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MINISTRY OF AGRICULTURE AND FORESTRY
GENERAL DIRECTORATE OF WATER MANAGEMENT

Water Efficiency Campaign

Water Efficiency Guidelines Series

FORGING, PRESSING, STAMPING AND ROLLING OF METALS; POWDER METALLURGY;

NACE CODE : 25.50

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

Table of Contents

Abbreviations

WWTP	Wastewater Treatment Plant
EU	European Union
SSM	Suspended Solids
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 Control Program Directive
EPA	United States Environmental Protection Agency
IPPC	Industrial Pollution Prevention and Control
ISO	International Standards Organization
BAT	Best Available Techniques
NACE	Statistical Classification of Economic Activities
GSWM	General Directorate of Water Management
RO	Reverse Osmosis
MAF	Republic of Turkey Ministry of Agriculture and Forestry
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, an area heavily impacted by global climate change, and it is considered among the regions that will be most affected by the adverse impacts of climate change. Projections regarding how the water resources in our basins may be influenced by climate change in the future suggest that our water resources could decrease by as much as 25% within the next century.

In 2022, the available annual water supply per capita in our country was 1,313 cubic meters, and due to human pressures and climate change impacts, it is expected that this amount will fall below 1,000 cubic meters per capita after 2030. Without necessary measures, Turkey will likely become a water-stressed country in the near future, bringing many social and economic challenges. As evidenced by future projections, the risks of drought and water scarcity facing our country make it essential to use existing water resources efficiently and sustainably.

Water efficiency can be defined as “using the minimum amount of water necessary in the production of a product or service.” The water efficiency approach emphasizes the rational, equitable, and effective use of water across all sectors—including drinking water, agriculture, industry, and households—while also considering the needs of the entire ecosystem.

As demand for water resources grows, changing precipitation and temperature patterns due to climate change, increasing population, urbanization, and pollution have made the equitable distribution of available water resources among users more crucial with each passing day. Therefore, it has become imperative to create a roadmap based on efficiency and optimization to ensure the conservation and sustainable management of limited water resources.

The United Nations Sustainable Development Goals, specifically Goal 7: Ensuring Environmental Sustainability under the Millennium Development Goals, and Goal 9: Industry, Innovation, and Infrastructure, along with Goal 12: Responsible Production and Consumption, emphasize the efficient, equitable, and sustainable use of resources, especially water, as well as environmentally friendly production and consumption practices that consider future generations.

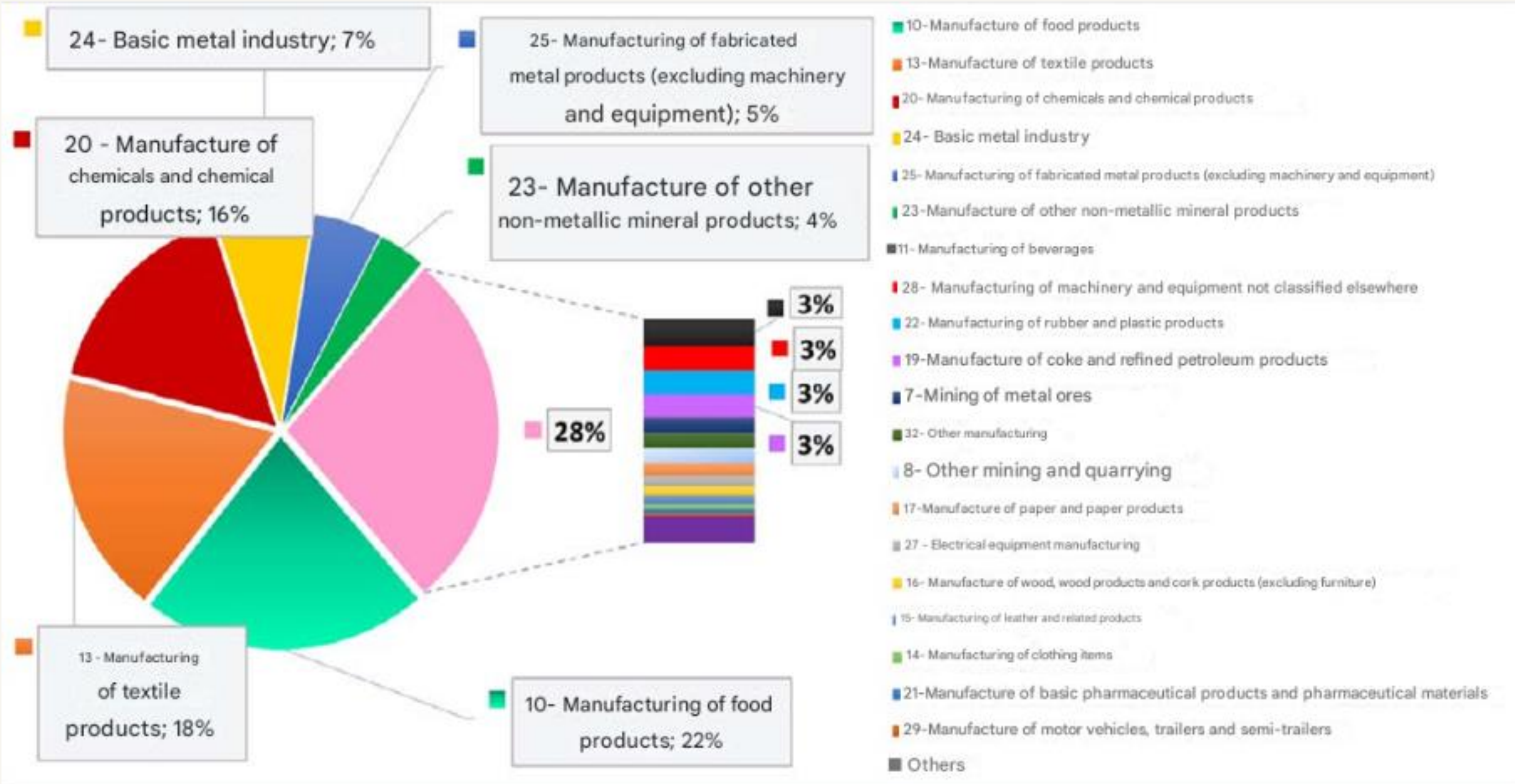
With a goal of achieving a carbon-neutral, circular economy, the European Green Deal, on which member states have agreed, aims to promote resource efficiency and reduce environmental impacts. In line with the European Green Deal Action Plan prepared by our country, various actions have been identified, especially in industry, to emphasize water and resource efficiency in production and consumption.

The European Union's environmental legislation, notably the "Industrial Emissions Directive (IED)," includes measures for the integrated control, prevention, or reduction of discharges/emissions from industrial activities to air, water, and soil. To systematize the applicability of clean production processes and eliminate practical challenges, the directive includes Best Available Techniques (BAT). BAT represents the most effective technical practices for high-level environmental protection when considering costs and benefits. Under the directive, detailed Reference Documents (BAT-BREF) outlining BAT for each sector have been prepared. These BREF documents present BAT within a general framework that includes best management practices, general preventive measures, chemical usage and management, techniques for various production processes, wastewater management, emissions management, and waste management.

The Ministry of Agriculture and Forestry's General Directorate of Water Management has undertaken efforts to promote efficient water practices in urban, agricultural, industrial, and individual water use and to increase public awareness. Within the scope of the "Water Efficiency Strategy Document and Action Plan (2023-2033)," enacted by Presidential Decree No. 2023/9, water efficiency action plans addressing all sectors and stakeholders have been prepared. In the Industrial Water Efficiency Action Plan for the 2023-2033 period, a total of 12 actions were identified, and responsible and relevant institutions for these actions were assigned. The action plan tasks the General Directorate of Water Management with determining specific water usage ranges and quality requirements for various industrial sub-sectors, organizing sector-based technical training programs and workshops, and preparing water efficiency guidance documents.

Additionally, the "Industrial Water Use Efficiency Project by NACE Codes," conducted by the Ministry of Agriculture and Forestry's General Directorate of Water Management, aims to improve water efficiency in industry. As part of this project, sector-specific best practices for water efficiency tailored to our country have been identified. Based on this study, sector-specific guide documents and action plans categorized by NACE codes have been prepared, outlining recommended measures to improve water efficiency in high-water-consuming sectors operating in our country.

As globally and in our country, the food, textile, chemical, and primary metal sectors account for the highest water consumption. As part of the project, field visits were conducted to facilities representing 152 sub-sectors in 35 main sectors—including food, textile, chemical, and primary metal industries—characterized by different capacities and types of production. Data on water supply, sectoral water uses, wastewater generation, and recovery were collected, and information on water efficiency, clean production, water footprint, and other related topics was provided in line with the Best Available Techniques (BAT) and sectoral reference documents (BREF) published by the European Union.



Water Efficiency Guidance Document

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

As a result of this project, specific water consumption values and potential savings rates were identified for 152 distinct four-digit NACE codes covering high-water-consumption facilities. Water efficiency guidance documents were prepared, taking into account the EU's best available techniques (BAT) and other clean production techniques. The 500 technical BAT measures in the guides are classified into four main groups: (i) Good Management Practices, (ii) General Preventive Measures, (iii) Auxiliary Process-Related Measures, and (iv) Sector-Specific Measures.

In determining the BAT for each sector, the environmental benefits, operational data, technical specifications, and feasibility criteria were considered. The selection process incorporated a broad range of global data, case studies, innovative practices, and reports from industry stakeholders beyond just BREF documents, creating sectoral BAT lists. To assess the suitability of the BAT lists for our country's industrial infrastructure and capacity, the specific BAT lists for each NACE code were rated by businesses based on water savings, economic benefits, environmental impact, feasibility, and cross-media effects, thereby establishing prioritized final BAT lists. The sectoral water efficiency guides were then prepared based on these final BAT lists and the water and wastewater data from visited facilities, along with local dynamics specific to our country as highlighted by sectoral stakeholders.

2 Scope of the Study

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

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

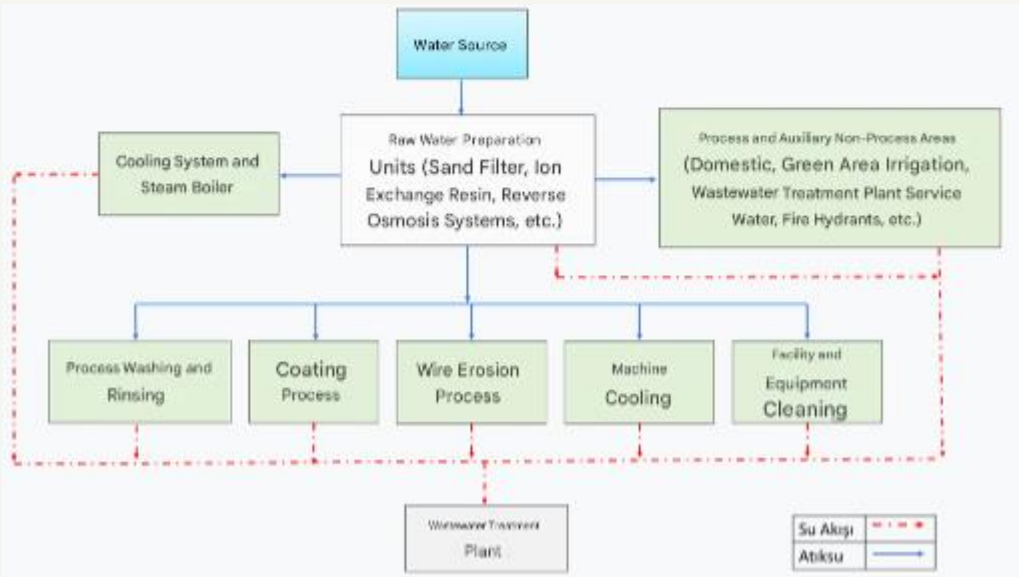
- Manufacture of other transport equipment (2 sub-production areas represented by four-digit NACE codes),
- Other manufacturing (2 sub-production areas represented by four-digit NACE codes),
- Installation and repair of machinery and equipment (2 sub-production areas represented by four-digit NACE codes),
- Electricity, gas, steam, and air conditioning supply (2 sub-production areas represented by four-digit NACE codes),
- Collection, treatment, and disposal of waste; recovery of materials (1 sub-production area represented by four-digit NACE codes),
- Construction of buildings (1 sub-production area represented by four-digit NACE codes),
- Warehousing and support activities for transportation (1 sub-production area represented by four-digit NACE codes),
- Accommodation (1 sub-production area represented by four-digit NACE codes),
- Educational activities (university campuses) (1 sub-production area represented by four-digit NACE codes),
- Sports activities, entertainment, and recreation activities (1 sub-production area represented by four-digit NACE codes).

"Basic metal industry" and "Manufacture of fabricated metal products (excluding machinery and equipment)"

The following sub-production branches have water efficiency guidance documents prepared under the "basic metal industry" and "manufacture of fabricated metal products (excluding machinery and equipment)" sectors:

24.10	Manufacture of basic iron and steel products and ferroalloys
24.20	Manufacture of tubes, pipes, hollow profiles and similar fittings of steel
24.31	Cold drawing of bars
24.32	Cold rolling of narrow strips
24.34	Cold drawing of wire
24.41	Production of precious metals
24.42	Production of aluminium
24.51	Cast iron
24.52	Casting of steel
24.53	Casting of light metals
24.54	Casting of other non-ferrous metals
25.12	Manufacture of doors and windows of metal
25.21	Manufacture of central heating radiators (excluding electric radiators) and hot water boilers (boilers)
25.30	Manufacture of steam generators, except central heating hot water boilers (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	Hand tools, machine tool bits, saw blades, etc. Manufacturing
25.92	Manufacture of light metal packaging materials
25.93	Manufacture of wire products, chains and springs
25.94	Manufacture of fastening materials and screw machine products
25.99	Manufacture of other fabricated metal products not elsewhere classified

2.1 Forging, Pressing, Stamping, and Rolling of Metals; Powder Metallurgy (NACE 25.50)



	Minimum	Maximum
Specific Water Consumption of Facilities Visited within the Scope of the Project (L/kg product)	0.04	0.12
Reference Specific Water Consumption (L/kg product)	6	42

Percentage Distribution of Water Efficiency Practices

The metal forging, pressing, stamping, and rolling; powder metallurgy sector encompasses various metal processing methods. Metals are converted into products using methods such as plastic forming, machining, casting, welding, and powder metallurgy. Plastic forming is applied to metals with a certain ductility in a solid state. This manufacturing method involves the application of loads large enough to cause stresses beyond the yield strength, resulting in permanent changes to the metal's shape. Types include forging, rolling, extrusion, drawing, bending, cutting, and deep drawing. Machining is the processing of metals by removing chips with cutting tools and includes turning, drilling, milling, and grinding. Welding is the joining of two or more separately produced metal pieces using heat and pressure. Types of welding include electric arc welding, spot welding, laser welding, and plasma welding. Powder metallurgy, also known as sintering, involves compressing metal powders produced in minimal amounts under high pressure and subjecting them to heat treatment at high temperatures. After reaching the final shape, surface processing is performed on metal parts to smooth, paint, or coat them.

In the metal forging, pressing, stamping, and rolling; powder metallurgy sector, water is used in coating, wire erosion, machine cooling, washing, and rinsing processes. Notable amounts of water consumption occur in raw water preparation units, such as sand filters, ion exchange resins, and reverse osmosis systems, used to produce soft water for production processes and for filter washing, resin regeneration, and membrane cleaning. Additionally, water is consumed in auxiliary processes such as steam boilers and cooling systems.

In this sector, the reference specific water consumption ranges from 6 to 42 L/kg, while the specific water consumption of the analyzed production line is between 0.04 and 0.12 L/kg. Implementing sector-specific techniques, good management practices, general preventive measures, and auxiliary process measures can achieve a water recovery rate of 39–71% in the sector.

The table below presents prioritized water efficiency techniques for the NACE code 25.50 for forging, pressing, stamping, and rolling of metals; powder metallurgy.

NACE Code	NACE Code Description		Prioritized Sectoral Water Efficiency Techniques
25.50	Forging, pressing, stamping, and rolling of metals; powder metallurgy		**Sector-Specific Measures**
		1.	Reducing carryover of rinse waters in baths by operating at the lowest possible concentration and raising bath temperatures to lower solution viscosity, thereby reducing carryover on materials
		2.	Installing sloped drainage plates between tanks to return solutions to the tanks, minimizing carryover of rinse waters
		3.	Removing materials from tanks at low speed to minimize carryover of rinse waters
			Good Management Practices
		1.	Use of integrated wastewater management and treatment strategies to reduce wastewater quantity and pollutant load.
		2.	Establishing an environmental management system
		3.	Developing water flow diagrams and water balance reports.
		4.	Preparing a water efficiency action plan to reduce water use and prevent water pollution.
		5.	Providing technical training for staff to reduce and optimize water use.
		6.	Setting water efficiency targets.
		7.	Monitoring the quantity and quality of water used and wastewater generated in production and auxiliary processes, and integrating this information into the environmental management system.
			General Preventive Measures
		1.	Minimizing spills and leaks.
		2.	Using automated equipment (sensors, smart handwashing systems, etc.) to save water at points like showers and toilets.
		3.	Using high-pressure washing systems for equipment cleaning and general cleaning processes.
		4.	Detecting and reducing water losses.
		5.	Using automatic control and shut-off valves to optimize water use.

NACE Code	NACE Code Description		Prioritized Sectoral Water Efficiency Techniques
25.50	Forging, pressing, stamping, and rolling of metals; powder metallurgy	6.	Documenting production procedures to prevent waste of water and energy and ensuring their use by employees.
		7.	Preventing the transport of toxic or hazardous chemicals to aquatic environments by using closed storage and impermeable waste/scrap areas.
		8.	Preventing substances that pose a risk to aquatic environments (such as oils, emulsions, binders) from contaminating wastewater.
		9.	Preventing the mixing of clean and dirty water streams.
		10.	Using closed-loop water cycles in appropriate processes.
		11.	Collecting gray water separately, treating it, and using it in areas where high water quality is not required (e.g., irrigation of green areas, floor cleaning).
		12.	Implementing time optimization in production and arranging all processes to be completed as quickly as possible.
		13.	Using rainwater as an alternative water source for facility cleaning or suitable areas.
		14.	Using compatible chemicals in consecutive processes to prevent the need for rinsing between activities.
			Auxiliary Process Measures
		1.	Identifying processes that require wet cooling and avoiding unnecessary cooling operations.
		2.	Using corrosion and scale inhibitors in closed-loop systems to increase the number of cycles.
			A total of 26 techniques have been recommended for this sector.

Specific Measures for NACE Code for Forging, Pressing, Stamping, and Rolling of Metals; Powder Metallurgy;

(i) Sector-Specific Measures,
(ii) Good Management Practices,
(iii) General Preventive Measures,
(iv) Auxiliary Process Measures are provided under separate headings.

2.1.1 Sector-Specific Measures

- ***Reducing Carryover of Rinse Waters by Removing Materials Slowly from Tank***
  Removing materials slowly from tanks ensures that chemicals and rinse water drip back into the tanks, preventing unwanted carryover outside the tank (ÇŞİDB, 2013).

- ***Minimizing Carryover of Rinse Waters by Using Sloped Drainage Plates Between Tanks***
  Using sloped drainage plates between non-consecutive tanks can allow solutions and rinse waters to flow back into the tank (ÇŞİDB, 2013).

- ***Reducing Carryover of Rinse Waters by Operating Baths at the Lowest Concentration and Raising Bath Temperatures to Lower Solution Viscosity***
  To reduce solution viscosity, especially fresh solutions should be kept at the lowest concentration levels, which can be increased over time as needed to reduce solution carryover on materials (ÇŞİDB, 2013).

https://www.lightmetalage.com/wp-content/uploads/2020/01/Pries-NEWFigure2-989x1024.jpg

Metal Ürünleri İmalatı Durulama Banyoları

2.1.2 Good Management Practices

- ***Establishing an Environmental Management System***

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

The most widely used Environmental Management Standard is ISO 14001. Among its alternatives is the Eco-Management and Audit Scheme Directive (EMAS) (761/2001). It is designed for evaluating, improving, and reporting businesses' environmental performance. As one of the leading applications within the EU legislation for eco-efficiency (clean production), participation is voluntary (TUBITAK MAM, 2016; TOB, 2021). Benefits of establishing and implementing an Environmental Management System include:

- Improved business performance, resulting in economic benefits (Christopher, 1998).
- Adoption of International Organization for Standardization (ISO) standards promotes greater alignment with global legal and regulatory requirements (Christopher, 1998).
- Reducing risks associated with environmental liabilities and achieving reductions in waste, resource consumption, and operational costs (Delmas, 2009).
- The use of internationally recognized environmental standards eliminates the need for multiple registrations and certifications for businesses operating in multiple locations worldwide (Hutchens Jr., 2017).
- In recent years, the enhancement of companies' internal control processes has also become valued by consumers. Implementing environmental management systems provides a competitive advantage over companies that do not adopt these standards and contributes to better positioning in international markets (Potoski & Prakash, 2005).

The benefits listed above depend on various factors, such as production processes, management practices, resource utilization, and potential environmental impacts (TOB, 2021). Practices like preparing annual inventory reports with content similar to the environmental management system and monitoring the quantity and quality of inputs and outputs in production processes can achieve water savings of 3-5% (Öztürk, 2014). The entire development and implementation phase of an EMS is estimated to take approximately 8-12 months (ISO 14001 User Manual, 2015).

Industrial establishments also work within the ISO 14046 Water Footprint Standard, an international standard defining the requirements and guidelines for assessing and reporting on water footprints. The implementation of this standard aims to reduce the freshwater use and environmental impacts required for production. Additionally, the ISO 46001 Water Efficiency Management Systems Standard, which helps industrial establishments to improve their water efficiency policies through monitoring, benchmarking, and review efforts, contributes to water savings and reduces operational costs.

- ***Use of integrated wastewater management and treatment strategies to reduce the quantity and pollutant load of wastewater***

  Wastewater management should adopt a holistic approach from wastewater generation to final disposal, encompassing functional elements such as composition, collection, sludge disposal, treatment, and reuse. The selection of appropriate treatment technologies for industrial wastewater depends on integrated factors such as land availability, the desired quality of treated water, and compliance with national and local regulations (Abbassi & Al Baz, 2008).

  Reusing treated wastewater within the facility not only improves the quality of water bodies but also reduces demand for freshwater. Therefore, selecting appropriate treatment strategies for various reuse purposes is essential.

  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). For industrial wastewater recovery, methods such as SWOT analysis (strengths, weaknesses, opportunities, and threats), PESTEL analysis (political, economic, social, technological, environmental, and legal factors), and decision trees are combined with expert opinions to establish an integrated wastewater management framework (Naghedi et al., 2020). Techniques like the Analytic Hierarchy Process (AHP) and the Combined Compromise Solution (CoCoSo) are used to prioritize criteria based on multiple factors for industrial wastewater management processes (Adar et al., 2021). Implementing integrated wastewater management strategies can lead to an average reduction of up to 25% in water consumption, wastewater quantity, and pollutant loads in wastewater. The potential payback period for these implementations 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 Warewater Treatment Plant

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

  This measure enhances training and awareness among personnel to promote water savings and recovery, thus reducing water consumption and costs while achieving water efficiency. Due to insufficient technical knowledge among staff in industrial facilities, issues related to high water usage and wastewater generation may arise. For instance, it is crucial for cooling tower operators—who play a significant role in water consumption in industrial operations—to be appropriately trained and technically proficient. Staff involved in setting water quality requirements, measuring water and wastewater quantities, and similar applications also need adequate technical knowledge (TOB, 2021). Therefore, it is essential to provide training on water reduction, optimization, and conservation policies. Including personnel in water-saving efforts, preparing regular reports on water usage before and after water efficiency initiatives, and sharing these reports with staff support participation and motivation in the process. The technical, economic, and environmental benefits gained through personnel training manifest in the medium to long term (TUBITAK MAM, 2016; TOB, 2021).

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

  Industrial facilities rely on resources, and inefficiencies and environmental problems arising from resource use are linked to input-output flows. Therefore, it is necessary to monitor the quantity and quality of water used and wastewater generated in production and auxiliary processes (TUBITAK MAM, 2016; TOB, 2021). Process-based monitoring of quantity and quality, along with other good management practices (staff training, establishment of an environmental management system, etc.), can reduce energy consumption by 6-10% and water and wastewater volumes by up to 25% (Öztürk, 2014).

  The main stages for monitoring the quantity and quality of water and wastewater include:
  - Use of monitoring equipment (such as meters) to track water, energy, etc., consumption on a process basis,
  - Development of monitoring procedures,
  - Identification of the usage/discharge points for all inputs and outputs (raw materials, chemicals, water, product, wastewater, sludge, solid waste, hazardous waste, and by-products) in terms of quantity and quality, documentation, comparative evaluation, and reporting,
  - Monitoring raw material losses in production processes where raw materials are converted into products and taking measures against such losses (ÇŞİDB, 2020e).

- ***Preparing a water efficiency action plan to reduce water and wastewater volumes and prevent water pollution***

  Preparing an action plan, outlining short-, medium-, and long-term measures to reduce water-wastewater volumes and prevent water pollution, is important for water efficiency in industrial facilities. At this point, water needs across the facility and in production processes, water quality requirements at points of use, wastewater generation points, and wastewater characterization should be determined (TOB, 2021). Additionally, measures to reduce water consumption, wastewater generation, and pollutant loads should be identified, feasibility studies conducted, and action plans prepared for the short, medium, and long term. This approach ensures water efficiency and sustainable water use in facilities (TOB, 2021).

- ***Setting water efficiency targets***

  The first step in achieving water efficiency in industrial facilities is setting targets (TOB, 2021). This requires a detailed water efficiency analysis on a process basis, identifying unnecessary water usage, water losses, practices impacting water efficiency, process losses, and reusable water-wastewater sources, treated or untreated. Determining water savings potential and water efficiency targets for each production process and facility is essential (TOB, 2021).

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

  Identifying water usage and wastewater generation points in industrial facilities, and establishing water-wastewater balances in both production processes and auxiliary processes, form the foundation of many good management practices. Developing process profiles across the facility and for specific production processes helps to identify unnecessary water use points and high water use points, assess water recovery opportunities, facilitate process modifications, and identify water losses (TOB, 2021).

2.1.3 General Measures

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

Water losses occur in equipment, pumps, and pipelines used in industrial production processes. Initially, water losses should be identified, and regular maintenance of equipment, pumps, and pipelines should be conducted to prevent leaks and ensure they are kept in good condition (IPPC BREF, 2003). Regular maintenance procedures should emphasize:

  - Adding pumps, valves, level switches, and pressure and flow regulators to the maintenance checklist,
  - Inspecting not only water systems but also heat transfer and chemical distribution systems for broken or leaking pipes, barrels, pumps, and valves,
  - Cleaning filters and pipelines regularly,
  - Calibrating and routinely monitoring measurement equipment such as chemical measurement and distribution devices, thermometers, etc., at designated intervals (IPPC BREF, 2003).

Effective maintenance, repair, cleaning, and loss control practices can reduce water consumption by 1-6% (Ozturk, 2014).

- ***Minimizing Spills and Leaks***

Spills and leaks in facilities can result in both raw material and water losses. Additionally, if wet cleaning methods are used to clean areas where spills have occurred, water consumption, wastewater volume, and pollutant loads in wastewater may increase (TOB, 2021). To reduce raw material and product losses, spill and splash losses are minimized by using splash guards, baffles, drip trays, and sieves (IPPC BREF, 2019).

- ***Preventing the Mixing of Clean and Contaminated Water Streams***

By identifying wastewater generation points and characterizing wastewater in industrial facilities, wastewater with high pollutant loads can be collected separately from relatively clean wastewater streams (TUBITAK MAM, 2016; TOB, 2021). This allows wastewater of suitable quality to be treated or reused directly. Separating wastewater streams reduces water pollution, enhances treatment performance, reduces treatment needs and energy consumption, and facilitates wastewater and valuable material recovery, thus reducing emissions. Additionally, heat recovery from separate hot wastewater streams is also possible (TUBITAK MAM, 2016; TOB, 2021). While separating wastewater streams may require high investment costs, significant savings can be achieved if large amounts of wastewater and energy can be recovered (IPPC BREF, 2006).

- ***Using Pressure Washing Systems for Equipment Cleaning and General Cleaning***

  Water nozzles are widely used in facility cleaning. Effective results can be achieved in reducing water consumption and wastewater pollution loads by using appropriately placed, suitable nozzles. Using active sensors and nozzles in areas with high water consumption can greatly enhance efficient water use. Mechanical equipment can be replaced with pressure nozzles to achieve substantial water savings (TUBITAK MAM, 2016). Optimizing water pressure in suitable processes can provide environmental benefits by reducing water consumption, wastewater generation, and pollution loads in wastewater.

- ***Using Automatic Control and Shutoff Valves to Optimize Water Use***

  Monitoring and controlling water consumption using flow control devices, meters, and computer-assisted monitoring systems provide significant technical, environmental, and economic advantages (Ozturk, 2014). Monitoring water consumption in the facility and specific processes prevents water losses (TUBITAK MAM, 2016). Flow meters and meters should be installed facility-wide and in production processes, with automatic shutoff valves in continuous machines, and monitoring and control mechanisms should be developed using computer-assisted systems based on certain quality parameters (TUBITAK MAM, 2016). This application can provide savings of up to 20-30% in process water consumption (DEPA, 2002; LCPC, 2010; IPPC BREF, 2003), and a 3-5% reduction in process water consumption is achievable through monitoring and control of process-specific water consumption (Ozturk, 2014).

- ***Implementing Automatic Water-Saving Devices at Water Use Points like Showers and Toilets***

  Water is critical in many sectors of manufacturing for both production processes and maintaining required hygiene standards for employees. In addition to various means of water use in production processes, installing sensor-activated faucets and smart handwashing systems in employee water use areas can reduce water consumption. Smart handwashing systems adjust the mix of water, soap, and air in optimal ratios, providing both water savings and resource efficiency.

- ***Separate Collection and Treatment of Greywater in the Facility for Use in Non-High-Quality Applications (Irrigating Green Spaces, Floor Cleaning, etc.)***

  Wastewater generated in industrial facilities includes not only industrial wastewater from production processes but also wastewater from showers, sinks, kitchens, etc. Wastewater from showers, sinks, and kitchens is considered greywater. Treating this greywater through various treatment processes and using it in areas where high water quality is not required can contribute to water savings.

- ***Collecting Rainwater for Facility Cleaning or as an Alternative Water Source in Suitable Areas Imesi***

  With declining water resources, rainwater harvesting is becoming increasingly popular, especially in areas with low rainfall. Various technologies and systems are available for rainwater collection and distribution, such as cistern systems, infiltration, surface collection, and filtration systems. Rainwater collected with specialized drainage systems can be used for production processes, garden irrigation, tank and equipment cleaning, surface cleaning, etc., provided it meets quality requirements (Tanik et al., 2015). In some examples, industrial facilities have achieved up to 50% water savings by using stored rooftop rainwater for landscape irrigation within the building and landscape areas (Yaman, 2009). Permeable stones and green spaces can be used to enhance ground infiltration, allowing rainwater to be absorbed into the soil. Collected rainwater can also be used for car washing and garden irrigation, and after biological treatment, it can be reclaimed for reuse at a rate of 95% (Sahin, 2010).

- ***Utilizing Closed-Loop Water Circulation in Appropriate Processes***

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

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

  Reusing cooling water in processes such as cleaning reduces water consumption and wastewater generation, though energy is required to cool and recirculate the water.

  Heat recovery is also achievable in cooling systems using heat exchangers. Closed-loop systems are generally used in facilities with water-based cooling systems, although cooling system blowdown is discharged directly into the wastewater treatment facility channel for removal.

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- ***Preventing Risky Substances (Oils, Emulsions, Binders) for Aquatic Environments from Mixing into Wastewater***

  Dry cleaning techniques can prevent the mixing of chemicals that pose a risk to aquatic environments, such as oils, emulsions, and binders, into wastewater streams. By doing so, water resources can be protected (TUBITAK MAM, 2016).

- ***Construction of Enclosed Storage and Impermeable Waste/Scrap Areas to Prevent the Transport of Toxic or Hazardous Chemicals to Aquatic Environments***

  Closed and impermeable storage areas for waste or scrap can be constructed in industrial facilities to prevent the transport of toxic or hazardous chemicals to receiving environments. This practice is already implemented under existing environmental regulations in our country. Within the scope of ongoing field studies, separate collection channels can be established in industrial facilities for areas where toxic or hazardous substances are stored, ensuring that leakage water is collected separately and does not mix with natural water bodies.

- ***Using Compatible Chemicals in Sequential Processes to Eliminate the Need for Rinsing Between Activities***

  Chemical compatibility is a measure of how stable a substance is when mixed with another substance. If two substances react chemically when mixed, they are considered incompatible.

  Various chemicals are used in industrial facilities to enhance washing and rinsing efficiency. If these chemicals are compatible and act as solvents, they positively contribute to increased efficiency. Consequently, contaminants on the material can be removed more quickly and effectively, significantly reducing the amount of water used in washing processes. Although this may result in reduced wastewater volumes, the chemical loads in wastewater may increase. Reusing the washing water that contains solvents used in washing and rinsing processes helps to minimize these adverse effects.

  Reusing washing water can save approximately 25-50% of water. Reserved tanks and new pipelines may be needed for implementation. In alternative cases, the washing solution is retained directly within the system and can be used multiple times until it loses its effectiveness.

- ***Maintaining Documented Production Procedures and Ensuring Employee Adherence to Prevent Water and Energy Waste***

  Effective procedures should be implemented in an enterprise to identify, assess, and control potential problems and resources, thereby enabling efficient production (Ayan, 2010). Determining and applying appropriate procedures in production processes ensures the efficient use of resources (such as raw materials, water, energy, chemicals, personnel, and time) and secures reliability and quality in production processes (Ayan, 2010). The presence of documented production procedures in production processes contributes to the assessment of enterprise performance and the development of rapid reflexes to solve problems (TÜBİTAK MAM, 2016; TOB, 2021). The effective implementation and monitoring of procedures established specifically for production processes is one of the most effective ways to secure product quality, receive feedback, and develop solution proposals (Ayan, 2010). Documenting, effectively implementing, and monitoring production procedures is a good management practice and a powerful tool for structuring and maintaining a clean production approach and an environmental management system. In addition to potential benefits, costs and economic gains of the practice may vary depending on the sector or facility structure (TÜBİTAK MAM, 2016; TOB, 2021). Although establishing and monitoring production procedures are not costly, considering the savings and benefits, the payback period can be short (TÜBİTAK MAM, 2016; TOB, 2021)

- ***Applying Time Optimization in Production to Arrange All Processes to Complete in the Shortest Time***

  Planning the transformation of raw materials into products using minimal processes in industrial production processes is an effective application to reduce labor costs, resource utilization costs, environmental impacts, and increase efficiency. In this context, it may be necessary to revise production processes by reconsidering them to use the fewest possible process steps (TÜBİTAK MAM, 2016). In cases where desired product quality cannot be achieved due to inefficiencies or design flaws in basic production processes, production processes may need to be renewed. In such cases, the resources required for producing a unit amount of product, as well as the resulting waste, emissions, and solid waste, increase. Time optimization in production processes is an effective practice (TÜBİTAK MAM, 2016).

2.1.4 Measures Related to Auxiliary Processes

Best Environmental Practices (BEPs) for Cooling Systems

- ***Using Corrosion and Scale Preventive Inhibitors in Closed-Loop Water Systems to Increase the Number of Cycles***

Cooling towers and evaporative condensers, commonly used in air conditioning and industrial process cooling systems, are effective and low-cost systems that dissipate heat (IPPC BREF, 2001b; TOB, 2021). Over 95% of the circulated water in these systems can be recovered (TÜBİTAK MAM, 2016). In such systems, as a portion of the recirculated water evaporates, impurities remain in the recirculated water, and impurity concentrations increase with each cycle. Impurities introduced through air can cause contamination in recirculation waters (TÜBİTAK MAM, 2016). If impurities and pollutants are not effectively controlled, they can cause scaling and corrosion, undesirable biological growth, and sludge buildup, which may lead to chronic issues that reduce heat transfer efficiency and increase operating costs. In such cases, a water conditioning program specifically designed for the feed water quality, cooling water system material, and operating conditions is required. In this context, appropriate practices may include blowdown control, control of biological growth, corrosion control, avoidance of hard water use, use of sludge control chemicals, filtration, and screening systems (TÜBİTAK MAM, 2016). Additionally, establishing and periodically implementing an effective cleaning procedure and program is a good management practice for maintaining cooling systems. Corrosion is one of the most significant problems in cooling systems. As the hardness in the recirculating water of the cooling tower increases, dissolved solids (such as sulfate, chloride, carbonate) cause scale and deposits that lead to corrosion, causing surface degradation over time. Furthermore, deposit formation negatively affects heat transfer, reducing energy efficiency. To prevent these issues, a conditioning program with scale and corrosion inhibitors and disinfection with biocides that inhibit biological activity should be implemented, and cooling towers in use should undergo chemical and mechanical cleaning at least twice a year to remove deposits. The hardness and conductivity of the makeup water should be kept as low as possible (IPPC BREF, 2001; Kayabek et al., 2005). Suitable treatment systems may be required to improve the quality of makeup water. Additionally, unwanted microbial growth should be controlled (IPPC BREF, 2001b; TOB, 2021). Due to micro-residues and sludge in cooling water, blowdown also occurs in cooling systems, as in steam boilers. The controlled drainage of cooling systems to balance the increased concentration of solids in the cooling system is referred to as cooling blowdown. Pre-treatment of cooling water using appropriate methods and continuous monitoring of cooling water quality can reduce the use of biocides and blowdown volumes (TÜBİTAK MAM, 2016). Although the investment cost depends on the scale of the application, the expected payback period for investment expenses varies between 3 to 4 years (IPPC BREF, 2001).

- ***Avoiding Unnecessary Cooling by Identifying Processes That Require Wet Cooling***

  The boundaries of a facility site may influence design parameters, such as the height of the cooling tower. In cases where it is necessary to reduce tower height, a hybrid cooling system may be applied. Hybrid cooling systems combine evaporative and non-evaporative (wet and dry) cooling systems. A hybrid cooling tower can be operated as a fully wet cooling tower or as a combined wet/dry cooling tower, depending on ambient temperature (TÜBİTAK MAM, 2016). In regions where sufficient cooling water is not available or where water costs are high, evaluating dry cooling systems or hybrid cooling systems to reduce the amount of cooling makeup water can be an effective solution (TÜBİTAK MAM, 2016).

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