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MINISTRY OF AGRICULTURE AND FORESTRY GENERAL
DIRECTORATE OF WATER MANAGEMENT

Water Efficiency
Campaign

Water Efficiency Guide Document Series

CASTING OF LIGHT METALS

NACE CODE: 24.53

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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.

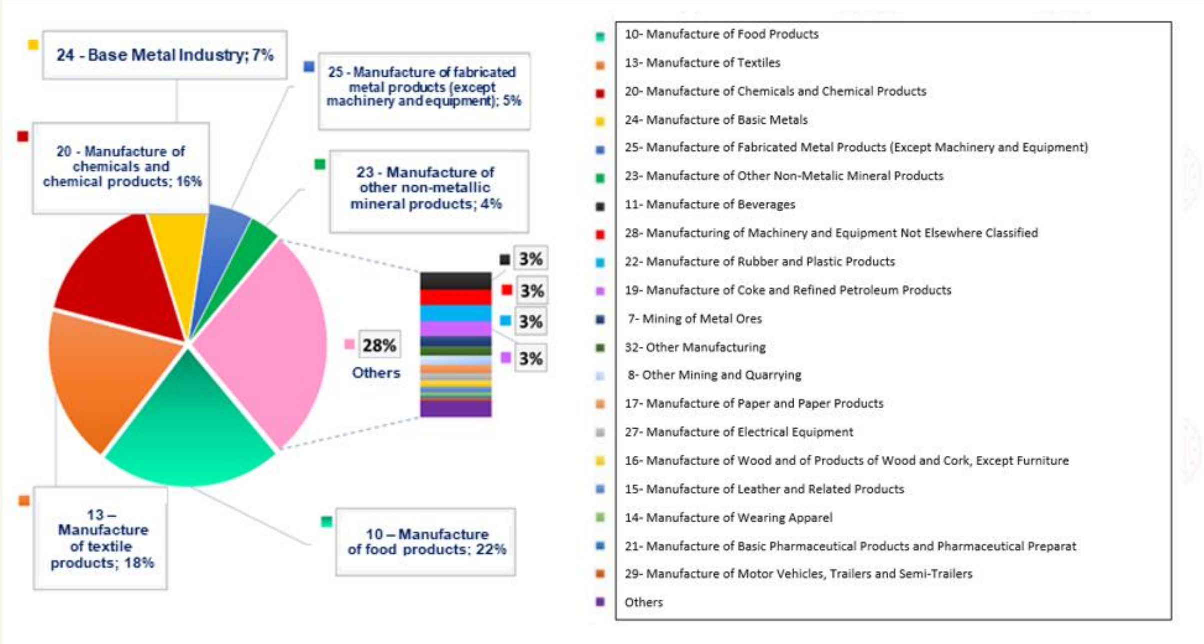
With the target of achieving carbon neutrality, the European Green Deal aims to implement a clean, circular economy model, promoting efficient use of resources and reducing environmental impacts—objectives agreed upon by member countries. In line with this, Turkey's European Green Deal Action Plan outlines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

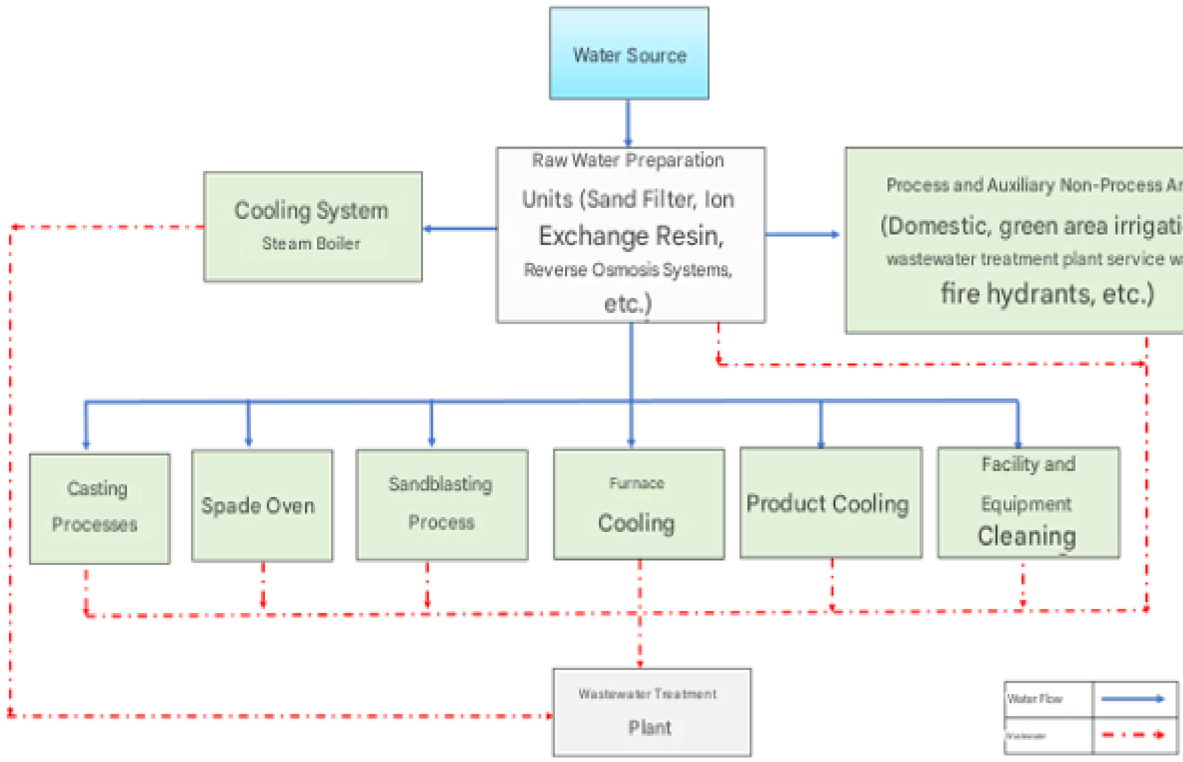
Basic Metal Industry and Manufacture of Fabricated Metal Products (excluding Machinery and Equipment)

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

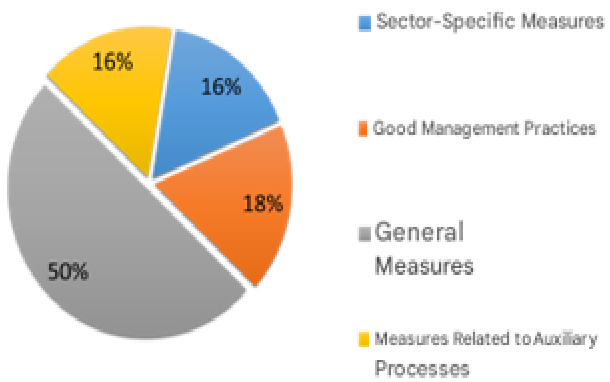
2.1 Casting Of Light Metals (NACE 24.53)

Light Metal Casting Industry Water Flow Diagram



	Minimum	Maximum
Specific Water Consumption of Facilities Visited within the Project Scope (L/unit of product)	2,5	6,8
Reference Specific Water Consumption (L/kg of product)	0,8	1,7

Percentage Distribution of Water Efficiency Practices



The most commonly cast light metal is aluminum. Due to its lightweight and high strength, aluminum is a preferred material in many industries, with the automotive sector being the one where it is used most extensively. The most commonly used methods for producing aluminum cast parts include aluminum gravity die casting, aluminum metal injection casting, and aluminum sand casting. These methods are chosen based on the physiological properties, shape, quality, and production volume of the aluminum part to be produced.

In facilities where light metal casting is performed, all raw materials that directly affect the structure of the product (such as sand preparation, molding, core and melting unit additives) are first procured and taken into the material warehouse. A sand mold containing a runner and feeder system is prepared. If the casting requires internal surfaces, cores are added as well. Sand molds and sand cores need to have high strength, permeability, thermal stability, and low expansion. Sand from broken molds is reused in other molds. The molten light metal (aluminum, magnesium, titanium, zinc, etc.) is poured into the sand mold. Once the metal is cooled and solidified, the molds are broken apart to remove the casting. Surface cleaning is performed to remove sand from the casting surface and improve surface appearance. A heat treatment process is applied to the casting to enhance its metallurgical properties.

Facilities that perform light metal casting may have a paint shop. In such cases, water consumption may occur during painting, rinsing, and chemical preparation processes. In the sector, water is also consumed in raw water preparation units such as ion exchange resin and reverse osmosis, which are used to produce soft water for the production processes, as well as in resin regeneration and membrane cleaning processes. Additionally, water consumption occurs in auxiliary processes such as dust collection systems, furnace cooling, and steam boilers.

The reference specific water consumption in facilities performing light metal casting ranges from 0.8 to 1.7 L/kg. In the production line analyzed within the scope of this study, specific water consumption ranges from 2.5 to 6.8 L/kg. By implementing sector-specific techniques, good management practices, general preventive measures, and measures related to auxiliary processes, it is possible to achieve water savings of 14% to 46% in the sector.

24.53 The recommended priority water efficiency application techniques under the Light Metal Casting NACE code are presented in the table below.

NACE Code	NACE Code Explanation	Prioritized Sectoral Water Efficiency Techniques
24.53	Casting of light metals	**Industry Specific Measures**
		1. Use of an automatic spray process to control the amount of release agent used
		2. Use of biological waste scrubbers or compost filters instead of traditional wet scrubbers
		3. Since wastewater is formed after the treatment of basic oxygen furnace (BOF) emissions by wet cleaning, dedusting should be done by dry methods instead of this method.
		4. Recovery of carbonates through a two-stage sedimentation process with carbon dioxide (CO_2) injection into the wash water stream prior to the second sedimentation stage to enhance sedimentation of carbonates
		5. Continuous casting instead of ingot casting
		6. Designing the water collection system to collect oils from leaks and using an oil interceptor for wastewater
		7. Disposal of oil in skimming tanks or other devices to minimize the amount of wastewater from continuous casting
		8. Implementation of dry processes for reuse instead of wet systems for dust removal
		9. Removal of suspended solids in the wash water circuit by hydrocyclone and/or sedimentation
		Good Management Practices
		1. Using an integrated wastewater management and treatment strategy to reduce wastewater volume and pollutant load
		2. Establishment of environmental management system
		3. Preparation of water flow diagrams and mass balances for water
		4. Preparation of a water efficiency action plan to reduce water use and prevent water pollution
		5. Providing technical training to personnel for the reduction and optimization of water usage
		6. Good production planning to optimize water consumption
		7. Determining water efficiency targets
		8. Monitoring the quantity and quality of water used in production processes and auxiliary processes and the wastewater generated, and adapting this information to the environmental management system.
		General Precautionary Measures
		1. Minimizing spills and leaks
		2. Recovering water from rinse solutions and reusing the recovered water in processes appropriate to its quality
		3. Use of automatic equipment and hardware (sensors, smart hand washing systems, etc.) that will save water at water usage points such as showers/toilets etc.
		4. Use of pressure washing systems in equipment cleaning, general cleaning, etc.
		5. Reusing filter wash water in filtration processes, reusing relatively clean cleaning water in production processes, and reducing water consumption by using cleaning-in-place systems (CIP)
		6. Avoiding the use of drinking water in production lines
		7. Use of cooling water as process water in other processes
		8. Detection and reduction of water losses
		9. Use of automatic control-shutoff valves to optimize water usage
		10. To prevent water and energy waste, production procedures must be documented and used by employees.
		11. Reuse of pressurized filtration backwash waters before water softening at appropriate points

NACE Code	NACE Code Explanation	Prioritized Sectoral Water Efficiency Techniques
		12.Optimizing the frequency and duration of regeneration (including rinses) in water softening systems
		13.Establishing closed storage and impermeable waste/scrap areas to prevent the transport of toxic or hazardous chemicals to the aquatic environment.
		14.substances that pose a risk to the aquatic environment (such as oils, emulsions, binders) from being stored, stored, and mixed with wastewater after use.
		15.Preventing clean water streams from mixing with dirty water streams
		16.Determination of wastewater streams that can be reused with or without treatment by characterizing the quantities and qualities of wastewater at all wastewater generation points.
		17.Use of closed loop water cycles in suitable processes
		18.Use of computer-aided control systems in production processes
		19.Determining the scope of reuse of washing and rinsing waters
		20.Grey water is collected and purified separately in the facility and used in areas that do not require high water quality (green area irrigation, ground washing, etc.)
		21.Implementing time optimization in production and arranging all processes to be completed in the shortest time possible.
		22.Collecting rainwater and using it as an alternative water source for facility cleaning or in suitable areas.
		23.Avoiding the need for rinsing between activities by using compatible chemicals in consecutive processes
		24.Reuse of nanofiltration (NF) or reverse osmosis (RO) concentrates with or without purification depending on their characterization
		Precautions Regarding Auxiliary Processes
		1. Avoiding unnecessary cooling processes by determining the processes that require wet cooling.
		2. Reducing water consumption by increasing the number of cycles in closed loop cooling systems and improving the quality of makeup water
		3. Reducing evaporation losses in closed loop cooling water
		4. Increasing the number of cycles by using corrosion and scale inhibitors in systems with closed water loops
		5. Using air cooling systems instead of water cooling in cooling systems
		6. Installation of water softening systems for the healthy operation of cooling water recovery systems.
		7. Use of a closed loop cooling system to reduce water usage
A total of 48 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.

2.1.1 Sector-Specific Measures

- ***Using Biological Waste Gas Scrubbers or Compost Filters Instead of Traditional Wet Gas Scrubbers***
  If the gases to be treated contain biologically degradable substances like phenols, biological waste gas scrubbers or compost filters are recommended over traditional wet gas scrubbers, as they produce less wastewater. Biological scrubbers are more effective for gases with easily degradable substances because they allow more frequent recirculation of biologically treated wastewater compared to conventional scrubbers, resulting in reduced wastewater production (IPPC BREF, 2005a).

- ***Recovery Using a Two-Stage Sedimentation Process with Carbon Dioxide (CO_2) Injection Before the Second Sedimentation Stage to Increase Carbonate Precipitation***
  One of the most effective methods to minimize wastewater discharge is to increase the circulation of wash water. By using high-circulation and advanced treatment techniques, reclaimed wastewater can be used for irrigation of green areas (BREF, 2013).

- ***Using an Automatic Spraying Process to Control the Amount of Release Agent Used***
  In iron casting, a water-based solution of the release agent is sprayed onto the high-pressure die casting (HPDC) mold with automatic spraying, which cools the mold. Such simple process adjustments can reduce the amount of release agent and water consumption in iron casting (IPPC BREF, 2005a).

- ***Implementing Continuous Casting Instead of Ingot Casting***
  This method has advantages such as energy savings, reduced emissions, lower water consumption, improved working conditions, and higher efficiency due to the elimination of machining mills and billet plants. After achieving the desired steel quality, the molten steel is transferred in casting pots to casting machines. In casting processes, the standard method is to pour molten steel into permanent molds in a discontinuous process (permanent mold or ingot casting). With the removal of machining mills and billet plants, emissions and water use are reduced, working conditions are improved, and efficiency over 95% is achieved (BREF, 2013).

- ***Reducing Wastewater Quantity from Continuous Casting by Removing Oil from Stripping Tanks or Other Devices***
  Techniques such as removing solids through flocculation, sedimentation, and/or filtration, removing oil in stripping tanks or other devices, and maximizing the recirculation of cooling water and water from vacuum producers can collectively reduce oil and wastewater quantities (BREF, 2013).

- ***Applying Dry Processes Instead of Wet Systems for Dust Removal to Enable Reuse***

  Both wet and dry systems are used for dust and particulate removal. The primary advantage of dry systems is that they capture dust in a dry form, avoiding the transfer of additional contaminants to the environment, as seen with wet systems (IPPC BREF, 2005a).

- ***Removing Suspended Solids in the Wash Water Circuit Through***

Hydrocyclones and/or Sedimentation

Wash wastewater can be recovered and reused after proper pH adjustments. In the wash water circuit, hydrocyclones and/or sedimentation processes can remove suspended solids, resulting in sludge formation (BREF, 2013).

- ***Designing the Water Collection System to Capture Oils from Leaks and Using Oil Separators for Wastewater***

Oil separators are used for wastewater from permanent mold foundries. Hydraulic systems in mold casting machines have the potential to leak oil and hydraulic fluids. Therefore, the water collection system should be designed to capture oil from leaks. Using oil separators for resulting wastewater can prevent water pollution (IPPC BREF, 2005a).

- ***Using Dry Methods Instead of Wet Cleaning for Basic Oxygen Furnace (BOF) Emissions to Avoid Wastewater Generation***

Wet cleaning processes for BOF gas emissions involve using scrubbers. While this system cleans the gas, it also produces wastewater as pollutants transfer to the water. By using dry methods to de-dust BOF gas, water consumption and primary wastewater generation can be prevented (BREF, 2013).

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.

Using Integrated Wastewater Management and Treatment Strategy to Reduce Wastewater Quantity and Pollutant Load

Wastewater management should take a comprehensive approach from production to final disposal, covering functional elements like wastewater composition, collection, sludge disposal, treatment, and reuse. The selection of an appropriate treatment technology 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 on freshwater resources. Hence, identifying suitable treatment strategies for different reuse objectives is crucial.

In integrated industrial wastewater treatment, various aspects—such as the wastewater collection system, treatment processes, and reuse objectives—are considered together (Naghedi et al., 2020). For industrial wastewater recovery, methods like SWOT analysis (Strengths, Weaknesses, Opportunities, Threats), PESTEL analysis (Political, Economic, Social, Technological, Environmental, and Legal factors), and decision trees, combined with expert opinions, can establish an integrated wastewater management framework (Naghedi et al., 2020). Techniques like Analytic Hierarchy Process (AHP) and Combined Compromise Solution (CoCoSo) can also be integrated to prioritize criteria in industrial wastewater management processes based on multiple criteria (Adar et al., 2021).

Implementing integrated wastewater management strategies can lead to reductions in water consumption, wastewater volume, and pollutant loads in wastewater by up to 25% on average. The potential payback period for implementing these strategies ranges from 1 to 10 years (TOB, 2021).

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

Industrial Wastewater Treatment Plant

Providing Technical Training to Personnel for Reducing and Optimizing Water Usage

Through this measure, water conservation and recovery can be achieved by enhancing personnel training and awareness, leading to reduced water consumption and costs while improving water efficiency. In industrial facilities, issues related to high water usage and wastewater generation often arise due to personnel lacking necessary technical knowledge. For example, it is crucial that cooling tower operators, who play a significant role in water consumption for industrial operations, are properly trained and knowledgeable. Personnel also need sufficient technical skills to perform tasks such as determining water quality requirements in production processes, measuring water and wastewater quantities, etc. (TOB, 2021). Therefore, training personnel on water conservation policies and usage optimization is essential. Involving employees in water-saving initiatives, creating regular reports on water usage before and after implementing water efficiency initiatives, and sharing these reports with personnel can support engagement and motivation. The technical, economic, and environmental benefits derived from personnel training manifest in the medium to long term (TUBITAK MAM, 2016; TOB, 2021).

Monitoring the Quantity and Quality of Water and Wastewater in Production and Auxiliary Processes and Integrating This Data into Environmental Management Systems

Industrial facilities utilize resources, and inefficiencies and environmental issues can arise from the flow of inputs and outputs. Thus, it is necessary to monitor the quantity and quality of water and wastewater in production and auxiliary processes (TUBITAK MAM, 2016; TOB, 2021). Process-based monitoring of quantity and quality, when combined with other effective management practices (such as personnel training and environmental management systems), can lead to reductions of up to 6-10% in energy consumption and up to 25% in water consumption and wastewater volume (Öztürk, 2014).

Key stages for monitoring water and wastewater include:

- Utilizing monitoring equipment (e.g., meters) to track water, energy, and other consumptions at the process level,
- Developing monitoring procedures,
- Identifying, documenting, comparing, and reporting all inputs and outputs (raw materials, chemicals, water, products, wastewater, sludge, solid waste, hazardous waste, and by-products) by quantity and quality in relation to the production process,
- Monitoring raw material losses in production processes and implementing measures to prevent such losses (Ministry of Environment and Urbanization, 2020).

Optimizing Water Consumption through Effective Production Planning

Planning production with minimal processes from raw material to finished product helps reduce labor costs, resource usage costs, and environmental impacts, thereby enhancing efficiency (TUBITAK MAM, 2016; TOB, 2021). When production planning in industrial facilities incorporates water efficiency as a factor, it can lower water consumption and wastewater generation. Modifying or combining processes in industrial production also yields significant benefits in terms of water efficiency and time management (TOB, 2021).

Creating a Water Efficiency Action Plan to Reduce Water Use and Prevent Pollution

Developing an action plan with short, medium, and long-term steps to reduce water and wastewater volumes and prevent water pollution is crucial for water efficiency in industrial facilities. This involves determining water needs across the facility and production processes, identifying water quality requirements at various usage points, and characterizing wastewater generation points (TOB, 2021). Measures to reduce water consumption, wastewater, and pollutant loads should be identified, assessed for feasibility, and planned for short, medium, and long-term implementation, promoting both water efficiency and sustainable water use (TOB, 2021).

Setting Water Efficiency Targets

Establishing water efficiency goals is the first step toward improving water efficiency in industrial facilities (TOB, 2021). A detailed analysis of water efficiency in each process is essential to identify unnecessary water use, water losses, inefficient practices affecting water efficiency, process losses, and reusable water-wastewater sources. Setting water savings potentials and water efficiency targets for each process and the facility overall is critical (TOB, 2021).

Creating Water Flow Diagrams and Water Mass Balances

Identifying points of water use and wastewater generation, and creating water-wastewater balances within both production and auxiliary processes form the basis of many good management practices. Developing process profiles across the facility and for specific production processes helps pinpoint unnecessary or high water usage points, assess water recovery opportunities, implement process modifications, and identify water losses (TOB, 2021).

2.1.3 General Measures-Type Precautions

Detecting and Reducing Water Losses

Water losses can occur in industrial production processes due to equipment, pumps, and pipelines. First, water losses should be identified, and regular maintenance of equipment, pumps, and pipelines should be conducted to prevent leaks (IPPC BREF, 2003). Regular maintenance procedures should focus on the following aspects:

- Including pumps, valves, level switches, pressure, and flow regulators in the maintenance checklist.
- Conducting inspections not only within the water system but also in systems for heat transfer and chemical distribution, focusing on broken or leaking pipes, barrels, pumps, and valves.
- Regularly cleaning filters and pipelines.
- Calibrating and routinely checking measurement equipment, such as chemical measurement and distribution devices, thermometers, etc. (IPPC BREF, 2003).

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

Minimizing Spills and Leaks

Spills and leaks in businesses can lead to losses of both raw materials and water. Moreover, using wet cleaning methods to clean spill areas can result in increased water consumption, wastewater volumes, and pollutant loads in wastewater (TOB, 2021). To reduce losses from splashing and spilling, measures such as splash guards, wings, drip trays, and sieves are employed (IPPC BREF, 2019).

Preventing the Mixing of Clean Water Flows with Wastewater Flows

By identifying points of wastewater generation and characterizing wastewater in industrial facilities, high-pollution-load wastewaters can be collected separately from relatively clean wastewater flows (TUBITAK MAM, 2016; TOB, 2021). This enables the reuse of wastewater flows of appropriate quality, either treated or untreated. Separating wastewater flows reduces water pollution, improves treatment performance, decreases treatment needs, and consequently lowers energy consumption, while also facilitating wastewater recovery and the recovery of valuable materials, thereby reducing emissions. Additionally, heat recovery from separated hot wastewater flows is possible (TUBITAK MAM, 2016; TOB, 2021). However, separating wastewater flows typically requires high investment costs, but it can lead to reduced costs when large quantities of wastewater and energy recovery are feasible (IPPC BREF, 2006).

Characterization of Wastewater Quantities and Qualities at All Wastewater Generation Points to Determine Reusable Wastewater Streams

By identifying and characterizing wastewater generation points in industrial facilities, it is possible to reuse various wastewater streams either treated or untreated (Öztürk, 2014; TUBITAK MAM, 2016; TOB, 2021). In this context, backwash water, TO concentrates, blowdown water, condensate, and relatively clean washing and rinsing waters can be reused without treatment in the same or different processes and in areas that do not require high water quality (such as facility and equipment cleaning). Additionally, wastewater streams that cannot be reused directly can be treated using appropriate treatment technologies and then reused in production processes.

Membrane filtration processes are an integral part of many wastewater reuse systems. Nanofiltration (NF) and Reverse Osmosis (RO) filtration systems are utilized for industrial wastewater recovery. Microfiltration (MF) and ultrafiltration (UF) are generally employed for pre-treatment of water before it undergoes NF or RO processes (Singh et al., 2014).

Using Cooling Water as Process Water in Other Processes

Cooling systems using water are commonly employed in processes where thermal energy is extensively used and cooling is necessary. Recovering heat through heat exchangers during the return of cooling water, preventing the contamination of cooling water, and increasing cooling water return rates facilitate water and energy savings (TUBITAK MAM, 2016; TOB, 2021). Furthermore, if cooling waters are collected separately, it is generally possible to use the collected water for cooling purposes or to reassess it in suitable processes (EC, 2009). Reusing cooling water can lead to a reduction in total water consumption by 2-9% (Greer et al., 2013), and energy savings of up to 10% can also be achieved (Öztürk, 2014; TOB, 2021).

*Determining the Scope for the Reuse of Washing and Rinsing Waters***

In industrial facilities, relatively clean wastewater streams, particularly washing and final rinsing wastewater and filter backwash wastewater, can be reused without treatment in applications such as floor washing and garden irrigation, which do not require high water quality (Öztürk, 2014). This can result in savings of 1-5% in raw water consumption (TOB, 2021).

*Utilizing Pressure Washing Systems in Equipment Cleaning and General Cleaning***

Water nozzles are commonly used for cleaning equipment in facilities. Effective results can be achieved in reducing water consumption and wastewater pollution loads by using appropriately placed nozzles. The use of active sensors and nozzles in locations with high water consumption is crucial for efficient water usage. Replacing mechanical equipment with pressure nozzles can lead to significant water savings (TUBITAK MAM, 2016). In technically suitable processes, using optimized nozzles with adjusted water pressure can reduce water consumption, wastewater generation, and wastewater pollution loads, representing the primary environmental benefits of the application.

Using Automatic Control and Shut-Off Valves to Optimize Water Usage**

Monitoring and controlling water consumption through flow control devices, meters, and computer-assisted monitoring systems provide significant technical, environmental, and economic advantages (Öztürk, 2014). Tracking the amount of water consumed within the facility and across various processes helps prevent water losses (TUBITAK MAM, 2016). It is essential to utilize flow meters and gauges throughout the facility and in specific production processes, employ automatic shut-off valves and valves in continuously operating machines, and develop monitoring and control mechanisms based on water consumption and specific quality parameters using computer-assisted systems (TUBITAK MAM, 2016). With these practices, savings of up to 20-30% in water consumption can be achieved on a process basis (DEPA, 2002; LCPC, 2010; IPPC BREF, 2003). Monitoring and controlling water consumption at the process level can result in savings of 3-5% in process water usage (Öztürk, 2014).

Avoiding the Use of Drinking Water in Production Line

Different subsectors of the manufacturing industry may utilize waters of varying quality based on production needs. In industrial facilities, raw waters sourced from underground water sources are typically treated before being used in production processes. However, in some cases, despite the costs, drinking water may be used directly in production processes, or raw waters may be disinfected with chlorine compounds before being utilized. These chlorinated waters can react with organic compounds present in the water (natural organic matter, DOM), forming harmful disinfection byproducts for living organisms (Özdemir & Toröz, 2010; Oğur et al.; TOB, 2021). The use of drinking water or raw waters treated with chlorinated compounds should be avoided whenever possible. Instead of chlorine disinfection, high oxidation potential disinfection methods such as ultraviolet (UV), ultrasound (US), or ozone can be employed. By determining and utilizing the necessary water quality parameters for each production process, this approach can help reduce unnecessary water supply and treatment costs, leading to savings in water, energy, and chemical expenses (TUBITAK MAM, 2016).

Collecting Rainwater to Utilize as an Alternative Water Source for Facility Cleaning or Suitable Areas

With dwindling water resources, rainwater harvesting is increasingly preferred, especially in regions with low rainfall. Various technologies and systems exist for rainwater collection and distribution, including cistern systems, ground infiltration, surface collection, and filtration systems. Collected rainwater can be used for production processes, garden irrigation, cleaning of tanks and equipment, surface cleaning, etc., provided it meets the required quality standards (Tanık et al., 2015).

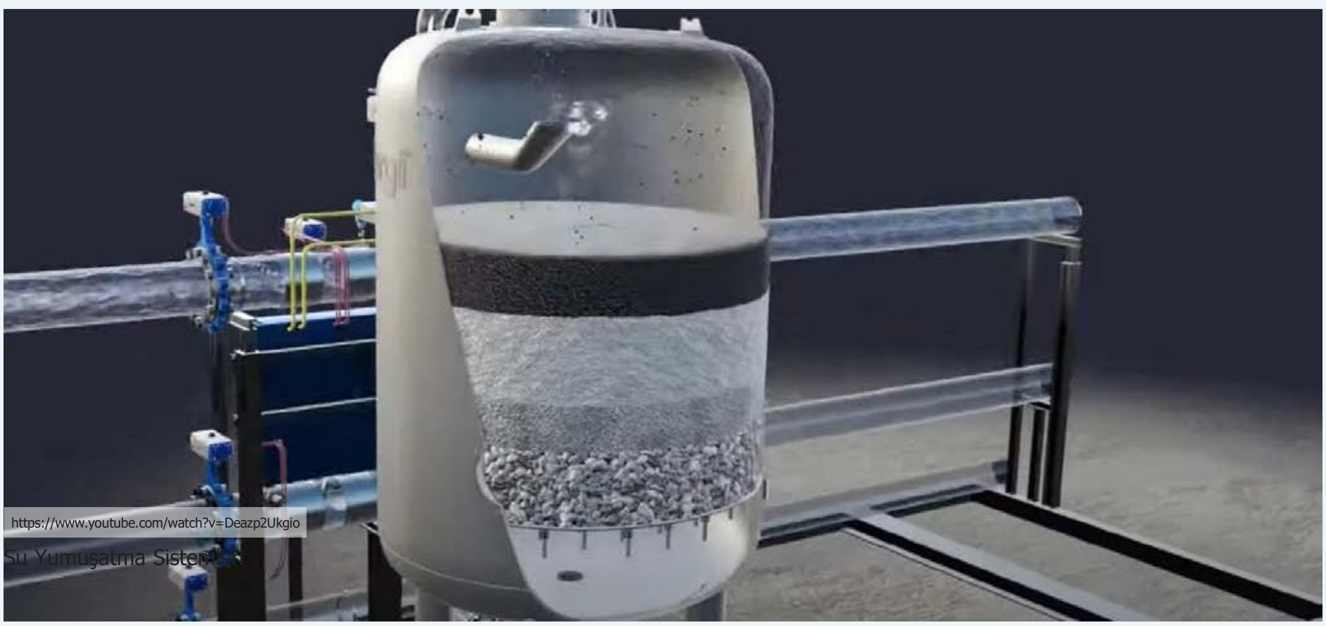
In various instances, rainwater collected from industrial facility roofs has been stored and used within the building and in landscaping areas, resulting in a 50% water savings in landscape irrigation (Yaman, 2009). To enhance soil permeability and facilitate the absorption of rainwater into the ground,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

Optimizing the Frequency and Duration of Regeneration in Water Softening Systems (Including Rinses

One of the most commonly used methods for softening raw water in industrial facilities is the use of cation exchange resins, which are routinely regenerated. The regeneration process involves a series of steps: a pre-wash with raw water, regeneration with brine, and a final rinse. The frequency of regeneration is determined based on the hardness of the water; if the hardness is high, more frequent regenerations are necessary.

In the regeneration process, wash water, regeneration effluent, and rinse water are typically discharged directly. However, if the wash and final rinse water meet raw water quality standards, they can be redirected to the raw water storage tank or reused in processes that do not require high water quality, such as facility cleaning or irrigation of green areas (TOB, 2021).

Determining the optimal regeneration frequency in these systems is critical. Although regeneration in water softening systems is often adjusted according to the recommended frequencies from the supplier or based on the inflow rate and duration of the softening system, this frequency can also change based on the calcium concentration in the raw water. Therefore, online hardness measurement is utilized when determining regeneration frequency. This allows for the optimization of regeneration intervals and prevents unnecessary wash rinses or brine backwashing through the use of online hardness sensors.



Reuse of Backwash Water from Pressurized Filtration Before Water Softening at Appropriate Points

Many industrial processes require softened water with low concentrations of calcium and magnesium. Water softening systems work by removing calcium, magnesium, and other metal cations from hard water to produce soft water.

By reusing backwash water from pressurized filtration before water softening at suitable points, savings can be achieved. This measure is similar in content to practices such as "reusing filter backwash water in filtration processes, reusing relatively clean water in production processes, and reducing water consumption by using in situ cleaning systems."

Reuse of Nanofiltration (NF) or Reverse Osmosis (RO) Concentrates Based on Characterization

Depending on the characterization of wastewater and suitable reuse points, the potential for reusing other wastewaters generated from membrane processes (such as backwashing without chemicals, cleaning-in-place (CIP), module cleaning, and cleaning of chemical tanks, etc.) should be evaluated.

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

Savings can be achieved by reusing nanofiltration or reverse osmosis concentrates based on their characterization, either after treatment or without treatment. Measures should be taken to reuse clean water in production processes from filtration backwash waters and to reduce water consumption through the use of cleaning systems (TOB, 2021).

https://genesiswatertech.com/wp-content/uploads/2019/08/RO-waste-water-recycling-1.jpg

Use of Closed-Loop Water Cycles in Suitable Processes

Coolants are chemical compounds that absorb heat from substances to be cooled and have specific thermodynamic properties that affect the performance of the cooling process (Kuprasertwong et al., 2021).

In manufacturing processes, water is often used as a coolant in many processes, particularly in product cooling. During this cooling process, water can be reused 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).

Reusing cooling water in processes such as cleaning reduces both water consumption and the amount of wastewater generated. However, the need for energy for cooling and recirculation of cooling water presents a side effect. Heat recovery is also achieved through the use of heat exchangers in cooling waters. Generally, closed-loop systems are employed in facilities using water-based cooling systems. However, blowdown from the cooling system is usually discharged directly into the wastewater treatment facility. The discharged blowdown water can be reused in suitable production processes.

Preventing the Mixing of Risky Substances into Wastewater

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

Closed Storage and Impermeable Waste/Discard Areas to Prevent the Transport of Toxic or Hazardous Chemicals

In industrial facilities, closed and impermeable waste/discard storage areas can be created to prevent the transport of toxic or hazardous chemicals to receiving environments. This practice is already being implemented under current environmental regulations in our country. Through field studies, separate collection channels can be constructed for toxic or hazardous material storage areas in industrial facilities, allowing for the separate collection of leakage water and preventing it from contaminating natural water environments.

Recovery of Water from Rinsing Solutions and Reuse in Appropriate Processes

In industrial facilities, rinsing wastewater, which has a relatively clean character, can be reused without treatment in processes that do not require high water quality, such as ground washing and garden irrigation (Öztürk, 2014). Recovering rinsing water can lead to savings of approximately 1-5% in raw water consumption.

Preventing the Need for Rinsing Between Operations by Using Compatible Chemicals in Sequential Processes

Chemical compatibility is a measure of how stable a substance is when mixed with another substance. If two substances mix and undergo a chemical reaction, they are considered incompatible.

In industrial facilities, various chemicals are used to increase the efficiency of washing and rinsing. The compatibility of these chemicals, which act as solvents, positively impacts the efficiency of the process. Consequently, contaminants on materials can be removed more quickly and effectively, significantly reducing the amount of water used in washing operations. Although this can lead to a decrease in the volume of wastewater, it may also result in an increase in the chemical loads carried by the wastewater. Reusing washing waters that contain solvents can help minimize these negative effects.

Reusing washing water can lead to savings of 25-50% in water consumption. This application may require reserve tanks and new piping. In alternative scenarios, the washing solution can be retained directly within the system and reused multiple times until it loses its effectiveness.

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

Water is essential in many sectors of the manufacturing industry, both for production processes and for ensuring that personnel meet necessary hygiene standards. Water consumption in industrial facilities can be managed through various methods, including the use of equipment such as sensor faucets and smart handwashing systems in personnel water usage areas. Smart handwashing systems optimize the mixture of water, soap, and air, promoting water conservation while also enhancing resource efficiency.

Separate Collection and Treatment of Gray Water in the Facility for Use in Areas with Low Water Quality Requirements (e.g., irrigation of green areas, floor washing)

Wastewater generated in industrial facilities includes not only industrial wastewater from production processes but also wastewater from showers, sinks, kitchens, etc. Wastewater from areas such as showers and sinks is referred to as gray water. Treating this gray water through various treatment processes and using it in areas that do not require high water quality can result in significant water savings.

https://sayachizmet.com/wp-content/uploads/2020/01/SCADA-nedir-1280x720-1.jpg.webp

Computer Aided Control System

Use of Computer-Aided Control Systems in Production Processes

In industrial facilities, inefficient resource utilization and environmental issues are directly related to input-output flows, necessitating the optimal definition of process inputs and outputs specific to production processes (TUBİTAK MAM, 2016). This enables the development of measures to enhance resource efficiency and improve economic and environmental performance. Organizing input-output inventories is considered a prerequisite for continuous improvement. Such management practices require the involvement of technical staff and upper management, yet they can quickly pay off through the contributions of various experts (IPPC BREF, 2003). The use of measurement equipment for application processes and conducting routine analyses or measurements for specific processes is essential. To maximize efficiency from applications, utilizing computer monitoring systems as much as possible can increase the technical, economic, and environmental benefits achieved (TUBİTAK MAM, 2016).

Reusing Backwash Water from Filtration Processes, Reusing Relatively Clean Cleaning Waters in Production Processes, and Reducing Water Consumption through On-Site Cleaning Systems (CIP)

Wastewater from backwashing activated carbon filters and softening devices primarily contains a high concentration of suspended solids (SS). Backwash water, one of the easiest types of wastewater to recover, can be filtered through ultrafiltration plants. This process can achieve water savings of up to 15% (URL - 1, 2021).

The wastewater generated after regeneration contains soft water with high salt content, constituting approximately 5-10% of total water consumption. These regeneration wastes can be collected in a separate tank and utilized in processes requiring high salt, for facility cleaning, and for domestic uses. This requires a reserve tank, plumbing, and a pump. Reusing regeneration wastewater can reduce water consumption, energy use, wastewater volume, and the salt content in wastewater by approximately 5-10% (Öztürk, 2014). The payback period varies depending on the use of regeneration waters in production processes, facility cleaning, and domestic applications. It is estimated that the potential payback period for processes requiring high salt will be less than one year since both water and salt will be recovered. However, for facility and equipment cleaning or domestic uses, the payback period is expected to exceed one year (TOB, 2021).

In Turkey, reverse osmosis (RO) concentrates are combined with other wastewater streams and discharged into the wastewater treatment plant channel. Concentrates generated from RO systems, used for additional hardness removal, can be used for garden irrigation and cleaning of tanks and equipment within the facility (TUBİTAK MAM, 2016; TOB, 2021). Moreover, by structuring monitoring for raw water quality, it is also possible to return RO concentrates to raw water tanks for mixing and reuse (TOB, 2021).

Documenting and Utilizing Production Procedures to Prevent Water and Energy Waste

To achieve efficient production in an enterprise, effective procedures must be implemented to identify, evaluate, and control potential problems and resources during production stages (Ayan, 2010). By determining and applying appropriate procedures in production processes, resources (such as raw materials, water, energy, chemicals, personnel, and time) can be utilized more efficiently, ensuring reliability and quality in production processes (Ayan, 2010). Having documented production procedures contributes to evaluating operational performance and enhancing the capability to develop quick reflexes for problem-solving (TUBİTAK MAM, 2016; TOB, 2021).

The effective implementation and monitoring of procedures established for production processes is one of the most effective ways to ensure product quality, receive feedback, and develop solutions (Ayan, 2010). Documenting and effectively applying production procedures is a good management practice and an effective tool in structuring and ensuring the continuity of clean production approaches and environmental management systems. While potential benefits can vary between sectors or facility structures regarding the costs and economic gains of the application, the establishment and monitoring of production procedures are generally not costly. Given the savings and benefits they provide, the payback period can be short (TUBİTAK MAM, 2016; TOB, 2021).

Applying Time Optimization in Production and Organizing All Processes to Be Completed in the Shortest Time Possible

In industrial production processes, planning the conversion of raw materials into products with minimal process usage is an effective practice for reducing labor costs, resource utilization costs, environmental impacts, and improving efficiency. In this context, it may be necessary to revise production processes to use the least number of process steps (TUBİTAK MAM, 2016). When some inadequacies in basic production processes, inefficiencies, and design flaws prevent the desired product quality from being achieved, it may be necessary to renew the production processes. In such cases, the resource utilization for manufacturing a unit quantity of product, as well as the resulting waste, emissions, and solid waste amounts, may increase. Therefore, optimizing time in production processes is an effective practice (TUBİTAK MAM, 2016).

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).

Utilizing Air-Cooling Systems Instead of Water-Cooling Systems in Cooling Systems

Industrial cooling systems are used to cool heated products, processes, and equipment. These can include both closed and open-loop cooling systems, as well as systems that use a fluid (gas or liquid) or dry air for cooling (IPPC BREF, 2001b; TOB, 2021). Air-cooling systems consist of finned tube components, condensers, and air fans (IPPC BREF, 2001b; TOB, 2021). Air-cooling systems can operate on different principles. In industrial air-cooling systems, heated water is cooled with air in closed-loop cooling condensers and heat exchangers (IPPC BREF, 2001b; TOB, 2021). In water-cooling systems, heated water is directed to a cooling tower, where it is cooled through evaporation. However, despite operating in a closed circuit, water-cooled systems experience significant evaporation. Additionally, some water is discharged as blowdown in cooling systems, resulting in further water loss (IPPC BREF, 2001b; TOB, 2021). Employing air-cooling systems instead of water-cooling systems can effectively reduce evaporation losses and minimize the risk of contamination of cooling water (IPPC BREF, 2001b; TOB, 2021).

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).

Identifying Processes Requiring Wet Cooling to Avoid Unnecessary Cooling Operations

The boundaries of a facility's site affect design parameters such as cooling tower height. In cases where reducing the height of the cooling tower is necessary, a hybrid cooling system can be implemented. Hybrid cooling systems are a combination of evaporative and non-evaporative (wet and dry) cooling systems. Depending on the ambient temperature, a hybrid cooling tower can operate entirely as a wet cooling tower or as a combined wet/dry cooling tower (TUBİTAK MAM, 2016). In regions where sufficient cooling water is unavailable or where water costs are high, evaluating dry cooling systems or hybrid cooling systems can be an effective solution to reduce the amount of makeup water for cooling (TUBİTAK MAM, 2016).

Reducing Evaporation Losses in Closed Loop Cooling Water

During the cooling of heated water in cooling systems, a certain amount of water evaporates. Therefore, in closed loop cooling systems, makeup water is added to compensate for the amount of evaporated water. Optimizing cooling systems can help prevent evaporation losses. Furthermore, practices such as treating the makeup water added to cooling systems and preventing biological growth in cooling systems can also reduce the amount of blowdown. In practice, the blowdown water generated in cooling systems is typically discharged directly into wastewater channels. By reusing cooling system blowdown water, savings of up to 50% in water consumption can be achieved. The implementation of this measure may require the installation of new pipelines and reserve tanks (TOB, 2021).

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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