T.R.
MINISTRY OF AGRICULTURE AND FORESTRY
GENERAL DIRECTORATE OF WATER MANAGEMENT

Water Efficiency Campaign

Water Efficiency
Guidance Documents Series

FLAT GLASS MANUFACTURING

NACE CODE: 23.11

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Abbreviations

WWTP	Wastewater Treatment Plant
EU	European Union
SSM	Suspended Solid Matter
BREF	Best Available Techniques Reference Document
EMS	Environmental Management System
MOEUU	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
GDWM	General Directorate of Water Management
RO	Reverse Osmosis
TOB	Republic of Turkey Ministry of Agriculture and Forestry
TUIK	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 felt intensely, and is considered to be among the regions that will be most affected by the negative effects of climate change. Projections on how our water resources in our basins will be affected in the future due to climate change show that our water resources may decrease by up to 25 percent in the next hundred years.

For the year 2022, the annual amount of water available per capita in Turkey is 1,313 m^3, and it is expected that the annual amount of water available per capita will fall below 1,000 cubic meters after 2030 due to human pressures and the effects of climate change. If the necessary measures are not taken, it is obvious that Turkey will become a water scarce country in the very near future, bringing with it many negative social and economic consequences. As it can be understood from the results of future projections, the risk of drought and water scarcity awaiting our country necessitates the efficient and sustainable use of our existing water resources.

The concept of water efficiency can be defined as *"using the least amount of water in the production of a product or service"*. The water efficiency approach is based on the rational, sharing, equitable, efficient and effective use of water in all sectors, especially in drinking water, agriculture, industry and household use, in a way that protects water in terms of quantity and quality and takes into account not only the needs of humans but also the needs of all living things with ecosystem sensitivity.

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

In the vision of sustainable development set by the United Nations, *Goal 7: Ensuring Environmental Sustainability* from the Millennium Development Goals, *Goal 9: Industry, Innovation and Infrastructure* from the Sustainable Development Goals and *Goal 12: Responsible Production and Consumption* from *the* Sustainable Development Goals include issues such as efficient, fair and sustainable use of resources, especially water, environmentally friendly production and consumption with concern for future generations.

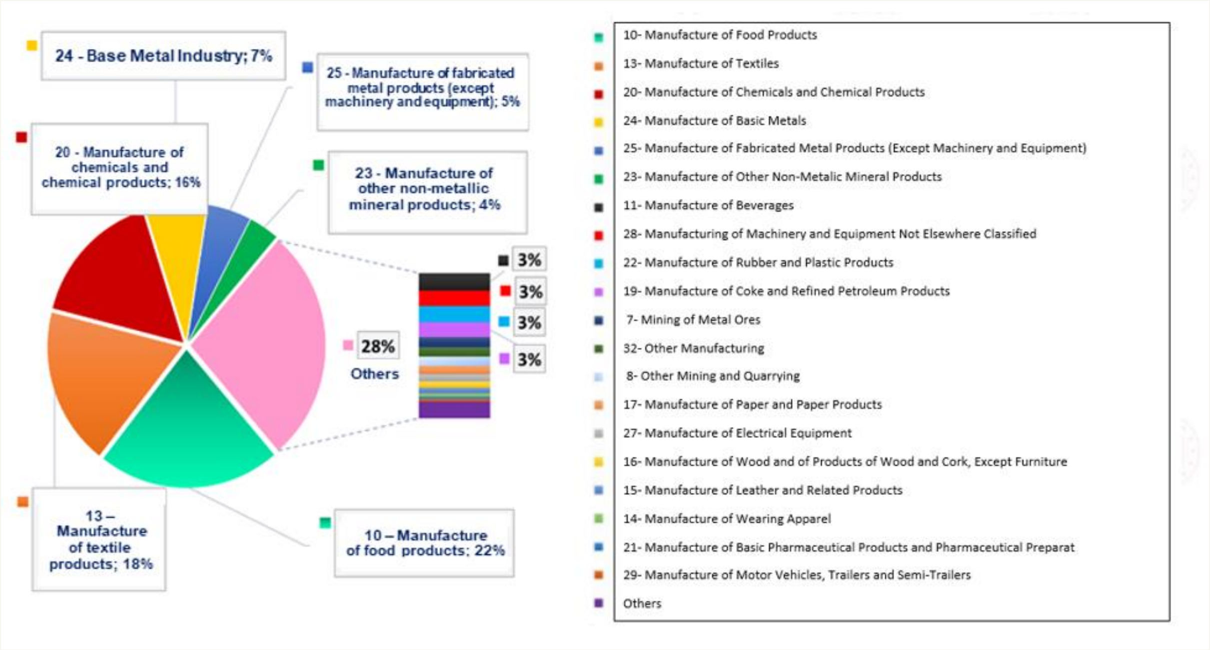
Within the scope of the European Green Deal, where member countries have agreed on goals such as implementing a clean, circular economy model with a carbon neutral target, expanding the efficient use of resources and reducing environmental impacts, actions emphasizing water and resource efficiency in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

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

The Ministry of Agriculture and Forestry, General Directorate of Water Management carries out activities aimed at disseminating efficient practices in urban, agricultural, industrial and individual water use and raising social awareness. Water efficiency action plans addressing all sectors and stakeholders were prepared within the scope of the *"Water Efficiency Strategy Document and Action Plan (2023-2033) within the Framework of Adaptation to a Changing Climate"*, which entered into force with the Presidential Circular No. 2023/9. In the Industrial Water Efficiency Action Plan, a total of 12 actions have been determined for the 2023-2033 period and responsible and relevant institutions have been assigned for these actions. Within the scope of the Action Plan, the General Directorate of Water Management has been assigned the responsibility of conducting studies to determine specific water use ranges and quality requirements on the basis of sub-sectors in industry, organizing technical training programs and workshops on sectoral basis and preparing water efficiency guidance documents.

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

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



Sectoral distribution of water uses in industry in Türkiye

As a result of the studies, specific water consumption and potential savings rates for the processes of enterprises for 152 different 4-digit NACE codes with high water consumption were determined, and water efficiency guidance documents were prepared by taking into account the EU best available techniques (BAT) and other cleaner production techniques. The guidelines include 500 techniques (BATs) for water efficiency; (i) Good Management Practices, (ii) General Measures, (iii) Measures Related to Auxiliary Processes and (iv) Sector Specific Measures.

Within the scope of the project, environmental benefits, operational data, technical specifications-requirements and applicability criteria were taken into consideration during the determination of BATs for each sector. In the identification of BATs, not only BREF documents were not limited, but also different data sources such as current literature data on a global scale, real case studies, innovative practices, reports of sector representatives were examined in detail and sectoral BAT lists were created. In order to assess the suitability of the BAT lists created for the local industrial infrastructure and capacity of our country, the BAT lists prepared specifically for each NACE code were prioritized by the enterprises by scoring them on the criteria of water saving, economic savings, environmental benefit, applicability, cross-media impact and the final BAT lists were determined using the scoring results. Water and wastewater data of the facilities visited within the scope of the project and the final BAT lists prioritized by sectoral stakeholders and taking into account the local dynamics specific to our country were used to create sectoral water efficiency guides based on NACE codes.

2 Scope of the Study

Guidance documents prepared within the scope of water efficiency measures in industry cover the following main sectors:

- Crop and animal production and hunting and related service activities (including sub-production area represented by 6 four-digit NACE codes)
- Fisheries and aquaculture (including sub-production area represented by 1 four-digit NACE Code)
- Coal and lignite extraction (including sub-production represented by 2 four-digit NACE codes)
- Service activities in support of mining (including sub-production area represented by 1 four-digit NACE Code)
- Metal ores mining (including the sub-production area represented by 2 four-digit NACE codes)
- Other mining and quarrying (including sub-production represented by 2 four-digit NACE codes)
- Manufacture of food products (including 22 sub-production areas represented by four-digit NACE codes)
- Manufacture of beverages (including sub-production represented by 4 four-digit NACE codes)
- Manufacture of tobacco products (including sub-production area represented by 1 four-digit NACE Code)
- Manufacture of textile products (including 9 sub-production areas represented by four-digit NACE codes)
- Manufacture of apparel (including sub-production area represented by 1 four-digit NACE Code)
- Manufacture of leather and related products (including sub-production area represented by 3 four-digit NACE codes)
- Manufacture of wood, wood products and cork products (except furniture); manufacture of articles made of thatch, straw and similar materials (including sub-production area represented by 5 four-digit NACE Codes)
- Manufacture of paper and paper products (including sub-production area represented by 3 four-digit NACE codes)
- Manufacture of coke and refined petroleum products (including sub-production area represented by 1 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 ingredients (including sub-production area represented by 1 four-digit NACE Code)
- Manufacture of rubber and plastic products (including sub-production area represented by 6 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, electronic and optical products (including sub-production area represented by 2 four-digit NACE codes)
- Electrical equipment manufacturing (including sub-production area represented by 7 four-digit NACE codes)

- Manufacture of machinery and equipment not elsewhere classified (including sub-production area represented by 8 four-digit NACE codes)
- Manufacture of motor vehicles, trailers (semi-trailers) and semi-trailers (semi-trailers) (including sub-production area represented by 3 four-digit NACE codes)
- Manufacture of other means of transportation (including the sub-production area represented by 2 four-digit NACE codes)
- Other manufacturing (including sub-production represented by 2 four-digit NACE codes)
- Installation and repair of machinery and equipment (including sub-production represented by 2 four-digit NACE codes)
- Electricity, gas, steam and ventilation system production and distribution (including sub-production area represented by 2 four-digit NACE codes)
- Waste collection, reclamation and disposal activities; recovery of materials (including sub-production represented by 1 four-digit NACE Code)
- Construction of non-building structures (including sub-production area represented by 1 four-digit NACE Code)
- Warehousing and supporting activities for transportation (including sub-production area represented by 1 four-digit NACE Code)
- Accommodation (including sub-production area represented by 1 four-digit NACE Code)
- Educational Activities (Higher Education Campuses) (including sub-production area represented by 1 four-digit NACE Code)
- Sports, leisure and recreation activities (including sub-production area represented by 1 four-digit NACE Code

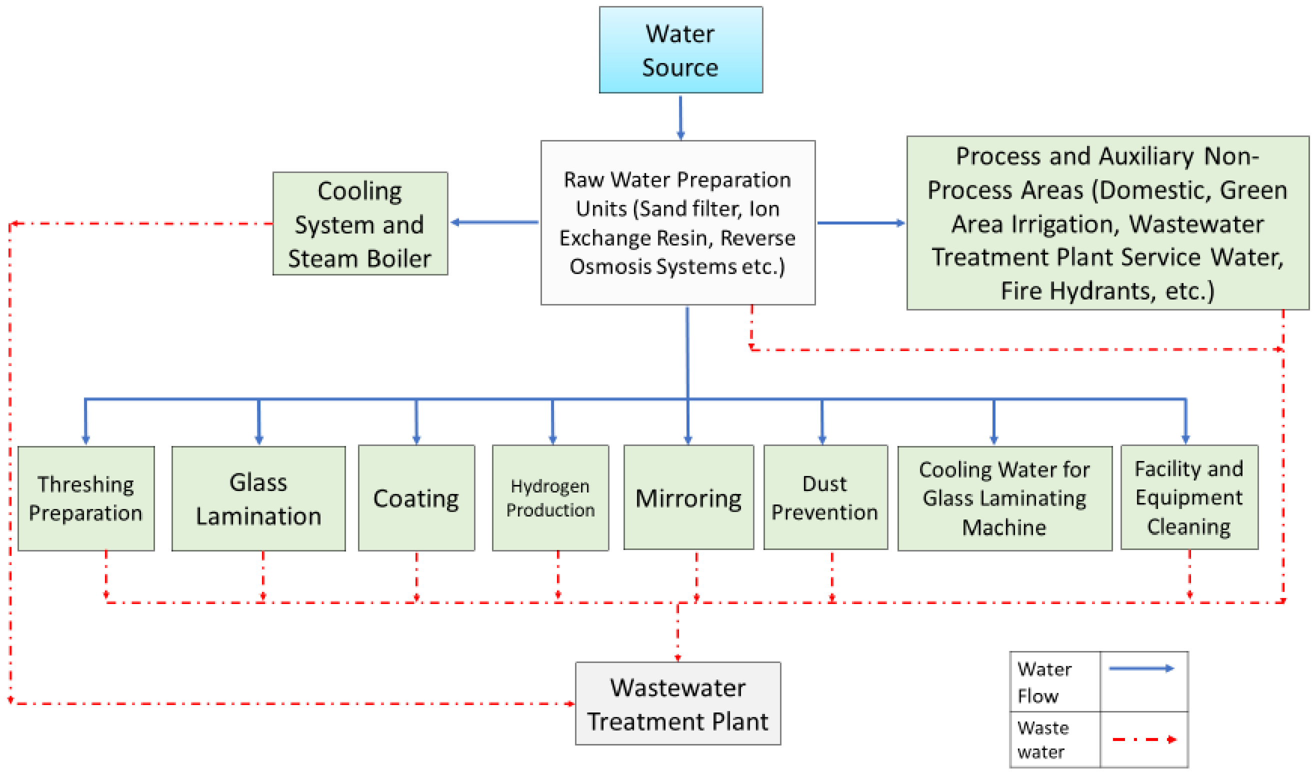
Manufacture of other non-metallic mineral products

Under the Manufacture of other non-metallic mineral products sector, the sub-production branches for which guidance documents were prepared are as follows

23.11	Flat glass manufacturing
23.13	Pit glass manufacturing
23.14	Glass fiber production
23.20	Manufacture of refractory products
23.31	Manufacture of ceramic tiles and paving stones
23.41	Manufacture of ceramic household and ornaments
23.42	Manufacture of ceramic sanitary products
23.52	Lime and plaster production
23.61	Manufacture of concrete products for construction purposes
23.62	Manufacture of gypsum products for construction purposes
23.64	Powder mortar production
23.99	Manufacture of other non-metallic mineral products not elsewhere classified

2.1 Flat Glass Manufacturing (NACE 23.11)

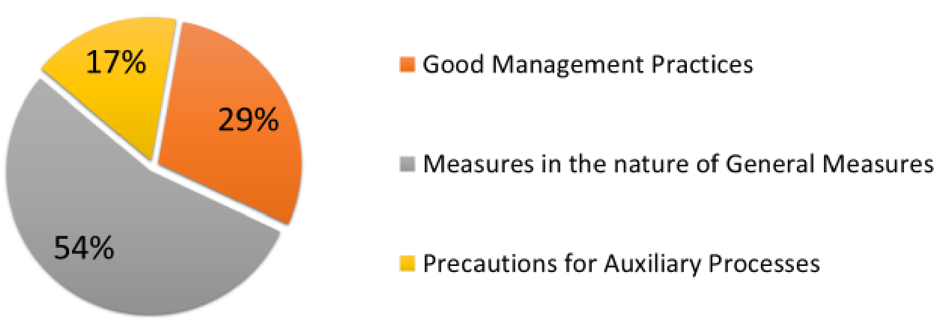
Flat Glass Manufacturing Sector Water Flow Chart



	Minimum	Maximum
Specific Water Consumption of the Facilities Visited under the Project (L/m^2 product)	10,2*	
Reference Specific Water Consumption (L/kg product)	0,3	9

* Since the reference specific water consumption value and the specific water consumption units of the facilities visited within the scope of the project are different, no comparison could be made.

Percentage Distribution of Water Efficiency Practices



A glass blend is prepared with a mixture of raw materials of certain quantities and properties, mainly sand, soda and limestone. The glass blend is melted in furnaces at a temperature of approximately 1,600°C and this melt is transferred to the tin pool at 1,100°C. By floating in the tin pool, the two sides of the glass are ensured to be parallel to each other and error-free. At this stage, the thickness of the glass and the width of the strip are created. After this process, the temperature of the glass strip is reduced in a controlled manner and glass stresses are removed in the cooling section. Finally, the glass is cut to the desired dimensions in the glass cutting line and collected in packages and made ready for shipment.

In flat glass manufacturing, water is used in batch preparation, laminating and coating, mirror production and dust prevention processes. Significant water consumption is also realized for filter washing, resin regeneration and membrane cleaning processes in raw water preparation units such as activated carbon filter, ion exchange resin, reverse osmosis, which are used to produce soft water for use in production processes in the sector. Water is also consumed in auxiliary processes such as cooling towers and steam boilers.

The reference specific water consumption in the flat glass manufacturing sector is in the range of 0.3 - 9 L/kg. The specific water consumption of the production line analyzed in the study is 10.2 L/m². With the implementation of good management practices, general measures and measures related to auxiliary processes, it is possible to achieve water savings of 12 - 18% in the sector.

Flat Glass Production Line

https://www.flatglass.eu/gallery/manuf04.jpg

23.11 Prioritized water efficiency implementation techniques recommended within the scope of flat glass manufacturing NACE code are presented in the table below.

NACE Code	NACE Code Description		Prioritized Sectoral Water Efficiency Techniques
23.11	Flat Glass Manufacturing		**Good Management Practices**
		1.	Use integrated wastewater management and treatment strategy to reduce wastewater quantity and pollutant load
		2.	Establishment of an environmental management system
		3.	Preparation of water flow diagrams and mass balances for water
		4.	Providing technical trainings to staff for the reduction and optimization of water use
		5.	Good production planning to optimize water consumption
		6.	Setting water efficiency targets
		7.	Monitoring the quantity and quality of water used in production processes and auxiliary processes and the wastewater generated and adapting this information to the environmental management system
			Measures in the nature of General Measures
		1.	Minimization of spills and leaks
		2.	Use of automatic hardware and equipment (sensors, smart hand washing systems, etc.) to save water at water usage points such as showers/toilets etc.
		3.	Avoiding the use of drinking water in production lines
		4.	Identification and reduction of water losses
		5.	Use of automatic control-close valves to optimize water use
		6.	Production procedures are documented and used by employees to prevent water and energy waste
		7.	Construction of closed storage and impermeable waste/scrap sites to prevent the transportation of toxic or hazardous chemicals for the aquatic environment
		8.	Storage and storage of substances that pose a risk to the aquatic environment (such as oils, emulsions, binders) and prevention of their mixing with wastewater after use
		9.	Prevention of mixing of clean water flows with polluted water flows
		10.	Determination of wastewater flows that can be reused with or without treatment by characterizing wastewater quantities and qualities at all wastewater generation points
		11.	Use of closed loop water cycles in appropriate processes
		12.	Computer aided control systems in production processes

NACE Code	NACE Code Descriptio		Prioritized Sectoral Water Efficiency Techniques
23.11	Flat Glass	13.	Separate collection and treatment of gray water and high water quality Use in areas that do not require irrigation (green area irrigation, floor washing, etc.)
		14.	Implementing time optimization in production and organizing all processes to be completed as soon as possible
		15.	Nanofiltration (NF) or reverse osmosis (RO) concentrates reuse with or without treatment depending on the characterization
			Precautions for Auxiliary Processes
		1.	Reducing water consumption by increasing the number of cycles in closed loop cooling systems and improving the quality of make-up water
		2.	Reduction of evaporation losses in closed loop cooling water Water
		3.	recovery with tower cooling application in systems without closed loop
		4.	Increasing the number of cycles by using corrosion and scale inhibitors in systems with closed water cycles

A total of 26 techniques have been proposed in this sector.

For flat glass manufacturing NACE Code;

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

2.1.1 Good Management Practices

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

Environmental Management Systems (EMS) include the organizational structure, responsibilities, procedures and resources necessary to develop, implement and monitor the environmental policies of industrial organizations. The establishment of an environmental management system improves the decision-making processes of organizations between raw materials, water and wastewater infrastructure, planned production process and different treatment techniques. Environmental management organizes how resource supply and waste discharge demands can be managed 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. Alternatives include the Eco Management and Audit Scheme Directive (EMAS) (761/2001). It was developed to assess, improve and report on the environmental performance of businesses. It is one of the leading practices within the scope of eco-efficiency (cleaner production) in EU legislation and voluntary participation is provided (TUBITAK MAM, 2016; TOB, 2021). The benefits of establishing and implementing an Environmental Management System are as follows:

- Economic benefits can be achieved by improving business performance (Christopher, 1998).
- International Organization for Standardization (ISO) standards are adopted, ensuring greater compliance with global legal and regulatory requirements (Christopher, 1998).
- While minimizing the risks of penalties associated with environmental responsibilities, the amount of waste, resource consumption and operating costs are reduced (Delmas, 2009).
- The use of internationally recognized environmental standards eliminates the need for multiple registrations and certifications for businesses operating in different locations around the world (Hutchens Jr., 2017).
- Especially in recent years, the improvement of companies' internal control processes has also been emphasized by consumers. The implementation of environmental management systems provides a competitive advantage against companies that do not adopt the standard. It also contributes to the better position of organizations in international areas / markets (Potoski & Prakash, 2005).

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

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

- ***Use integrated wastewater management and treatment strategy to reduce wastewater quantity and pollutant load***

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

On-site reuse of treated wastewater not only improves the quality of water bodies, but also reduces the demand for freshwater. It is therefore crucial to identify appropriate treatment strategies for different reuse objectives.

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

The implementation of integrated wastewater management strategies can reduce water consumption, wastewater quantity and pollution loads of wastewater by up to 25% on average. The potential payback period of implementation varies between 1-10 years (MoAF, 2021).

Industrial Wastewater Treatment Plant

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

- ***Providing technical trainings to staff for the reduction and optimization of water use***

With this measure, water saving and water recovery can be achieved by increasing the training and awareness of the personnel, and water efficiency can be achieved by reducing water consumption and costs. In industrial facilities, problems related to high water use and wastewater generation may arise due to the lack of necessary technical knowledge of the personnel. For example, it is important that cooling tower operators, who represent a significant proportion of water consumption in industrial operations, are properly trained and have technical knowledge. It is also necessary for the relevant personnel to have sufficient technical knowledge in applications such as determining water quality requirements in production processes, measuring water and wastewater quantities, etc. (TOB, 2021). Therefore, it is important to train staff on water use reduction, optimization and water saving policies. Practices such as involving staff in water conservation efforts, creating regular reports on water use 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 of staff training are realized in the medium to long term (TUBITAK MAM, 2016; TOB, 2021).

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

inefficiency and environmental problems can arise from input-output flows. For this reason water and wastewater used in production processes and auxiliary processes should be monitored in terms of quantity and quality (TUBITAK MAM, 2016; TOB, 2021). Process-based quantity and quality monitoring together with other good management practices (personnel training, establishment of an environmental management system, etc.) can reduce energy consumption by 6-10%, water consumption and wastewater quantities by
It can provide up to 25% reduction (Öztürk, 2014).

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

- Use of monitoring equipment (such as meters) to monitor water, energy, etc. consumption on a process-by-process basis,
- Establish monitoring procedures,
- Identifying the use/exit points of all inputs and outputs (raw materials, chemicals, water, products, wastewater, sludge, solid waste, hazardous waste and by-products) related to the production process, monitoring, documenting, comparative evaluation and reporting in terms of quantity and quality,
- Monitoring raw material losses in production processes where raw materials are transformed into products and taking measures against raw material losses (MoEU, 2020e).

- ***Good production planning to optimize water consumption***

  In industrial production processes, planning by using the least amount of process from raw material to product is an effective practice to reduce labor costs, resource utilization costs and environmental impacts and to ensure efficiency (TUBITAK MAM, 2016; TOB, 2021). Production planning in industrial plants, taking into account the water efficiency factor, reduces water consumption and wastewater amount. Modifying production processes or combining some processes in industrial plants provides significant benefits in terms of water efficiency and time planning (TOB, 2021).

- ***Determination of water efficiency targets***

  The first step in achieving water efficiency in industrial facilities is to set targets (TOB, 2021). For this, first of all, a detailed water efficiency analysis should be carried out on the basis of processes. In this way, unnecessary water use, water losses, wrong practices affecting water efficiency, process losses, reusable water-wastewater resources with or without treatment, etc. can be determined. It is also extremely important to determine the water saving potential and water efficiency targets for each production process and the plant as a whole (TOB, 2021).

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

  Determining the points of water use and wastewater generation in industrial plants, establishing water-wastewater balances in production processes and auxiliary processes other than production processes constitute the basis of many good management practices in general. Establishing process profiles on a plant-wide and production process basis facilitates the identification of unnecessary water use points and high water use points, evaluation of water recovery opportunities, process modifications and determination of water losses (TOB, 2021).

2.1.2 General Water Efficiency BATs

- ***Identification and reduction of water losses***

  Water losses occur in equipment, pumps and pipelines in industrial production processes. First of all, water losses should be identified and equipment, pumps and pipelines should be regularly maintained and kept in good condition to prevent leaks (IPPC BREF, 2003). Regular maintenance procedures should be established, paying particular attention to the following points:

  - Adding pumps, valves, level switches, pressure and flow regulators to the maintenance checklist,
  - Inspections not only of the water system, but also, in particular, of heat transfer and chemical distribution systems, broken and leaking pipes, drums, pumps and valves,
  - Regular cleaning of filters and pipelines,
  - Calibrate, routinely check and monitor measurement equipment such as chemical measuring and dispensing devices, thermometers, etc. (IPPC BREF, 2003).

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

- ***Minimization of spills and leaks***

  Both raw material and water losses can occur due to spills and leaks in enterprises. In addition, if wet cleaning methods are used to clean the areas where spills occur, water consumption, wastewater amounts and pollution loads of wastewater may also increase (TOB, 2021). In order to reduce raw material and product losses, spill and splash losses are reduced by using splash guards, flaps, drip trays, screens (IPPC BREF, 2019).

- ***Prevention of mixing of clean water flows with polluted water flows***

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

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

  Determination and characterization of wastewater generation points in industrial facilities. It is possible to reuse various wastewater streams with or without treatment (Öztürk, 2014; TUBİTAK MAM, 2016; TOB, 2021). In this context, filter backwash waters, TO concentrates, blowdown waters, condensate waters, relatively clean washing and rinsing waters can be reused without treatment in the same/different processes and in areas that do not require high water quality (such as facility and equipment cleaning). In addition, wastewater streams that cannot be directly reused can be reused in production processes after treatment using appropriate treatment technologies.

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

- ***Use of automatic control-close valves to optimize water use***

  Monitoring and controlling water consumption using flow control devices, meters and computer-aided monitoring systems provides significant technical, environmental and economic advantages (Öztürk, 2014). Monitoring the amount of water consumed in the plant and in various processes prevents water losses (TUBITAK MAM, 2016). It is necessary to use flow meters and meters in the plant in general and in production processes in particular, to use automatic shut-off valves and valves in continuously operating machines, and to develop monitoring-control mechanisms according to water consumption and some determined quality parameters by using computer-aided systems (TUBITAK MAM, 2016). With this practice, it is possible to save up to 20-30% of water consumption on a process basis (DEPA, 2002; LCPC, 2010; IPPC BREF, 2003). By monitoring and controlling water consumption on a process basis, 3-5% savings in process water consumption can be achieved (Öztürk, 2014).

- ***Avoiding the use of drinking water in production lines***

  In different sub-sectors of the manufacturing industry, waters with different water quality can be used for production purposes. In industrial plants, raw water from groundwater sources is generally used in production processes after treatment. However, in some cases, although it is costly, drinking water can be used directly in production processes or raw water is disinfected with chlorinated compounds and then used in production processes. These waters containing residual chlorine can react with organic compounds (natural organic matter (DOM)) in water in production processes and form disinfectant by-products harmful to living metabolisms (Özdemir & Toröz, 2010; Oğur et al.) The use of drinking water containing residual chlorine compounds or raw water disinfected with chlorinated compounds should be avoided as much as possible. Highly oxidizing disinfection methods such as ultraviolet (UV), ultrasound (US) or ozone can be used instead of chlorine disinfection for disinfection of raw water. In order to increase the technical, economic and environmental benefits of the application, it helps to reduce unnecessary water supply and treatment costs by determining and using the water quality parameters required in each production process. With this application, it is possible to reduce water, energy and chemical costs (TUBITAK MAM, 2016).

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

Based on the wastewater characterization and appropriate point of use, the potential for reuse of other wastewater from membrane processes (backwashing without or with chemicals, CIP cleaning, module cleaning, cleaning of chemical tanks, etc.) should be assessed.

Nanofiltration is a membrane-based liquid separation technique with low energy consumption and low operating pressures suitable for the treatment of well water and surface water. Reverse osmosis is also a membrane-based liquid separation technique and can separate smaller substances than nanofiltration (Akgül, 2016).

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

- ***Preventing substances that pose a risk to the aquatic environment (such as oils, emulsions, binders) from being mixed into wastewater as much as possible after storage, storage and use***

In industrial facilities, substances that pose a risk to the aquatic environment such as oils, emulsions and binders dry cleaning techniques to prevent chemicals from mixing into wastewater streams can be used and leaks can be prevented. In this way, water resources can be protected (TUBITAK MAM, 2016).

- ***Construction of closed storage and impermeable waste/scrap sites to prevent the transportation of toxic or hazardous chemicals for the aquatic environment***

Closed and impermeable waste/scrap storage sites can be constructed in industrial facilities to prevent the transportation of toxic or hazardous chemicals for the aquatic environment to receiving environments. This practice is already being implemented in our country within the scope of existing environmental regulations. Within the scope of the field studies carried out, a separate collection channel can be built in the storage areas of toxic or hazardous substances in industrial facilities to collect the leachate separately and prevent it from mixing into natural water environments.

Reverse Osmosis System

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

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

In general terms, refrigerants are chemical compounds with certain thermodynamic properties that take heat from the substances to be cooled and cool them, affecting the performance of the cooling process (Kuprasertwong et al., 2021).

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

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

Heat recovery is also provided by the use of heat exchangers in cooling water. Generally, closed loop systems are used in plants using aqueous cooling systems. However, cooling system blowdowns are discharged directly to the wastewater treatment plant channel. This blowdown water can be reused in appropriate production processes.

- ***Production procedures are documented and used by employees to prevent water and energy waste***

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

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

Since inefficient resource utilization and environmental problems in industrial facilities are directly linked to input-output flows, it is necessary to define the process inputs and outputs in the best way for production processes (TUBITAK MAM, 2016). Thus, it becomes possible to develop measures to improve resource efficiency, economic and environmental performance. The organization of input-output inventories is considered a prerequisite for continuous improvement. While such management practices require the participation of technical staff and senior management, they pay for themselves in a short time with the work of various experts (IPPC BREF, 2003). On the basis of the implementation processes, the use of measurement equipment and some routine analyzes/measurements specific to the processes are required. Utilizing computerized monitoring systems as much as possible in order to maximize the efficiency of the application increases the technical, economic and environmental benefits (TUBITAK MAM, 2016).

- ***Implementing time optimization in production and organizing all processes to be completed as soon as possible***

In industrial production processes, planning the process from raw material to product by using the minimum number of processes is an effective practice to reduce labor costs, resource utilization costs and environmental impacts and to ensure efficiency. In this context, it may be necessary to revise the production processes to use the minimum number of process steps (TUBITAK MAM, 2016). In cases where the desired product quality cannot be achieved due to some inadequacies, inefficiencies and design errors in basic production processes, production processes may need to be renewed. Therefore, in this case, the resource utilization and the amount of waste, emissions and solid waste generated in the production of a unit amount of product increases. Time optimization in production processes is an effective practice (TUBITAK MAM, 2016).

Computer Aided Control System

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

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

  Water is very important in many sectors of the manufacturing industry, both for production processes and for personnel to maintain the necessary hygiene standards. Water consumption in the production processes of industrial facilities can be achieved in various ways, and water consumption can be saved by using equipment such as sensor faucets and smart hand washing systems in the water usage areas of personnel. Smart hand washing systems provide resource efficiency in addition to water savings while adjusting the mixture of water, soap and air at the right ratio.

- ***Separate collection and treatment of grey water in the facility and its use in areas that do not require high water quality (green area irrigation, floor washing, etc.)***

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

2.1.3 Precautions for Auxiliary Processes

BATs for cooling systems

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

Water is used as a refrigerant in many processes such as production processes of the manufacturing industry and cooling of products. The water is recirculated through cooling tower or central cooling systems and cooling process is carried out. If an unwanted microbial growth occurs in the cooling water, it can be controlled by adding chemicals to the recirculated water (TUBITAK MAM, 2016). The number of cycles can be increased with good chemical conditioning in the recirculation process. In this way, the amount of fresh water fed to the system can be reduced and water savings can be achieved. In addition, good conditioning of the cooling make-up water can also increase the number of cycles (TOB, 2021).

- ***Water recovery by tower cooling in non-closed loop systems***

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

Various chemicals are used in cooling towers to prevent the formation of bacteria and parasites and to control lime deposits. These chemicals condense with the evaporation of water and cause unwanted deposits and deposits in the tower. Blowdown system is used to keep this condensation at a certain level. Blowdown water can be treated and recovered by membrane filtration systems or by using ion exchange resins. Recycling of blowdown wastewater is important for water efficiency.

Tower Type Cooling Systems

https://www.revueconflits.com/geopolitique-de-lenergie-francois-campagnola

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

  Cooling towers and evaporative condensers are efficient and low-cost systems that remove heat from air conditioning and industrial process cooling systems (IPPC BREF, 2001b; TOB, 2021). In these systems, more than 95% of the circulating water can be recovered (TUBITAK MAM, 2016). In cooling systems, impurities remain in the recirculated water due to the evaporation of a portion of the recirculated water, and impurity concentrations gradually increase with each cycle. Impurities that can enter the cooling system with air can cause contamination in recirculating water (TUBITAK MAM, 2016). If impurities and contaminants are not effectively controlled, they can cause scaling and corrosion, unwanted biological growth and sludge accumulation. This can become a chronic problem leading to reduced efficiency of heat transfer surfaces and increased operating costs. In this case, it is necessary to implement a water treatment program specifically designed for the quality of the feed water supplied to the cooling system, the cooling water system construction material and the operating conditions. This may include blowdown control, control of biological growth, corrosion control, avoidance of hard water, use of sludge control chemicals, filtration and screening systems (TUBITAK MAM, 2016). Establishing and periodically implementing an effective cleaning procedure and program is also a good management practice for the protection of cooling systems. Corrosion is one of the most important problems in cooling systems. Dissolved solids (sulfate, chloride, carbonate, etc.) in the tower recirculation water, which cause corrosion as a result of the formation of limestone and deposits on the walls as the degree of hardness increases, will cause corrosion on the surface over time. In addition, the formation of deposits negatively affects heat transfer and reduces energy efficiency. In order to prevent these problems, a chemical treatment program to prevent scale and corrosion, disinfection with biological activation inhibitor biocide, chemical and mechanical cleaning of the cooling towers in use at least twice a year to remove deposits, hardness and conductivity values of the make-up water should be as low as possible (IPPC BREF, 2001; Kayabek et al., 2005). Treatment (conditioning) using an appropriate treatment system may be necessary to improve the quality of the makeup water. It is also necessary to control undesirable microbial growth (IPPC BREF, 2001b; TOB, 2021). Blowdown occurs in cooling systems as well as in steam boilers due to micro-residues and deposits in the cooling water. The deliberate draining of the cooling system to compensate for the increased concentration of solids in the cooling system is called cooling blowdown. By pre-treatment of cooling water with appropriate methods and continuous monitoring of cooling water quality, biocide usage and blowdown amounts can be reduced (TUBITAK MAM, 2016). The investment cost depends on the scale of implementation, but the payback period for the expected investment costs varies between 3 and 4 years (IPPC BREF, 2001).

- ***Reduction of evaporation losses in closed loop cooling water***

Some water evaporates during the cooling of heated water in cooling systems. Therefore, in closed cycle cooling systems, cooling water is added as much as the amount of evaporated water. Evaporation losses can be prevented by optimizing cooling systems. In addition, the amount of blowdown can be reduced with applications such as treatment of make-up water added to cooling systems and prevention of biological growth in cooling systems. Within the scope of the field studies carried out, the blowdown water generated in the cooling system is generally discharged directly to the wastewater channel. By reusing cooling system blowdown water, water consumption of cooling systems can be saved up to 50%. Implementation of this measure may require the installation of new pipelines and reserve tanks (MoAF, 2021).

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