. In industrial facilities, raw water obtained from underground sources is generally treated before being used in production processes. However, in some cases, despite being costly, drinking water may be directly used in production processes, or untreated water may be disinfected with chlorine compounds before being utilized in production processes. These waters, containing residual chlorine, can react with organic compounds present in the water (natural organic matter (DOM)) to produce harmful disinfection byproducts from a biological metabolism perspective (Özdemir & Toröz, 2010; Oğur et al.; TOB, 2021). The use of drinking water containing residual chlorine compounds or untreated water disinfected with chlorine compounds should be avoided whenever possible. Instead of chlorine for disinfecting raw water, disinfection methods with high oxidation potential, such as ultraviolet (UV), ultrasound (US), or ozone, can be utilized. To enhance the technical, economic, and environmental benefits of this application, it is essential to determine and use the water quality parameters required for each production process, which will help reduce unnecessary water supply and treatment costs. This application will lead to reductions in water, energy, and chemical costs (TUBİTAK MAM, 2016).

- ***Reusing Filter Wash Water in Filtration Processes, Reusing Relatively Clean Cleaning Water in Production Processes, and Reducing Water Consumption by Using On-Site Cleaning Systems***

Wastewater generated from the backwashing of activated carbon filters and softening devices mostly contains only a high concentration of suspended solids (SS). Backwash water, one of the easiest types of wastewater to recover, can be filtered through ultrafiltration plants, allowing for savings of up to 15% in water usage. This investment can pay itself back within 1-2 months (URL - 1, 2021).

Regeneration wastewater produced after the regeneration process consists of soft water with high salt content and accounts for about 5-10% of total water consumption. Regeneration wastewater can be accumulated in a separate tank and utilized in processes that require high salt, for facility cleaning, and for domestic uses. This requires a reserve tank, water piping, and a pump. By reusing regeneration wastewater, reductions of approximately 5-10% can be achieved in water consumption, energy consumption, wastewater volumes, and the salt content of wastewater (Öztürk E., 2014). The expected initial investment cost for this application is around 250-350 USD/m³ (TUBİTAK MAM, 2016; TOB, 2021). The payback period varies depending on the use of regeneration water in production processes, facility cleaning, and domestic purposes. In production processes requiring high salt, reusing regeneration water (as both water and salt recovery will occur) is estimated to have a potential payback period of less than one year. However, for facility and equipment cleaning and domestic uses, the payback period is expected to exceed one year (TOB, 2021).

In our country, reverse osmosis (RO) concentrates are mixed with other wastewater flows and discharged into the wastewater treatment plant. The concentrates formed in RO systems used for additional hardness removal can be used for garden irrigation, as well as for facility and tank/equipment cleaning (TUBİTAK MAM, 2016; TOB, 2021). Additionally, with the establishment of continuous monitoring practices for raw water quality, it is possible to feed back and mix RO concentrates into raw water tanks for reevaluation (TOB, 2021).

- ***Reusing Nanofiltration (NF) or Reverse Osmosis (RO) Concentrates Based on Characterization, Either with or Without Treatment***

Depending on the characterization of the wastewater and suitable usage points, the potential for the reuse of other wastewater generated from membrane processes (including backwashes without chemicals or with chemicals, CIP cleanings, module cleanings, cleaning of chemical tanks, etc.) should be assessed.

Nanofiltration is a membrane-based liquid separation technique that is suitable for treating groundwater and surface water, featuring low energy consumption and low operating pressures. Reverse osmosis is also a membrane-based liquid separation technique but can remove smaller particles than nanofiltration (AKGÜL, 2016).

By reusing nanofiltration or reverse osmosis concentrates, savings can be achieved either with or without treatment. Measures should be taken to ensure the reuse of clean waters from filter backwash in production processes and to reduce water consumption by utilizing cleaning systems (TOB, 2021).

- ***Use of Automatic Control-Shutoff Valves to Optimize Water Use***

Monitoring and controlling water consumption through flow control devices, meters, and computer-aided monitoring systems provides significant technical, environmental, and economic advantages (Öztürk, 2014). Tracking the amount of water consumed within the facility and in various processes helps prevent water losses (TUBİTAK MAM, 2016). The use of flow meters and meters throughout the facility and in specific production processes, automatic shutoff valves and controls in continuously operating machines, and the development of monitoring-control mechanisms based on water consumption and certain defined quality parameters using computer-assisted systems are necessary (TUBİTAK MAM, 2016). With this application, savings of up to 20-30% in water consumption can be achieved on a process basis (DEPA, 2002; LCPC, 2010; IPPC BREF, 2003). Monitoring and controlling water consumption in processes can lead to savings of 3-5% in process water use (Öztürk, 2014).

- ***Reuse of Pressurized Filtration Backwash Waters at Appropriate Points Before Water Softening***

Today, there is a need for softened process waters with low calcium and magnesium concentrations. Water softening systems remove calcium, magnesium, and other metal cations from hard water to produce soft water.

Various savings can be achieved by reusing pressurized filtration backwash waters at appropriate points before water softening. This measure is similar in content to practices such as “the reuse of filter backwash waters in filtration processes, the reuse of relatively clean waters in production processes, and the reduction of water consumption using onsite cleaning systems.”

- ***Minimizing the Storage, Handling, and Contamination of Aquatic Environments by Hazardous Substances (such as Oils, Emulsions, Binders, etc.)***

In industrial facilities, dry cleaning techniques can be employed to prevent the mixing of chemicals that pose risks to aquatic environments, such as oils, emulsions, and binders, with wastewater flows, and to prevent leaks. This helps ensure the protection of water resources (TUBİTAK MAM, 2016).

- ***Preventing the Mixing of Clean Water Flows with Contaminated Water Flows***

By identifying the points of wastewater generation and characterizing the wastewater in industrial facilities, it is possible to collect wastewater with high pollution loads separately from relatively clean wastewater in distinct lines (TUBİTAK MAM, 2016; TOB, 2021). This allows for the treatment or reuse of separated wastewater flows with suitable water-wastewater quality. The separation of wastewater flows reduces water pollution, enhances treatment performance, and lowers energy consumption associated with reduced treatment needs while enabling the recovery of wastewater and valuable materials, thus reducing emissions. Additionally, waste heat recovery is possible from separated hot wastewater flows (TUBİTAK MAM, 2016; TOB, 2021). The separation of wastewater flows may require high investment costs; however, in cases where significant amounts of wastewater and energy can be recovered, it can lead to a reduction in costs (IPPC BREF, 2006).

- ***Determining Wastewater Flows That Can Be Reused with or Without Treatment by Identifying the Quantities and Characterization of Wastewater at All Generation Points***

Different types of wastewater are generated in industrial facilities. Therefore, by identifying and characterizing the points of wastewater generation, various wastewater flows can be reused with or without treatment (Öztürk E., 2014; TUBİTAK MAM, 2016; TOB, 2021). In this context, backwash waters, RO (Reverse Osmosis) concentrates, blowdown waters, condensate waters, and relatively clean wash and rinse waters can be reused without treatment in areas with high water quality requirements (such as facility and equipment cleaning) across the same or different processes. Additionally, wastewater flows that cannot be reused directly can be treated using appropriate treatment technologies and then reused in production processes.

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 typically used for pre-treatment of water before it goes through the NF or RO process (Singh et al., 2014).

In some industrial facilities operating in the food sector, the reuse of treated or untreated wastewater can result in reductions of up to 13% in water consumption, 18% in wastewater volumes, and 48% in COD (Chemical Oxygen Demand) loads (TUBİTAK MAM, 2016; TOB, 2021). Furthermore, the initial investment cost required for this application is estimated at 100,000 TL, with a payback period of approximately 3 years (including energy savings) (TUBİTAK MAM, 2016; TOB, 2021). In the textile industry, the reuse of washing and rinsing waters without treatment can achieve water savings of 30-70% (USEPA, 2008; LCPC, 2010; TOB, 2021). Additionally, in a clean production study conducted in the textile industry, it was reported that suitable wastewater flows could result in reductions of 29-55% in total water consumption and 42-53% in pollution loads of composite wastewater through reuse applications with or without treatment (Öztürk E., 2014). In another textile facility engaged in textile finishing-dyeing, the reuse of treated or untreated wastewater resulted in reductions of 46-50% in water consumption, 48-56% in wastewater volumes, and 16-20% in COD loads (Öztürk E., 2014).

- ***Implementation o f Time Optimization in Production, Organizing All Processes to Complete in the Shortest Possible Time***

In industrial production processes, planning the transition of a raw material to a product with minimal processes can be an effective practice for reducing labor costs, resource utilization costs, efficiency, and environmental impacts. In this context, it may be necessary to revise production processes to use the fewest possible process steps (TUBİTAK MAM, 2016). Some deficiencies in basic production processes may require the renewal of production processes when the desired product quality cannot be achieved due to inefficiencies and design errors. Consequently, the amount of resources needed for manufacturing a unit quantity of product, as well as the quantities of waste, emissions, and solid waste generated, may increase. Time optimization in production processes is an application that can be effectively used alongside other good management practices (TUBİTAK MAM, 2016).

- ***Use of Closed-Loop Water Circulation in Appropriate Processes (e.g., in Cooling Processes and Wet Holders)*****

Coolants are chemical compounds that absorb heat from the materials being cooled, possessing certain thermodynamic properties that affect the performance of the cooling process (Kuprasertwong et al., 2021). Water can be used as a coolant in various processes, especially in manufacturing processes where the cooling of products is essential. During this cooling operation, water is recycled through cooling towers or central cooling systems. If undesirable microbial growth occurs in the cooling water, it can be controlled by adding chemicals to the recirculation water (TUBİTAK MAM, 2016).

Cooling water can be reused in processes such as cleaning. This increases the efficiency of water treatment and reduces pollutant emissions in natural environments (Özlem Demir, 2017). Additionally, this application results in a reduction in water consumption and wastewater volume. However, the need for energy to cool and recirculate cooling waters presents a side effect. Heat recovery can also be achieved by using heat exchangers with cooling water. The payback period for the investment required for closed-loop cooling systems and cooling towers used in the cooling of fermentation processes is approximately one year (IPPC BREF, 2006). Field studies show that closed-loop systems are used in facilities with water cooling systems. However, the cooling system blowdown is directly discharged into the wastewater treatment plant channel. Blowdown water can be reused in all other suitable production processes.

- ***Reuse of Relatively Clean Wastewaters from Washing, Rinsing, and Equipment Cleaning Processes without Treatment in Production Processes***

In industrial facilities, relatively clean wastewaters, such as those from washing and final rinsing, as well as filter backwash wastewaters, can be reused without treatment in floor washing and garden irrigation processes that do not require high water quality. This can result in savings of 1-5% in raw water consumption. The initial investment costs for this application may include the establishment of new pipelines and reserve tanks (Öztürk E., 2014).

- ***Use of Automatic Equipment and Devices (Sensors, Smart Handwashing Systems, etc.) in Water Use Points (e.g., Showers/Toilets) for Water Savings***

Water is essential in many sectors of the manufacturing industry, both for production processes and for personnel to maintain necessary hygiene standards. In industrial facilities, water consumption can be managed in various ways, including the use of sensor-operated faucets and smart handwashing systems in personnel water use areas, which help achieve water savings. Smart handwashing systems adjust the water, soap, and air mixture in the correct proportions, contributing not only to water conservation but also to resource efficiency.

- ***Separate Collection and Treatment of Gray Water in the Facility and Its Use in Areas That Do Not Require High Water Quality (e.g., Irrigation of Green Areas, Floor Washing, etc.)***

The wastewater generated in industrial facilities includes not only industrial wastewater from production processes but also wastewater from areas like showers, sinks, and kitchens. Wastewater from showers, sinks, and kitchens is referred to as gray water. By treating this gray water through various treatment processes, it can be reused in areas that do not require high water quality, resulting in water savings.

2.1.3 Measures Related to Auxiliary Processes

METs Related to Cooling Systems

- ***Use of Corrosion and Scale Inhibitors to Increase Cycle Numbers in Closed Water Loop Systems***

Cooling towers and evaporative condensers are effective and low-cost systems for removing heat from air conditioning and industrial process cooling systems (IPPC BREF, 2001b; TOB, 2021). In these systems, more than 95% of the circulating water can be reclaimed (TUBİTAK MAM, 2016). Because part of the recirculation water is evaporated, impurities remain in the recirculated water, leading to increasing concentrations of contaminants with each cycle. Impurities that can enter the cooling system along with air can cause contamination in recirculation waters (TUBİTAK MAM, 2016). If impurities and pollutants are not effectively controlled, they can lead to scale (kışır) and corrosion, unwanted biological growth, and sludge accumulation. This can become a chronic issue that reduces the efficiency of heat transfer surfaces and increases operating costs. Therefore, the quality of the makeup water supplied to the cooling system, along with a specially designed water conditioning program based on the construction materials of the cooling water system and operating conditions, is essential. This includes bluff control, biological growth control, corrosion control, avoiding hard water usage, using sludge control chemicals, and employing filtration and screening systems (TUBİTAK MAM, 2016). Additionally, establishing and periodically implementing an effective cleaning procedure and program is a good management practice for protecting cooling systems.

Corrosion is one of the most significant problems in cooling systems. In the tower recirculation water, as the hardness level increases, dissolved solids (sulfates, chlorides, carbonates, etc.) can cause the formation of scale and deposits on the walls over time, leading to wear on the surface. Additionally, the formation of deposits negatively affects heat transfer, reducing energy efficiency. To prevent these issues, a chemical conditioning program for scale and corrosion inhibitors should be implemented, disinfecting with a biocide to inhibit biological activity, and cooling towers should be subjected to chemical and mechanical cleaning at least twice a year to remove deposits. The makeup water's hardness and conductivity levels should be kept as low as possible (IPPC BREF, 2001; Kayabek et al., 2005). Improving the quality of the makeup water may require the use of an appropriate treatment system. Furthermore, unwanted microbial growth must also be kept under control (IPPC BREF, 2001b; TOB, 2021).

Due to micro-impurities and deposits in the cooling water, blowdown occurs in cooling systems just as it does in steam boilers. To balance the increasing concentration of solids in the cooling system, the conscious draining of the cooling system is referred to as cooling blowdown. By pre-treating the cooling water using appropriate methods and continuously monitoring the quality of the cooling water, the use of biocides and the amount of blowdown can be reduced (TUBİTAK MAM, 2016). While the investment cost depends on the scale of the implementation, the expected payback period for investment expenses ranges from 3 to 4 years (IPPC BREF, 2001).

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