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MINISTRY OF AGRICULTURE AND FORESTRY GENERAL
DIRECTORATE OF WATER MANAGEMENT

Water Efficiency
Guide Document Series

CASTING OF OTHER NON-FERROUS METALS

NACE CODE: 24.54

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Prepared by the Ministry of Agriculture and Forestry, General Directorate of Water Management, Contractor io Environmental Solutions R&D Co. Ltd.

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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 m³, but with increasing human pressures and the impacts of climate change, this figure is expected to fall below 1,000 m³ 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.

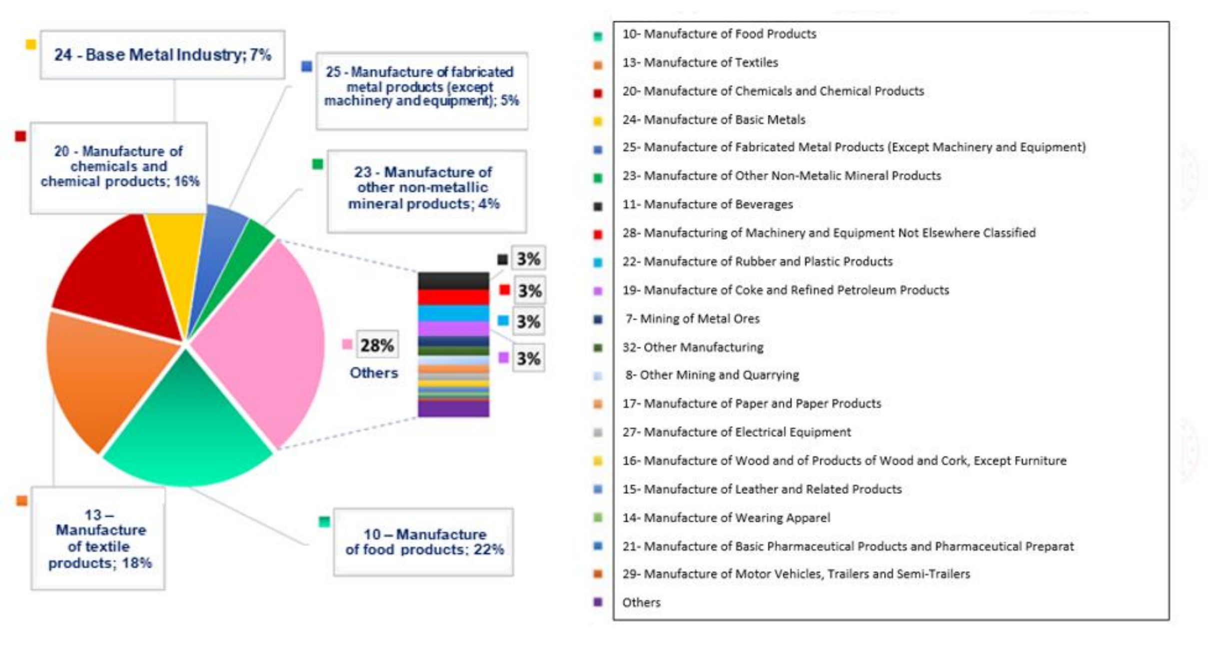
With the target of achieving carbon neutrality, the European Green Deal aims to implement a clean, circular economy model, promoting efficient use of resources and reducing environmental impacts—objectives agreed upon by member countries. In line with this, Turkey's European Green Deal Action Plan outlines 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)

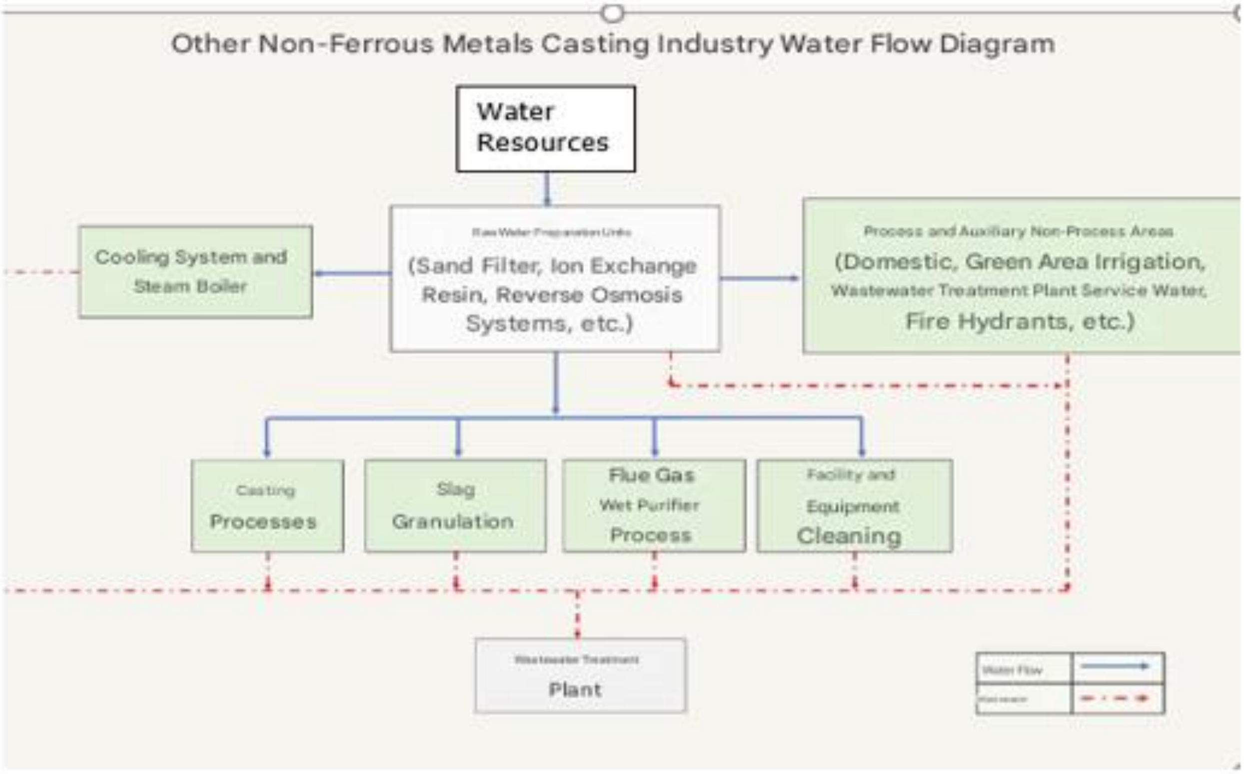
- Storage and supporting activities for transportation (including 1 sub-production area represented by a four-digit NACE code)
- Accommodation (including 1 sub-production area represented by a four-digit NACE code)
- Educational activities (Higher Education Campuses) (including 1 sub-production area 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 Casting of other non-ferrous metals (NACE 24.54)



Other Non-Ferrous Metals Casting Industry Water Flow Diagram

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

Percentage Distribution of Water Efficiency Practices

The casting activities of non-ferrous metals include brass, copper and its alloys, aluminum, lead, tin, zinc, cadmium, precious metals, ferroalloys, nickel, and cobalt. In the casting industry for these metals, raw materials first undergo quality control. In the melting process, raw materials are taken to induction furnaces and/or pit furnaces for melting. In the casting process, the melted raw materials in the furnaces are cast. In the cutting and deburring process, excess material from the casting is trimmed. Finally, the finished products are made ready for sale/shipment according to their specific types.

In the non-ferrous metals casting sector, water is consumed in the casting mold cooling process to cool and solidify the cast material, as well as in slag granulation and wet flue gas treatment systems. Water is also consumed for producing soft water in production processes through raw water preparation units, such as ion-exchange resins and reverse osmosis, as well as for resin regeneration and membrane cleaning. Additionally, water is consumed in auxiliary processes, such as cooling systems and steam boilers.

The reference specific water consumption for the non-ferrous metals casting industry is between 3 and 5 L/kg. The specific water consumption for the analyzed production branch within this study ranges from 0.1 to 1.5 L/kg. Through the implementation of industry-specific measures, good management practices, general preventive measures, and measures related to auxiliary processes, it is possible to achieve a water savings rate of 54% to 81% in the industry.

Casting machine

24.54 The recommended priority water efficiency application techniques under the casting of other non-ferrous metals NACE code are presented in the table below.

NACE Code	NACE Code Descpition		Prioritized Sectoral Water Efficiency Techniques
24.54	Casting of other non-ferrous metals		**Sector Specific Measures**
		1.	Use of "Closed Mold Application with Release Agent"
		2.	Implementation of Automatic Spraying Process to Control the Amount of Release Agent Used
		3.	Recovery of Wastewater from Process Water through Neutralization, Sedimentation, and Electrolysis Methods
			Good Management Practices
		1.	Establishment of an environmental management system
		2.	Providing technical training to personnel to reduce and optimize water usage
		3.	Monitoring the quantity and quality of water used in production and auxiliary processes, as well as the wastewater generated, and integrating this data into the environmental management system
			General Precautionary Measures
		1.	- Minimizing spills and leaks
		2.	- Recovering water from rinsing solutions and reusing it in processes suitable for the recovered water’s quality
		3.	- Utilizing automatic equipment (sensors, smart handwashing systems, etc.) at water usage points like showers and toilets to save water
		4.	- Avoiding the use of drinking water on production lines
		5.	- Using cooling water as process water in other processes
		6.	- Identifying and reducing water losses
		7.	- Documenting production procedures and ensuring their use by employees to prevent water and energy waste
		8.	- Reusing backwash water from pressurized filtration before water softening at appropriate points
		9.	- Optimizing the frequency and duration of regeneration in water softening systems (including rinsing)
		10.	- Implementing closed storage and impermeable waste/scrap areas to prevent the transport of toxic or hazardous chemicals to aquatic environments
		11.	- Storing, managing, and preventing materials that pose a risk to aquatic environments (such as oils, emulsions, binders) from entering wastewater after use

NACE Code	NACE Code Description	Prioritized Sectoral Water Efficiency
24.54	Casting of other non-ferrous	12. Prevention of mixing of clean water flows with polluted water flows
		Use of closed loop water cycles in appropriate processes
		14. Untreated reuse of relatively clean wastewater from washing, rinsing and equipment cleaning in production processes
		15. Separate collection and treatment of gray water and high water quality in areas that do not require (green area irrigation, floor washing, etc.) -
		16. Applying time optimization in production and organizing all processes to be completed as quickly as possible
		17. Collecting rainwater and utilizing it as an alternative water source for facility cleaning or in suitable areass
		Measures for Auxiliary Processes
		1. Reducing water consumption by increasing the cycle count in closed-loop cooling systems and improving the quality of the make-up water
		2. Implementing tower cooling applications for water recovery in systems without closed loops
		3. Increasing the cycle count in systems with closed water loops by using corrosion and scale inhibitors
		4. Installing water softening systems to ensure efficient operation of water recovery systems
		5. Using closed-loop cooling systems to reduce water consumption

A total of 31 techniques were proposed in this sector.

For the NACE Code for Casting of Light Metals;

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

21.1 Sector-Specific Measures

Recovery of Wastewater from Process Water through Neutralization, Precipitation, and Electrolysis

Wastewater generated from processes like acid pickling, the Bayer process in alumina production, the processing of lead-acid batteries, or the treatment of precious metals can be recovered through neutralization, precipitation, and electrolysis. Acidic wastewaters from sulfuric acid plants, weak sulfuric acids, and wastewater from refining elements like germanium and gallium can also be treated with these methods (IPPC BREF, 2017d).

Use of Automatic Spraying Processes to Control the Amount of Release Agent

In cast iron processes, the water-based solution of the release agent is sprayed onto the high-pressure die casting (HPDC) mold using an automatic spray process, which also cools the mold. Simple process modifications like this can reduce both the consumption of the release agent and water use in iron casting (IPPC BREF, 2005a).

Use of Closed Mold Application for Release Agent

In closed mold applications, the release agent is vaporized and applied to the closed mold casting. This process leads to the condensation and accumulation of the release film and offers an alternative to spraying water-based release agents onto an open mold. By using a closed mold application instead of spraying, water usage and the consumption of release agents are reduced (IPPC BREF, 2005a).

2.1.2 Good Management Practices

- ***Establishing an Environmental Management System (EMS)***

Environmental Management Systems (EMS) include the necessary organizational structure, responsibilities, procedures, and resources for industrial establishments to develop, implement, and monitor environmental policies. Implementing an EMS enhances decision-making processes related to raw materials, water-wastewater infrastructure, production planning, and various treatment techniques. Environmental management organizes how to handle resource supply and waste discharge demands with maximum economic efficiency, maintaining product quality and minimizing environmental impact.

The most widely used EMS standard is ISO 14001, with alternatives such as the Eco-Management and Audit Scheme (EMAS) Directive (761/2001). These standards were developed to evaluate, improve, and report the environmental performance of businesses. EMAS is recognized as a leading practice in EU legislation under eco-efficiency (clean production) initiatives, and participation is voluntary (TUBITAK MAM, 2016; TOB, 2021). Benefits of establishing and implementing an EMS include:

- Improved business performance, leading to economic benefits (Christopher, 1998).
- Enhanced compliance with global legal and regulatory requirements through adherence to International Organization for Standardization (ISO) standards (Christopher, 1998).
- Minimization of penalty risks associated with environmental responsibilities and reductions in waste, resource consumption, and operating costs (Delmas, 2009).
- Use of internationally recognized environmental standards reduces the need for multiple registrations and certifications for businesses operating in various locations globally (Hutchens Jr., 2017).
- Increased importance by consumers on enhanced internal control processes, providing a competitive advantage over companies without standardized EMS practices and aiding in better positioning within international markets (Potoski & Prakash, 2005).

These benefits depend on multiple factors, including production processes, management practices, resource utilization, and potential environmental impacts (TOB, 2021). Through similar practices, such as preparing annual inventory reports and monitoring the quantity and quality of inputs and outputs in production processes, water savings of approximately 3-5% can be achieved (Ozturk, 2014). The process of developing and implementing an EMS typically takes about 8-12 months (ISO 14001 User Manual, 2015).

Industrial establishments are also working under the ISO 14046 Water Footprint Standard, which defines requirements and guidelines for assessing and reporting water footprint. The standard aims to reduce freshwater use and environmental impacts required for production. Additionally, the ISO 46001 Water Efficiency Management Systems Standard helps companies improve their water efficiency policies through monitoring, benchmarking, and review, assisting them in saving water and reducing operational costs.

- ***Providing Technical Training to Personnel for Reducing and Optimizing Water Use***

  This measure aims to increase personnel training and awareness, facilitating water conservation and recovery, which can help reduce water consumption and costs while improving water efficiency. In industrial facilities, high water usage and wastewater generation issues can arise from personnel lacking the necessary technical knowledge. For instance, it is crucial to properly train cooling tower operators, who represent a significant portion of water consumption in industrial operations. Personnel must also possess adequate technical knowledge for applications such as determining water quality requirements and measuring water and wastewater quantities (TOB, 2021). Therefore, it is essential to provide training on water reduction, optimization, and conservation policies. Engaging staff in water conservation initiatives, creating regular reports on water usage before and after efficiency efforts, and sharing these reports with personnel support process participation and motivation. The technical, economic, and environmental benefits obtained from personnel training yield results in the medium to long term (TUBİTAK MAM, 2016; TOB, 2021).

- ***Monitoring the Quantity and Quality of Water Used and Wastewater Generated in Production and Auxiliary Processes, and Adapting this Information to the Environmental Management System***

  Industrial facilities have existing resource utilizations, and the inefficiencies and environmental problems arising from resource use can stem from input-output flows. Therefore, it is necessary to monitor the quantity and qualities of water used and wastewater generated in production and auxiliary processes (TUBİTAK MAM, 2016; TOB, 2021). Process-based monitoring of quantity and quality, alongside other good management practices (such as personnel training and the establishment of environmental management systems), can achieve reductions of up to 6-10% in energy consumption and up to 25% in water consumption and wastewater generation (Öztürk, 2014).

  The main steps for monitoring water and wastewater in terms of quantity and quality include:

  - Using monitoring equipment (such as meters) to track water, energy, etc., consumption on a process basis.
  - Establishing monitoring procedures.
  - Identifying, documenting, and reporting all input and output points (raw materials, chemicals, water, products, wastewater, sludge, solid waste, hazardous waste, and by-products) related to the production process, monitoring them in terms of quantity and quality, and evaluating them comparatively.
  - Monitoring raw material losses in production processes where raw materials are converted to products and taking measures against these losses (ÇŞİDB, 2020e).

2.1.3 General Measures-Type Precautions

Collecting Rainwater to be Used as an Alternative Water Source for Facility Cleaning or in Suitable Areas

In today's context of diminishing water resources, rainwater harvesting is increasingly preferred, especially in regions with low rainfall. Various technologies and systems are available for rainwater collection and distribution systems. Cistern systems, infiltration into the ground, surface collection, and filtration systems are utilized. If the rainwater collected through special drainage systems meets the necessary quality requirements, it can be used for production processes, garden irrigation, tank and equipment cleaning, surface cleaning, etc. (Tanık et al., 2015).

In various examples, rainwater collected from industrial facility rooftops has been stored and then used within the building and landscape areas, resulting in a 50% water savings in landscape irrigation (Yaman, 2009). To enhance soil permeability and ensure that rainwater infiltrates and is absorbed by 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. It is possible to recover up to 95% of the collected water for reuse through biological treatment after use (Şahin, 2010).

Utilizing Closed Loop Water Circuits in Suitable Processes

Coolants are chemical compounds with specific thermodynamic properties that cool substances by absorbing heat from them, affecting the performance of the cooling process (Kuprasertwong et al., 2021).

Water is commonly used as a coolant in various manufacturing processes, including product cooling operations. During this cooling process, water can be reused through cooling towers or central cooling systems. If undesirable microbial growth occurs in the cooling water, chemicals can be added to the recirculated water to control it (TUBİTAK MAM, 2016).

By reusing cooling water in processes such as cleaning, water consumption and the amount of wastewater generated can be reduced. However, the need for energy to cool and recirculate the cooling water can present a trade-off. The use of heat exchangers in cooling waters also facilitates heat recovery. Generally, closed-loop systems are used in facilities that employ water-based cooling systems. However, blowdowns from the cooling system are directly discharged into the wastewater treatment plant channel. The discharged blowdown water can be reused in suitable production processes.

Preventing the Storage, Retention, and Post-Use Contamination of Wastewater with Risk-Inducing Substances in Aquatic Environments

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

Establishing Closed Storage and Impermeable Waste/Discard Areas to Prevent the Transfer of Toxic or Hazardous Chemicals in Aquatic Environments

In industrial facilities, closed and impermeable waste/discard storage areas can be constructed to prevent the transfer of toxic or hazardous chemicals to receiving environments. This practice is already implemented under existing environmental regulations in our country. Through field studies, separate collection channels can be established for toxic or hazardous material storage areas in industrial facilities to collect any leaking water separately and prevent it from mixing with natural water environments.

Implementing Time Optimization in Production and Organizing All Processes to be Completed in the Shortest Possible Time

In industrial production processes, planning the conversion of raw materials to products with minimal process use is an effective practice to reduce labor costs, resource use costs, environmental impacts, and to enhance efficiency. This may require a review of production processes to revise them so that the fewest possible process steps are used (TUBİTAK MAM, 2016). In cases where some deficiencies in fundamental production processes lead to inefficiencies and design errors, resulting in failure to achieve the desired product quality, it may be necessary to renew production processes. Consequently, this increases the resource usage required for the manufacturing of a unit quantity of product, as well as the amount of waste, emissions, and solid waste generated. Optimizing time in production processes is an effective practice (TUBİTAK MAM, 2016).

Minimizing Spills and Leaks

Spills and leaks in operations can lead to losses of both raw materials and water. Furthermore, the use of wet cleaning methods to clean up spill areas can increase water consumption, wastewater amounts, and the pollution load of wastewater (TOB, 2021). To reduce losses of raw materials and products, anti-splash devices, wings, drip trays, and sieves can be used to minimize spillage and splashing losses (IPPC BREF, 2019).

Recovering Water from Rinse Solutions and Reusing the Recovered Water in Suitable Processes

In industrial facilities, rinse wastewater is relatively clean and can be reused without treatment in ground washing and garden irrigation operations that do not require high water quality (Öztürk, 2014). The recovery of rinse water can lead to savings of 1-5% in raw water consumption.

*Avoiding the Use of Drinking Water on Production Lines***

In various subsectors of the manufacturing industry, different qualities of water can be used based on production needs. Typically, raw water sourced from underground water supplies is treated and then used in production processes. However, in some cases, despite being costly, drinking water can be used directly in production processes or raw water can be disinfected with chlorinated compounds and then utilized in production. Water containing residual chlorine can react with organic compounds present in the water (natural organic matter, DOM), leading to the formation of harmful disinfection by-products from a biological metabolism perspective (Özdemir & Toröz, 2010; Oğur et al.; TOB, 2021). The use of drinking water or raw water disinfected with chlorinated compounds should be avoided whenever possible. Instead of chlorination for disinfection, methods with high oxidation capacity, such as ultraviolet (UV), ultrasound (US), or ozone disinfection, can be employed. By identifying and using the necessary water quality parameters for each production process, unnecessary water procurement and treatment costs can be reduced, thus enhancing the technical, economic, and environmental benefits of the application. This approach allows for reductions in water, energy, and chemical costs (TUBİTAK MAM, 2016).

Using Cooling Water as Process Water in Other Processes

Cooling systems that use water are commonly employed in processes where thermal energy is heavily utilized and cooling is required. Heat recovery can be achieved through the use of heat exchangers in the return of cooling water, preventing contamination of the cooling water and increasing the rates of cooling water return, resulting in water and energy savings (TUBİTAK MAM, 2016; TOB, 2021). Additionally, if cooling waters are collected separately, it is generally possible to use the collected waters for cooling purposes or to re-evaluate them in suitable processes (EC, 2009). The reuse of cooling waters can lead to savings of 2-9% in total water consumption (Greer et al., 2013). Energy consumption can also be reduced by up to 10% (Öztürk, 2014; TOB, 2021).

Reusing Backwash Water from Pressurized Filtration Before Water Softening in Appropriate Locations

Many industrial processes require softened water with low concentrations of calcium and magnesium. Water softening systems remove calcium, magnesium, and certain other metal cations from hard water to produce soft water. By reusing backwash water from pressurized filtration before the water softening process in appropriate locations, savings can be achieved. This measure is similar in content to practices such as "the reuse of filter backwash water in filtration processes, the reuse of relatively clean water in production processes, and the reduction of water consumption through the use of on-site cleaning systems."

Detection and Reduction of Water Losses

In industrial production processes, water losses occur in equipment, pumps, and piping systems. First, water losses should be detected, and regular maintenance of equipment, pumps, and pipelines should be performed to keep them in good condition and prevent leaks (IPPC BREF, 2003). Regular maintenance procedures should pay particular attention to the following aspects:

- Inclusion of pumps, valves, level switches, pressure, and flow regulators in the maintenance checklist.
- Inspections should be conducted not only on the water system but also on heat transfer and chemical distribution systems, broken and leaking pipes, barrels, pumps, and valves.
- Regular cleaning of filters and piping.
- Calibration of measurement equipment such as chemical measurement and distribution devices, thermometers, etc., and routine checks and monitoring at specified intervals (IPPC BREF, 2003).

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

Optimization of Regeneration Frequency and Duration (Including Rinsing) in Water Softening Systems

One of the most commonly used methods for softening raw water in industrial facilities is the use of cationic ion exchange resins, which are routinely regenerated. The regeneration process typically involves pre-washing the resin with raw water, regenerating with brine, and performing a final rinse. The regeneration periods are determined based on the hardness of the water. If the hardness is high, more frequent regeneration in the water softening systems is necessary.

In regeneration processes, the wash, regeneration, and rinse wastewater is generally disposed of directly. However, if the wash and final rinse water is of raw water quality, it can be sent to the raw water storage or reused in processes that do not require high water quality, such as facility cleaning and landscape irrigation (TOB, 2021).

Determining the optimum regeneration frequency in regeneration systems is crucial. Although regeneration in water softening systems is typically adjusted according to the frequencies recommended by the supplier or based on the flow rate and duration entering the softening system, this frequency can also vary based on the calcium concentration in the raw water. Therefore, online hardness measurement is used to determine the regeneration frequency. This approach not only optimizes regeneration frequencies but also prevents excessive washing, rinsing, or brine backwashing by utilizing online hardness sensors.

*Establishment of Closed Storage and Impermeable Waste/ Scrap Yards to Prevent the Transportation of Toxic or Hazardous Chemicals to Aquatic Environments***

In industrial facilities, closed and impermeable waste/scrap storage areas can be constructed to prevent the transportation of toxic or hazardous chemicals to receiving water environments. This practice is currently implemented under existing environmental regulations in our country. As part of field studies, separate collection channels can be established in industrial facilities for toxic or hazardous material storage areas to collect leakage waters separately, thereby preventing them from mixing with natural water environments.

Prevention of Clean Water Streams from Mixing with Contaminated Water Streams

By identifying the points of wastewater generation in industrial facilities and characterizing the wastewater, highly polluted wastewater can be collected in separate lines from relatively clean wastewater (TUBİTAK MAM, 2016; TOB, 2021). This separation allows for the treated or untreated reuse of wastewater streams that meet the appropriate quality. By separating wastewater streams, water pollution is reduced, treatment performances are enhanced, and energy consumption related to reduced treatment needs is minimized. Additionally, wastewater recovery and recovery of valuable materials can reduce emissions. Heat recovery from separated hot wastewater streams is also possible (TUBİTAK MAM, 2016; TOB, 2021). However, the separation of wastewater streams typically requires high investment costs, although it can lead to cost reductions when substantial amounts of wastewater and energy recovery are feasible (IPPC BREF, 2006).

Reuse of Relatively Clean Wastewaters from Washing, Rinsing, and Equipment Cleaning Processes without Treatment

In industrial facilities, relatively clean wastewaters, such as those from washing-final rinsing and filter backwashing, can be reused without treatment for processes that do not require high water quality, such as floor cleaning and landscape irrigation. This practice can result in water savings of about 1% to 5% in raw water consumption. The initial investment costs for this application are associated with the installation of new piping systems and the creation of reserve tanks (Öztürk, 2014).

Documentation of Production Procedures to Prevent Water and Energy Waste

To achieve efficient production within an enterprise, effective procedures must be implemented to identify, assess, and control potential issues and resources during the production stages (Ayan, 2010). Establishing and applying suitable procedures in production processes ensures more efficient use of resources (such as raw materials, water, energy, chemicals, personnel, and time) and secures reliability and quality in production processes (Ayan, 2010). Having documented production procedures contributes to assessing operational performance and enhancing the ability to develop immediate responses to problems (TUBİTAK MAM, 2016; TOB, 2021). Effectively implementing and monitoring the procedures created for specific production processes is one of the most effective ways to ensure product quality, obtain feedback, and develop solutions (Ayan, 2010). Documenting, effectively implementing, and monitoring production procedures is a good management practice and serves as an effective tool in structuring and ensuring the continuity of clean production approaches and environmental management systems. While the costs and economic gains of such applications may vary from sector to sector or depend on facility structure, the creation and monitoring of production procedures are generally not costly. Given the potential savings and benefits, the payback period can be short (TUBİTAK MAM, 2016; TOB, 2021).

Use of Automatic Devices and Equipment for Water Conservation at Water Usage Points (e.g., Showers, Toilets)

Water is crucial in many sectors of the manufacturing industry for both production processes and for personnel to maintain necessary hygiene standards. Water consumption in industrial facilities can be managed through various means, including the use of sensor-operated faucets and smart handwashing systems, which help reduce water usage in personnel areas. 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 Greywater for Use in Low Water Quality Requirement Areas (e.g., Landscape Irrigation, Floor Cleaning)

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

2.1.4 Measures Related to Auxiliary Processes

METs Related to Cooling Systems

Using Closed-Circuit Cooling Systems to Reduce Water Usage

Closed-circuit cooling systems significantly reduce water consumption compared to open-loop systems that use larger amounts of water. In closed-loop systems, water is recirculated within the same system, and typically, only the amount of water that evaporates needs to be replenished. Optimizing cooling systems can also help to minimize evaporation losses.

Increasing the Number of Cycles in Closed-Circuit Cooling Systems and Improving the Quality of Makeup Water to Reduce Water Consumption

Water is widely used as a coolant in production processes and in cooling products within the manufacturing industry. The cooling process is performed by recirculating water 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 recirculated water (TUBİTAK MAM, 2016). By ensuring proper chemical conditioning during the recirculation process, the number of cycles can be increased. This reduces the amount of fresh water supplied to the system, thereby saving water. Furthermore, improving the conditioning of makeup water can also increase the number of cycles (TOB, 2021).

Water Recovery through Cooling Tower Applications in Non-Closed Loop Systems

Cooling towers are classified into two types based on their operating principles: counterflow and crossflow. In counterflow cooling towers, water flows downward while the air flows upward, whereas in crossflow cooling towers, water flows downward while the air moves horizontally. The water exposed to fresh air cools as it descends to the cold water basin, where it collects and is sent to the facility. During this process, some of the water evaporates. The evaporation of water increases the humidity of the air, which is then expelled into the atmosphere through the fan stack located at the top of the tower. The evaporation losses in cooling towers must be effectively managed.

To prevent the formation of bacteria and parasites in cooling towers and to control scale buildup, various chemicals are used. These chemicals concentrate as water evaporates, leading to unwanted deposits and accumulations within the tower. To maintain this concentration at a certain level, a bleed-off system is utilized. Bleed-off water can be treated and recovered using membrane filtration systems or ion exchange resins. The recovery of bleed-off wastewater is important for water efficiency.

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

Cooling Systems (Chiller)

Using Corrosion and Scale Inhibitors to Increase Cycles 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). More than 95% of the circulated water in these systems can be recovered (TUBİTAK MAM, 2016). Due to the operation of cooling systems based on the evaporation of a portion of the recirculated water, impurities remain in the recirculation water, leading to increasing concentrations of these impurities with each cycle. Contaminants that can enter the cooling system along with air can cause contamination in recirculated water (TUBİTAK MAM, 2016). If impurities and pollutants are not effectively controlled, they can lead to scale formation (fouling), corrosion, undesirable biological growth, and sludge accumulation. This situation can become a chronic problem, decreasing the efficiency of heat transfer surfaces and increasing operating costs. Therefore, it is essential to implement a water conditioning program designed specifically for the quality of the makeup water supplied to the cooling system, the materials used in the cooling water system, and the operating conditions. This may involve blowdown 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 an effective cleaning procedure and program that is applied periodically is a good management practice for protecting cooling systems.

Corrosion is one of the most significant problems in cooling systems. As the hardness level increases in the tower recirculation water, dissolved solids (such as sulfates, chlorides, and carbonates) that cause scale and deposits on the walls will lead to abrasion of the surfaces over time. Moreover, the formation of deposits adversely affects heat transfer, reducing energy efficiency. To prevent these adverse effects, a chemical conditioning program that includes scale and corrosion inhibitors should be implemented, alongside the use of biocides for biological deactivation and disinfection. Cooling towers in use should be subjected to chemical and mechanical cleaning at least twice a year to remove deposits, and the hardness and conductivity levels of the makeup water should be maintained as low as possible (IPPC BREF, 2001; Kayabek et al., 2005). To improve the quality of makeup water, suitable treatment systems should be used for conditioning. Additionally, it is necessary to control unwanted microbial growth (IPPC BREF, 2001b; TOB, 2021). Due to micro-contaminants and deposits in the cooling water, blowdown occurs in cooling systems similar to that in steam boilers. To balance the increasing concentration of solids in the cooling system, intentional drainage of the cooling system is referred to as cooling blowdown. Appropriate pre-treatment of cooling waters using suitable methods and continuous monitoring of cooling water quality can reduce the usage of biocides and blowdown amounts (TUBİTAK MAM, 2016). The investment cost depends on the scale of the implementation, but the expected payback period for investment expenses ranges from 3 to 4 years (IPPC BREF, 2001).

Installing Water Softening Systems for Effective Operation of Cooling Water Recovery Systems

Cooling waters are collected separately for use in cooling or for recycling in appropriate processes (EC, 2009). A water softening system is required for the effective operation of this system. Cooling water has suitable quality for reuse as cleaning and irrigation water. However, because it contains some hardness when used as cooling water, additional softening is necessary to prevent potential corrosion problems over time. Before the cooling water or process water is reused, it must undergo appropriate disinfection. Additionally, these waters can be treated using suitable purification techniques (such as membrane filtration, advanced oxidation, chemical precipitation, granular activated carbon adsorption, etc.) to enable reuse not only in cooling processes but also in all production processes (TUBİTAK MAM, 2016). As the hardness level of cooling water increases, scale and deposits form on surfaces. The formation of deposits adversely affects heat transfer, reducing energy efficiency and increasing energy costs. Increased evaporation in the system leads to higher ion concentrations and conductivity values in the water. To mitigate these adverse effects, chemical conditioning with scale and corrosion inhibitors should be applied to the cooling water, disinfection with a biocide that prevents biological activation should be performed, and cooling towers should be subjected to chemical and mechanical cleaning at least twice a year to remove deposits. It is essential to maintain hardness and conductivity values at the lowest possible levels (TUBİTAK MAM, 2016).

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