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DIRECTORATE OF WATER
MANAGEMENT

Water Efficiency
Campaign

Water Efficiency Guidance Documents Series

PAPER AND PAPERBOARD MANUFACTURING

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Contents

Abbreviations

WWTP	Wastewater Treatment Plant
EU	European Union
SS	Suspended Solid Matter
BREF	Best Available Techniques Reference Document
EMS	Environmental Management System
ÇŞİDB	Republic of Turkey Ministry of Environment, Urbanization and Climate Change
NOM	Natural Organic Matter
EMAS	Eco-Management and Audit Programme Directive
EPA	United States Environmental Protection Agency
IPPC	Industrial Pollution Prevention and Control
ISO	International Standards Organization
BAT	Best Available Techniques
NACE	Statistical Classification of Economic Activities
SYGM	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
YAS	Groundwater
YÜS	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 per cent in the next hundred years.

For the year 2022, the annual amount of water available per capita in Turkey is 1,313 m³ 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 country suffering from water scarcity in the very near future and will bring many negative social and economic consequences. As 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, fair and balanced allocation of usable water resources among users is becoming more and more important every day. For this reason, it has become a necessity to create a road map based on efficiency and optimization in order to protect 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 and *Goal 9: Industry, Innovation and Infrastructure* 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 the concern of future generations.

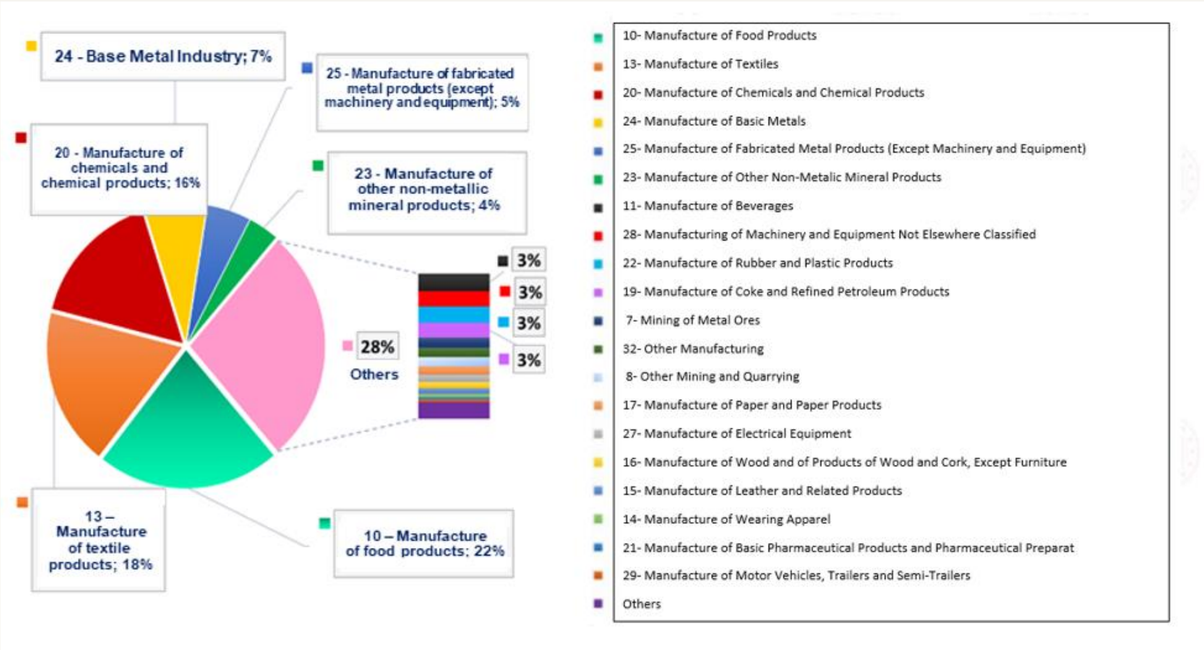
In the European Green Deal Action Plan prepared by our country within the scope of the European Green Deal Action Plan, in which member countries agreed on the objectives such as implementing a clean, circular economy model with a carbon neutral target, expanding the efficient use of resources and reducing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

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 in which BATs are explained in detail. In 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 period 2023-2033 and responsible and relevant institutions have been assigned for these actions. Within the scope of the Action Plan, the General Directorate of Water Management is responsible for carrying out studies to determine specific water use ranges and quality requirements on the basis of sub-sectors in industry, organizing technical training programmes 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, sectoral best techniques specific to our country were determined within the scope of the studies for improving water efficiency in industry. As a result of the study, sectoral guidance documents and action plans categorized by NACE codes, including the 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 the 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 use in industry in Turkey

As a result of the studies, specific water consumption and potential saving 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. Within the guidelines, 500 techniques (BAT) 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 determination 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 analyses, innovative practices, reports of sector representatives were examined in detail and sectoral BAT lists were created. In order to evaluate 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, which were prioritized by sectoral stakeholders and determined by taking into account the local dynamics specific to our country, were used to create sectoral water efficiency guides on the basis of NACE code.

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 area 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 the sub-production area 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 the sub-production area 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 articles of clothing (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 transport equipment (including sub-production area represented by 2 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 sub-production area 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 area 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 transport (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)
- Sporting activities, leisure and recreation activities (including sub-production area represented by 1 four-digit NACE Code)

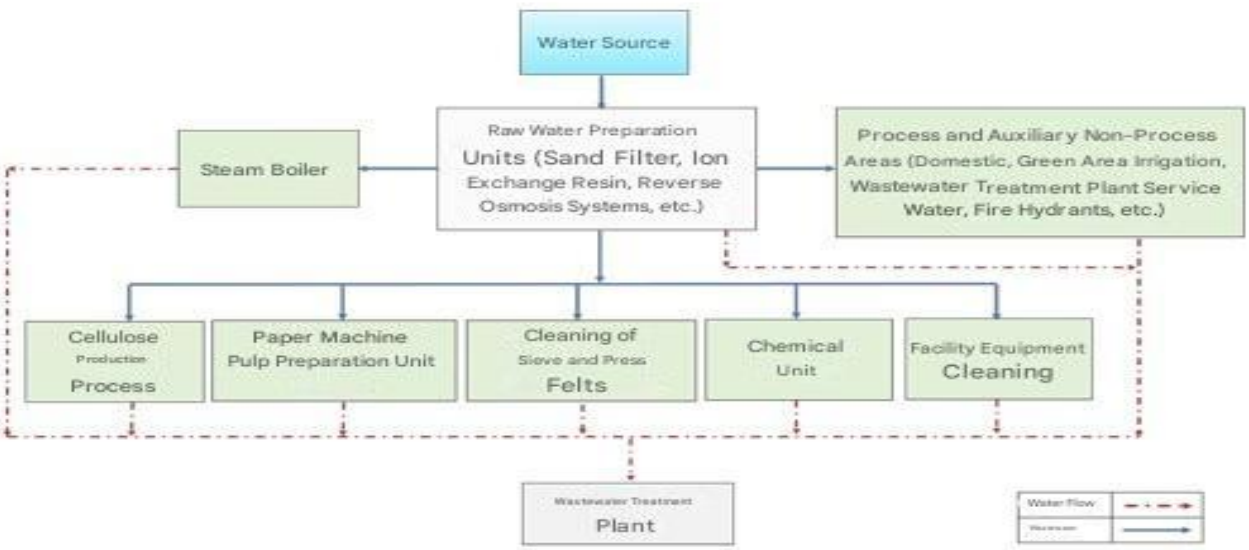
Manufacture of paper and paper products

Under the paper and paper products manufacturing sector, the sub-production branches for which guidance documents were prepared are as follows:

17.11	Paper pulp production
17.12	Paper and paperboard manufacturing
17.22	Manufacture of household, sanitary and toilet articles made of paper

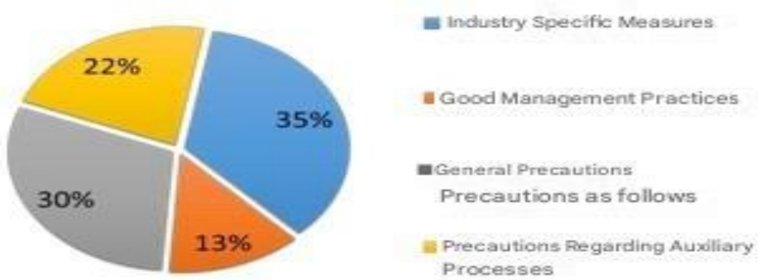
2.1 Paper and Paperboard Manufacturing (NACE 17.12)

Paper and Paperboard Manufacturing Water Flow Diagram



	Minimum	Maximum
Specific Water Consumption of Facilities Visited within the Scope of the Project (L/kg product)	3,5	28,6
Reference Specific Water Consumption (L/kg product)	1,5	55

Percentage Distribution of Water Efficiency Practices



Water Efficiency Guidance

In paper production, primary cellulose and secondary cellulose pulps produced from waste paper are taken to the pulper unit before the pulp preparation unit. Here, it is mixed with special blades with the addition of water and chemicals. The obtained pulp is passed through the selection and separation equipment and then taken to the grinder. After the grinder, it is transferred to the lower and upper sieve units. Here, various chemicals are introduced into the system according to the product to be produced and mixed with the pulp. The dry matter ratio of the pulp is increased by dewatering equipment. In the drying cylinders, the paper is contacted with hot surfaces to evaporate the water inside. In the glue press unit, glue (starch) is distributed on the paper surface. This process is carried out in order to increase the strength of the web tissue of the paper and to determine the ink holding capacity in printing and coating processes. During this process, the wetted paper is fed to the dryer unit and dried. It is wound on "shafts" and taken to the bobbin cutting machine. Rough texture is removed by applying the solution prepared by using water, white dye, binder and auxiliary chemicals. The chemicals used vary according to the desired product type.

Within the scope of 17.12 NACE code, cellulose pulp is generally obtained from paper wood, dry chips or partially recycled scrap paper waste and products such as craft paper, printable writing paper, packaging paper, adhesive paper are produced.

Water is consumed in the pulp preparation unit, screen, press and drying sections of the paper machine and in the chemical unit. High pressure steam is used to achieve the high temperatures applied in various process stages. For this reason, significant water consumption occurs in steam boilers in the paper industry. Significant water consumption also occurs 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 to be used in production processes in the sector.

The reference specific water consumption in the pulp manufacturing sector is in the range of 1.5 - 55 L/kg. The specific water consumption of the production line analyzed within the scope of the study is in the range of 3.5 - 28.6 L/kg. With the implementation of sector- specific techniques, good management practices, measures in the form of general measures and measures related to auxiliary processes
It is possible to provide 25 - 36% water recovery.

17.12 Paper and Paperboard Manufacturing NACE code, the recommended priority water efficiency implementation techniques are presented in the table below.

NACE Code	NACE Code Description	Sectoral Prioritizations Best Available
		Sector Specific Measures
17.12	Paper and paperboard manufacturing	1. Treatment of the white colored wastewater of the paper machine by dissolved air flotation (DAF) technique and recovery of the floc fibers and fillers for reintroduction into the process
		2. Regular and effective spill inspections for the control, collection and recovery of spills with high organic content, toxic or high pH values
		3. Recovery and reuse of acidic and alkaline filtrates, water and chemicals from bleaching stages in appropriate processes
		4. Anaerobic treatment of condensate from the evaporator
		5. Recirculation of water from the paper machine section to the pulp preparation section or from the pulp preparation section to the peeling unit
		6. Brown cellulose (pulp) screening for the early removal of impurities and chips with slotted and embossed screens in a gradual and closed water system
		7. Feeding fresh water (process water) from the paper machine showers to the pulp section with upward countercurrent flow and water recirculation
		Good Management Practices
		1. Use integrated wastewater management and treatment strategy to reduce wastewater quantity and pollutant load
		2. Establishment of environmental management system
		3. Preparation of water flow diagrams and mass balances for water
		4. Preparing a water efficiency action plan to reduce water use and prevent water pollution
		5. Providing technical trainings to personnel for the reduction and optimization of water use
		6. Good production planning to optimize water consumption
		7. Determination of water efficiency targets
		8. Monitoring the water used in production processes and auxiliary processes and the wastewater generated in terms of quantity and quality and monitoring this information in terms of environmental management system

NACE Code	NACE Code Description		Sectoral Prioritizations Best Available
			Measures in the nature of General Measures
17.12	Paper and paperboard manufacturing	1.	Minimizing spillages and leakages
		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.	Use of pressure washing systems for equipment cleaning, general cleaning, etc.
		4.	Avoiding the use of drinking water in production lines
		5.	Use of cooling water as process water in other processes
		6.	Identification and minimization of water losses
		7.	Use of automatic control-close valves to optimize water use
		8.	Documented production procedures are kept and used by employees to prevent water and energy wastage
		9.	Reuse of pressurized filtration backwash water prior to water softening at appropriate points
		10.	Optimizing the frequency and duration of regeneration (including rinses) in water softening systems
		11.	Construction of closed storage and impermeable waste/scrap sites to prevent the transport of toxic or hazardous chemicals for the aquatic environment
		12.	Storage and storage of substances (such as oils, emulsions, binders) that pose a risk in the aquatic environment and prevention of their mixing with wastewater after use
		13.	Prevention of mixing of clean water flows with polluted water flows Determination of wastewater flows that can be reused with or without
		14.	treatment by characterizing the wastewater quantities and qualities at all wastewater generation points
		15.	Use of closed loop water cycles in appropriate processes
		16.	Use of computer aided control systems in production processes
		17.	Untreated reuse of relatively clean wastewater from washing, rinsing and equipment cleaning in production processes
		18.	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.)
		19.	Implementation of time optimization in production and arrangement of all processes to be completed as soon as possible
		20.	Depending on the characterizations of nanofiltration (NF) or reverse osmosis (RO) concentrates, they can be reused with or without treatment.

NACE Code	NACE Code Description	Sectoral Prioritizations Best Available Techniques
17.12	Paper and paperboard	**Precautions for Auxiliary Processes**
		1. Saving water by reusing steam boiler condensate
		2. Water saving by insulation of steam and water lines (hot and cold)
		3. Prevention of water and steam losses in pipes, valves and connection points in the lines and monitoring with a computer system
		4. Reducing water consumption by increasing the number of cycles in closed loop cooling systems and improving the quality of make-up water With tower cooling application in systems without closed loop water recovery
		5. Increasing the number of cycles by using corrosion and scale inhibitors in systems with closed water cycle
		6. Prevention of flash steam losses due to boiler unloading Use of hot water produced in the cogeneration system in processes for heating purposes
		7. Installation of water softening systems for the healthy operation of cooling water recovery systems
		8. Use of a closed-loop cooling system to minimize water use
		9. Collecting the water generated by surface runoff with a separate collection system and using it for purposes such as cooling water, process water, etc.
		10. Reducing the amount of blowdown by using degassers in steam boilers
		11. Minimization of boiler discharge water (blowdown) in steam boilers
		12. Re-use of energy produced from steam condenser

A total of 48 techniques have been proposed in this sector.

For Paper and Paperboard Manufacturing NACE Code;

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

2.1.1 Sector Specific Measures

- ***Regular and effective spill inspections for the control, collection and recovery of spills with high organic content, toxic or high pH values***

  Conductivity and pH parameters are monitored at strategic locations to detect spills and leaks. Highly concentrated leachate or spillage water is collected and recovered for use in appropriate processes. Critical leaks such as tall oil and turpentine from process units are prevented before being sent to biological treatment. Appropriately sized buffer tanks are used for storage and collection of toxic or hot concentrated liquids (IPPC BREF, 2015a).

- ***Brown cellulose (pulp) screening for the early removal of impurities and chips with slotted and embossed screens in a gradual and closed water system***

  The use of a closed water system is important to reduce the amount of organic matter in the effluent. After the organics are recovered, they are incinerated in the recovery boiler. The aim of this process modification is to increase the amount of dry solids in the liquor solution by bringing clean water into the fiber line through a countercurrent flow. Another advantage of using this technique is the reduction of emissions in water.

- ***Feeding fresh water (process water) from the paper machine showers to the pulp section with upward countercurrent flow and water recirculation***

  In paper machine systems, paper machine showers are the most water-consuming unit. In order to reduce the use of clean water, process water should be used with the reverse flow principle. Process water supply and water recirculation to the pulp section with counter- current flow can reduce clean water consumption (IPPC BREF, 2015a).

- ***Recovery and reuse of acidic and alkaline filtrates, water and chemicals from bleaching stages in appropriate processes***

  In this process, acid and alkaline leachates from the bleaching stages are returned to the pulp process stream in a countercurrent flow. Effective scrubbers in the intermediate washing sections are essential to achieve low emissions (IPPC BREF, 2015a).

Dissolved Air Flotation Unit in Paper Industry

- ***Treatment of the white wastewater of the paper machine by dissolved air floatation (DAF) and recovery of flock fiber and fillers back into the process***

  Anionic fiber supernatant and fines are physically removed using additives are collected in treatable flocs. High molecular, water soluble flocculants polymers or inorganic electrolytes are used. The produced flocs are then floated in the treatment pond. In the dissolved air flotation technique, suspended solids (TSS) are attached to air bubbles (IPPC BREF, 2015a).

- ***Anaerobic treatment of condensate from the evaporator***

  In anaerobic wastewater treatment system, the organic content of wastewater is converted into methane, sulfur, carbon dioxide, etc. by microorganisms in an oxygen-free environment. In addition to aerobic treatment, anaerobic pretreatment reduces the organic pollution load of wastewater and the amount of sludge to be formed. However, anaerobic treatment should be considered as pretreatment before aerobic treatment due to the residual COD loads in the wastewater. Energy recovery can also be achieved by providing biogas production with anaerobic treatment (IPPC BREF, 2015a).

- ***Recirculation of water from the paper machine section to the pulp preparation section or from the pulp preparation section to the peeling unit***

  Wastewater such as disc filter filtrate from pulp production and peeling processes has a high pollution load. By recirculating water between these units and isolating the system so that there are no leaks, wastewater discharges and fiber losses to the canal are reduced. As part of the correct management of water in integrated systems, paper machine white wastewater can be reused with the reverse flow principle (IPPC BREF, 2015a).

- ***Treatment of the white wastewater of the paper machine by dissolved air floatation (DAF) and recycling of the flock fiber and fillers to be recirculated back into the process***

  This technique is described in the pulp making section.

- ***Recirculation of treated wastewater as process water within a unit or from the paper machine section to the pulping section or from the pulping section to the peeling unit to reduce wastewater generation***

  This technique is described in the section on paper and paperboard manufacturing. The manufacture of corrugated paper and paperboard is also used in the manufacture of other products from paper and paperboard.

Paper Machine

Paper Pulp

1.2 Good Management Practices

- **Establishment of environmental management system**

Environmental Management Systems (EMS) include the organizational structure, responsibilities, procedures and resources required to develop, implement and monitor the environmental policies of industrial organizations. The establishment of an environmental management system improves the decision-making processes 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 has been developed for the assessment, improvement and reporting of the environmental performance of enterprises. 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 obtained by improving business performance (Christopher, 1998).
- International Standards Organization (ISO) standards are adopted to ensure greater compliance with global legal and regulatory requirements (Christopher, 1998).
- While the risks of penalties related to environmental responsibilities are minimized, 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 certificates for businesses operating in different locations around the world (Hutchens Jr., 2017).
- Especially in recent years, consumers also consider the improvement of the internal control processes of companies important. 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 the 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 the 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, ISO 46001 Water Efficiency Management Systems Standard, which helps industrial organizations to save water and reduce operating costs, helps organizations to 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 very important 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 evaluated 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 determine priorities based on multiple criteria for industrial wastewater management processes (Adar et al., 2021).

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

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

In industrial production processes, planning by using the least process in the process from raw material to product is an effective practice for reducing labor costs, resource use costs and environmental impacts and ensuring efficiency (TUBITAK MAM, 2016; TOB, 2021). Production planning in industrial plants, taking into account the water efficiency factor, reduces water consumption and wastewater amount. Modification of production processes in industrial plants or combining some processes 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, 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 sources with or without treatment, etc. can be determined. It is also very 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***

Determination of water use and wastewater generation points in industrial plants, establishment of 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 the basis of plant-wide and production processes 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).

- ***Providing technical trainings to personnel 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 consumption 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, which represent a significant proportion of water consumption in industrial operations, are properly trained and have technical knowledge. Determination of water quality requirements in production processes, measurement of water and wastewater quantities, etc. It is also necessary for the relevant personnel to have sufficient technical knowledge (TOB, 2021). Therefore, it is important to provide training to staff on water use reduction, optimization and water saving policies. Practices such as involving the staff in water saving studies, creating regular reports on the amount of water use before and after water efficiency initiatives, and sharing these reports with the staff support participation and motivation in the process. The technical, economic and environmental benefits to be obtained through staff training yield results in the medium or long term (TUBITAK MAM, 2016; TOB, 2021).

- ***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***

There is resource utilization in industrial facilities, and inefficiency and environmental problems resulting from resource utilization may arise from input-output flows. Therefore, 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 25% (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 counters) to monitor water, energy, etc. consumption on a process basis,
- Establishment of monitoring procedures,
- Determining the usage/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).

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

It is important for water efficiency to prepare an action plan that includes short, medium and long term actions to be taken in order to reduce water-wastewater quantities and prevent water pollution in industrial facilities. At this point, determination of water needs throughout the facility and in production processes, determination of quality requirements at water use points, wastewater generation points and wastewater characterization should be carried out (TOB, 2021). At the same time, it is necessary to determine the measures to be implemented to reduce water consumption, wastewater generation and pollution loads, to make their feasibility and to prepare action plans for the short-medium-long term. In this way, water efficiency and sustainable water use are ensured in the facilities (TOB, 2021).

2.1.3 Measures in the nature of General Measures

- ***Identification and minimization of water losses***

Water losses occur in equipment, pumps and pipelines in industrial production processes. Firstly, water losses should be identified and leakages should be prevented by regular maintenance of equipment, pumps and pipelines to keep them in good condition (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,
- Carrying out inspections not only in the water system, but also in particular in the heat transfer and chemical distribution systems, broken and leaking pipes, barrels, pumps and valves,
- Regular cleaning of filters and pipework,
- Calibrate, routinely check and monitor measuring 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).

- ***Minimizing spillages and leakages***

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 spillage occurs, 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, sieves (IPPC BREF, 2019).

- ***Untreated reuse of relatively clean wastewater from washing, rinsing and equipment cleaning in production processes***

In industrial plants, relatively clean wastewater such as washing-final rinse wastewater and filter backwash wastewater can be reused without treatment in floor washing and garden irrigation processes that do not require high water quality, saving between 1-5% in raw water consumption. The initial investment costs required for the application are the installation of new pipelines and reserve tanks (Öztürk, 2014).

- ***Use of cooling water as process water in other processes***

Water cooling systems are widely used in processes where thermal energy is used intensively and cooling is required. It is possible to recover heat by using heat exchangers in cooling water return, prevent contamination of cooling water, and save water and energy by increasing cooling water return rates (TUBITAK MAM, 2016; TOB, 2021). In addition, in case of separate collection of cooling water, it is generally possible to use the collected water for cooling purposes or to reuse it in appropriate processes (EC, 2009). Reuse of cooling water can save 2-9% of total water consumption (Greer et al., 2013). Energy consumption can be saved up to 10% (Öztürk, 2014; TOB, 2021).

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

  By determining the wastewater generation points in industrial facilities and characterizing the 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. With the separation of 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 providing wastewater recovery and recovery of valuable materials. In addition, heat recovery from separated hot wastewater streams is also possible (TUBITAK MAM, 2016; TOB, 2021). Separation of wastewater streams usually requires high investment costs, and where it is possible to recover large amounts of wastewater and energy, costs can be reduced (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***

  It is possible to reuse various wastewater streams with or without treatment by determining and characterizing the wastewater generation points in industrial facilities (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 plant 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 provide 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 counters 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 application, it is possible to save up to 20-30% of water consumption on process basis (DEPA, 2002; LCPC, 2010; IPPC BREF, 2003). By monitoring and controlling water consumption on a process basis, 3-5% savings can be achieved in process water consumption (Öztürk, 2014).

- ***Use of pressure washing systems for equipment cleaning, general cleaning, etc.***

  Water nozzles are widely used in equipment plant cleaning. Effective results can be achieved by using correctly placed, appropriate nozzles to reduce water consumption and wastewater pollution loads. The use of active sensors and nozzles at points where high water consumption occurs and where possible is very important in terms of efficient use of water. It is possible to achieve significant water savings by replacing mechanical equipment with pressurized nozzles (TUBITAK MAM, 2016). Reducing water consumption, wastewater generation and wastewater pollution load through the use of water pressure optimized nozzles in technically appropriate processes are the main environmental benefits of the application.

- ***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 supplied from groundwater sources is generally used in production processes after treatment. However, in some cases, although it is costly in production processes, drinking water can be used directly 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 substances (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, the determination and use of the water quality parameters required in each production process helps to reduce unnecessary water supply and treatment costs. With this application, it is possible to reduce water, energy and chemical costs (TUBITAK MAM, 2016).

- ***Reuse of pressurized filtration backwash water prior to water softening at appropriate points***

  Softened water with low calcium and magnesium concentrations is required for many industrial processes. With water softening systems, calcium, magnesium and some other metal cations in hard water are removed from the water and soft water is obtained.

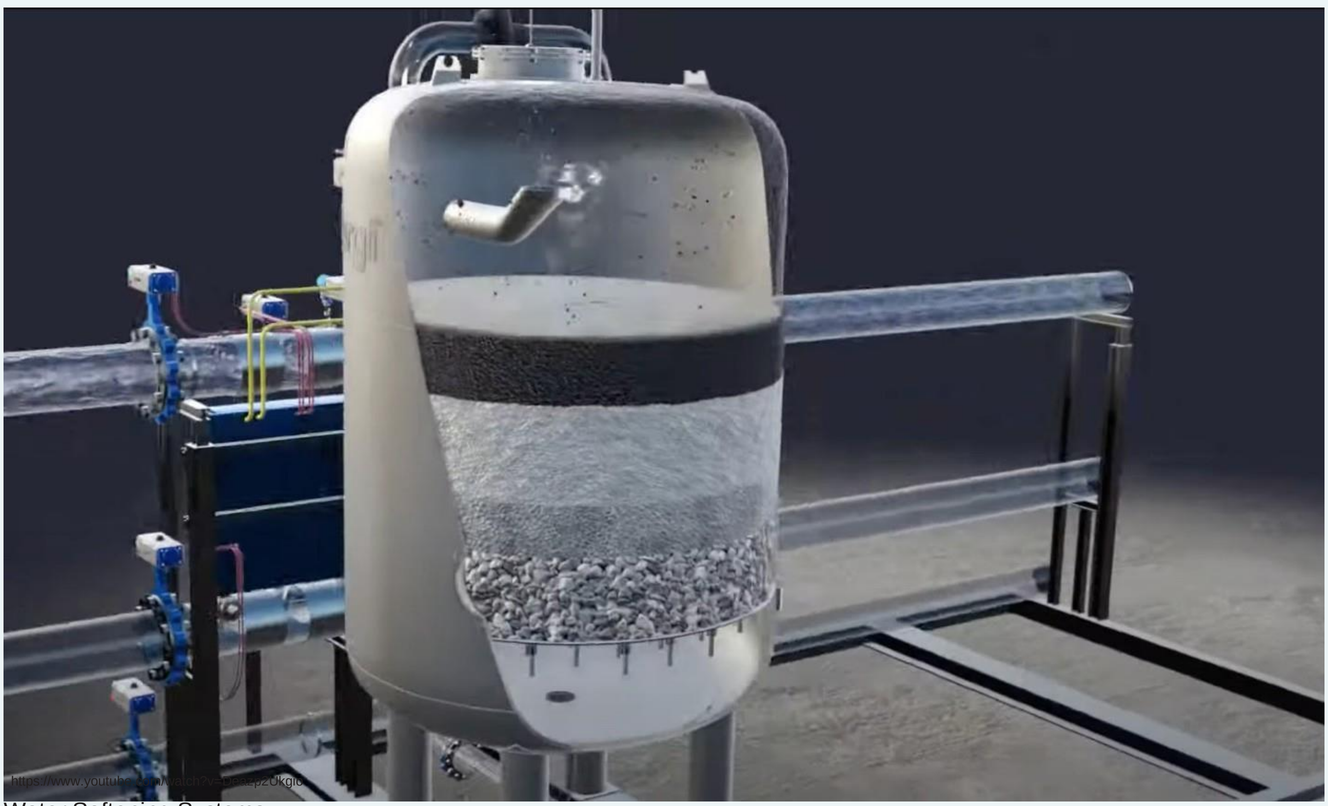
  Savings are achieved by reusing pressurized filtration backwash water at appropriate points before water softening. This measure is similar in content with practices such as "Reuse of filter backwash water in filtration processes, reuse of relatively clean water in production processes, reduction of water consumption by using on-site cleaning systems".

- ***Optimizing the frequency and duration of regeneration (including rinses) in water softening systems***

Cationic ion exchange resins, which are one of the most frequently used methods for softening raw water in industrial plants, are routinely regenerated. In regeneration, pre- washing of the resin using raw water, regeneration with salt water and final rinsing processes are carried out respectively. Regeneration periods are determined depending on the hardness of the water. If the hardness is high, regeneration should be performed more frequently in water softening systems.

In regeneration processes, washing, regeneration and rinsing wastewaters are generally removed directly. However, if the washing and final rinsing waters are of raw water quality, they can be sent to raw water storage or reused in processes that do not require high water quality such as facility cleaning and green area irrigation (TOB, 2021).

It is very important to determine the optimum regeneration frequency in regeneration systems. Although regeneration in water softening systems is adjusted according to the frequencies recommended by the supplier or depending on the flow rate and time entering the softening system, this frequency also varies depending on the calcium concentration in the raw water. For this reason, online hardness measurement is applied while determining the regeneration frequency. Thus, regeneration frequencies can be optimized and excessive washing rinsing or backwashing with salt water can be prevented by using online hardness sensors.


https://www.youtube.com/watch?v=Deazp2Ukgio

Water Softening Systems

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

Depending on the wastewater characterization and the appropriate point of use, the reuse potential 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 characterizations. 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).

- ***Storage, storage and post-use of substances (such as oils, emulsions, binders) that pose a risk to the aquatic environment should be prevented from mixing with wastewater as much as possible***

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

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

In industrial facilities, closed and impermeable waste/scrap storage sites can be constructed to prevent the transport 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 constructed in the storage areas of toxic or hazardous substances in industrial facilities and the leachate can be collected separately and prevented from mixing into natural water environments.

Reverse Osmosis System

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

  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 and in many processes led by the product cooling process. During this cooling process, water can be reused through cooling tower 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 are 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 where aqueous cooling systems are used. However, cooling system blowdowns are discharged directly to the wastewater treatment plant channel. This blowdown water can be reused in appropriate production processes.

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

  Since inefficient resource utilization and environmental problems in industrial facilities are directly related 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 as 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). It is necessary to use measurement equipment on the basis of application processes and to carry out some routine analyses/measurements specific to the processes. 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).

- ***Use of automatic hardware and equipment (sensors, smart hand washing systems, etc.) that will 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 meet the necessary hygiene standards. Water consumption in the production processes of industrial facilities can be provided in various ways, as well as water consumption savings can be achieved by using equipment such as sensor faucets and smart hand washing systems in the water usage areas of the personnel. Smart hand washing systems provide resource efficiency in addition to water saving while adjusting the water, soap and air mixture at the right rate.

- ***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 shower, sink, kitchen etc. areas is called grey water. Water savings can be achieved by treating these grey waters with various treatment processes and using them in areas that do not require high water quality.

- ***Documented production procedures are kept and used by employees to prevent water and energy wastage***

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 evaluation of business performance and the development of the ability to develop immediate reflexes to solve problems (TUBITAK MAM, 2016; TOB, 2021). Effective implementation and monitoring of the procedures created specifically for production processes is one of the most effective ways to ensure product quality, receive feedback and develop solutions (Ayan, 2010). Documentation, effective implementation and monitoring of 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 it will provide (TUBITAK MAM, 2016; TOB, 2021).

- ***Implementation of time optimization in production and arrangement of 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 for reducing labor costs, resource use costs and environmental impacts and ensuring efficiency. In this context, it may be necessary to revise the production processes so that the minimum number of process steps is used (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 utilisation and the amount of waste, emission and solid waste generated in the production of unit amount of product increases. Time optimisation in production processes is an effective application (TUBITAK MAM, 2016).

Computer Aided Control System

2.1.4 Precautions for Auxiliary Processes

BATs for steam generation

- ***Ensuring water saving by insulating steam and water lines (hot and cold) and preventing water and steam losses in pipes, valves and connection points in the lines and monitoring them with a computer system***

Steam losses may occur if the steam lines are not designed properly, routine maintenance and repairs of the steam lines are not carried out, mechanical problems occurring in the lines and the lines are not operated properly, steam lines and hot surfaces are not fully insulated. This situation affects both water consumption and energy consumption of the plant. It is necessary to use control systems with automatic control mechanisms in order to make steam isolation and continuous monitoring of steam consumption. Depending on the reduction of steam losses, similar savings can be achieved in fuel consumption and additional soft water consumption in boilers. Since fuel consumption in steam boilers will decrease, waste gas emissions are expected to decrease at the same rate. Since the use of additional soft water used in steam boilers will decrease with the application, the amount of regeneration water, the amount of salt used in regeneration and reverse osmosis concentrates are also reduced. Full steam isolation application and automatic control mechanisms to minimize steam losses are used in many plants with intensive steam consumption. With the configuration of the application, fuel savings of 2-4% are achieved in steam boilers.

In order to prevent losses in production processes; adding the most important parts of the equipment such as pumps, valves, control knobs, pressure, flow regulators to the maintenance check list, inspecting not only water systems but also heating and chemical dispensing systems, drums, pumps and valves, regular cleaning of filters and pipelines, regular calibration of measuring equipment (thermometers, chemical scales, dispensing/dosing systems, etc.) and inspection and cleaning of heat treatment units (including chimneys) at routinely determined periods, effective maintenance-repair, cleaning and loss control practices can reduce water consumption by %.Regular calibration of measuring equipment (thermometers, chemical scales, distribution/dosing systems, etc.), inspection and cleaning of heat treatment units (including chimneys) routinely at specified periods, effective maintenance-repair, cleaning and loss control practices can save 1-6% in water consumption (Hasanbeigi, 2010; Öztürk, 2014; TOB, 2021).

Industrial Steam Boilers

- ***Saving water by reusing steam boiler condensate***

When steam indirect heating techniques are used to transfer thermal energy in production processes, recovery of condensed steam (condensate) is an effective application in terms of reducing water consumption (IPPC BREF, 2009). An average of 5% reduction in water consumption can be achieved by recovering condensate (Greer et al., 2013). In addition, the potential payback period varies between 4-18 months (considering energy savings) (Öztürk, 2014; TUBİTAK MAM, 2016).

- ***Prevention of flush steam losses due to boiler unloading***

Steam boiler condensate is generally discharged from the system at atmospheric pressure from equipment outlets and steam traps. As the pressure decreases in condensate systems, some of the condensate re-evaporates and cools to the boiling point of water at atmospheric pressure. The re-evaporated condensate, called flash steam, is lost by being thrown into the atmosphere. In condensate return lines, which are usually quite long, cooling and therefore evaporation is inevitable. In order to prevent re-evaporation of condensate, savings can be achieved by keeping it in a flash tank under pressure until it returns to the boiler feed tank. As the pressure decreases in the condensate taken into the tank, the vapor formed is collected on the tank and feeds the low pressure steam system from here. The remaining hot condensate is taken from the bottom of the tank to the boiler.

- ***Minimization of boiler discharge water (blowdown) in steam boilers***

Boiler blowdown refers to the water wasted from a boiler to prevent the condensation of pollutants during the continuous evaporation of steam. Boiler blowdown can be reduced by 50% with condensate recovery (IPPC BREF, 2009).

In automatic systems, blowdowns in the boilers are continuously monitored and the system is re-analyzed with the water taken after the blowdown. In the analysis, data such as dissolved and undissolved particles in the water and water density are processed. If the density for the boiler is above the system limits, the blowdown process is repeated. The system should be automated and the optimum blowdown frequency should be determined. When the blowdown frequency is reduced, the amount of wastewater decreases. Energy and cooling water used for cooling this wastewater is saved (IPPC BREF, 2009). By optimizing the steam boiler blowdown process, operating costs are reduced by saving on boiler water consumption, waste costs, treatment and heating.

- ***Re-use of the energy generated from the steam condenser***

With a simple modification to the pipework system, the water supplying the water resting/decarbonizing unit can be obtained from the outlet of the turbine condenser unit. This water has a sufficient temperature for the resting/decarbonizing unit. Therefore, it is not necessary to heat this water by means of steam produced by the heat exchanger system. Significant vapor recovery can be achieved through this operation. Cooling water consumption can also be reduced (CPRAC, 2021).

- ***Reducing the amount of blowdown by using degassers in steam boilers***

Free oxygen dissolved in the feed water of steam boilers and hot water boilers and carbon dioxide formed by the decomposition of carbonates in boilers can cause corrosion in the form of pores, rusting and melting in steam boilers, steam appliances and especially in installations. The effects of these gases increase as the fresh feed water ratio and system operating pressure increase. If these dissolved gases are not removed from the boiler feed water, the useful life of these systems is shortened, corrosion and various deformations may occur. These gases also cause excessive corrosion in carbon dioxide coils, steam devices and condensate pipes. Boiler feed water must be purified from dissolved gases such as oxygen and carbon dioxide by passing through degasser. Degasser systems are mechanical systems that provide the evaporation of dissolved gases from the water by supplying air to the water with a fan. Dissolved gas removal can be increased by increasing the water and air contact surface in the degasser system. In this way, while corrosion formation is reduced, boiler efficiency is increased (TUBITAK MAM, 2016; TOB, 2021).

BATs for cooling systems

- ***Use of a closed-loop cooling system to minimize water use***

Closed loop cooling systems significantly reduce water consumption compared to open loop systems with more intensive water use. In closed loop systems, while the same water is recirculated within the system, it is usually necessary to add cooling water equal to the amount of water evaporated. By optimizing cooling systems, evaporation losses can also be reduced.

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

Water is used as a refrigerant in many processes such as production processes of the manufacturing industry and cooling of products. 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 recirculation 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 saving can be achieved. In addition, good conditioning of the cooling make-up water can also increase the number of cycles (TOB, 2021).

- ***Tower cooling application in systems without closed loop water reuse***

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 to 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. Recovery of blowdown wastewater is important for water efficiency.

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

  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 the impurity concentrations gradually increase in each cycle. Impurities that can be included in the cooling system together with air can cause contamination in recirculation 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 programme specifically designed for the quality of the feed water supplied to the cooling system, the cooling water system construction material and operating conditions. In this context; blowdown control, control of biological growth, corrosion control, avoidance of hard water, use of sludge control chemicals, filtration and screening systems may be appropriate (TUBITAK MAM, 2016). The establishment and periodic implementation of an effective cleaning procedure and programme is also a good management practice for the protection of cooling systems. Corrosion is one of the most important problems in cooling systems. In tower recirculation water, dissolved solids (sulphate, chloride, carbonate, etc.) that 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 reduces energy efficiency by negatively affecting heat transfer. In order to prevent these problems, chemical treatment programme should be applied to prevent scale and corrosion, disinfection with biological activation inhibitor biocide, cooling towers in use should be subjected to chemical and mechanical cleaning 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). In order to improve the quality of the makeup water, it may be necessary to treat (condition) it using an appropriate treatment system. In addition, unwanted microbial growth should be kept under control (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 stabilize the increasing 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). Although the investment cost depends on the scale of the application, the payback period for the expected investment costs varies between 3 and 4 years (IPPC BREF, 2001).

- ***Collecting the water generated by surface runoff with a separate collection system and using it for purposes such as cooling water, process water, etc.***

  In most industrial plants, wastewater is generated from process or non-process areas. The wastewater generated can be treated and reused in appropriate places. Savings can be achieved at varying rates in various industrial plants by reusing the wastewater generated in the plant after treatment. Water generated by surface runoff can be collected with a separate collection system and used as cooling water (TOB, 2021).

- ***Installation of water softening systems for the healthy operation of cooling water recovery systems***

  Cooling water is collected separately and used for cooling purposes or recycled in appropriate processes (EC, 2009). A water softening system is required for this system to work properly. Cooling water has suitable water quality for reuse as cleaning and irrigation water. However, since it contains some hardness in its use as cooling water, additional softening is required to prevent corrosion problems that will occur over time. These waters should be subjected to an appropriate disinfection process before being reused as cooling water or in the process. In addition, these waters can be treated with appropriate treatment techniques (membrane filtration, advanced oxidation, chemical precipitation, granular activated carbon adsorption, etc. processes) and reused not only in cooling processes but also in all production processes (TUBITAK MAM, 2016). As the hardness of the cooling water increases, limestone and deposit formation occurs on the walls. The formation of deposits adversely affects heat transfer, reducing energy efficiency and increasing energy costs. With the increase in evaporation in the system, the ion concentration and conductivity value in the water increases. In order to prevent these negativities, chemical treatment of the cooling water to prevent scale and corrosion, disinfection with a biocide that prevents biological activation, chemical and mechanical cleaning of cooling towers at least twice a year and cleaning of deposits, hardness and conductivity values should be kept as low as possible (TUBITAK MAM, 2016).

BATs for cogeneration system

- ***Utilization of hot water produced in the cogeneration system in processes for heating purposes***

  With the inclusion of cooling systems in cogeneration systems (trigeneration), it is possible to convert 10-30% efficiency losses into hot water, sub-air, cold air, hot air and water (absorption heat exchangers should be used for this purpose). In this way, it is possible to meet a part of the energy required in processes such as cooling and drying in the plant from the waste heat in the cogeneration systems. Energy costs can be reduced by up to 40% in plants utilizing cogeneration systems (TUBITAK MAM, 2016).

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