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MINISTRY OF AGRICULTURE AND FORESTRY
GENERAL DIRECTORATE OF WATER MANAGEMENT



Water Efficiency Guidance Documents Series

MAINTENANCE AND REPAIR OF AIRCRAFT AND SPACE VEHICLES

NACE CODE: 33.16

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Abbreviations

WTP	Wastewater Treatment Plant
EU	European Union
SSM	Suspended Solid Matter
BREF	Best Available Techniques Reference Document
EMS	Environmental Management System
MoEUCC	Republic of Turkey Ministry of Environment, Urbanization and Climate Change
NOM	Natural Organic Matter
EMAS	Eco Management and Audit Program Directive
EPA	United States Environmental Protection Agency
IPPC	Industrial Pollution Prevention and Control
ISO	International Organization for Standardization
BAT	Best Available Techniques
NACE	Statistical Classification of Economic Activities
GDWM	General Directorate of Water Management
RO	Reverse Osmosis
MAF	Ministry of Agriculture and Forestry of the Republic of Turkey
TurkStat	Turkish Statistical Institute
NF	Nanofiltration
MF	Microfiltration
UF	Ultrafiltration
GW	Groundwater
SW	Surface Water

1 Introduction

Türkiye 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 Türkiye is 1,313 m³, and it is expected that the annual amount of water available per capita will fall below 1,000 cubic metres after 2030 due to human pressures and the effects of climate change. If the necessary measures are not taken, it is obvious that Türkiye 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, the change in precipitation and temperature regimes as a result of climate change, the increase in population, urbanisation and pollution, the fair and balanced distribution 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 optimisation 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.

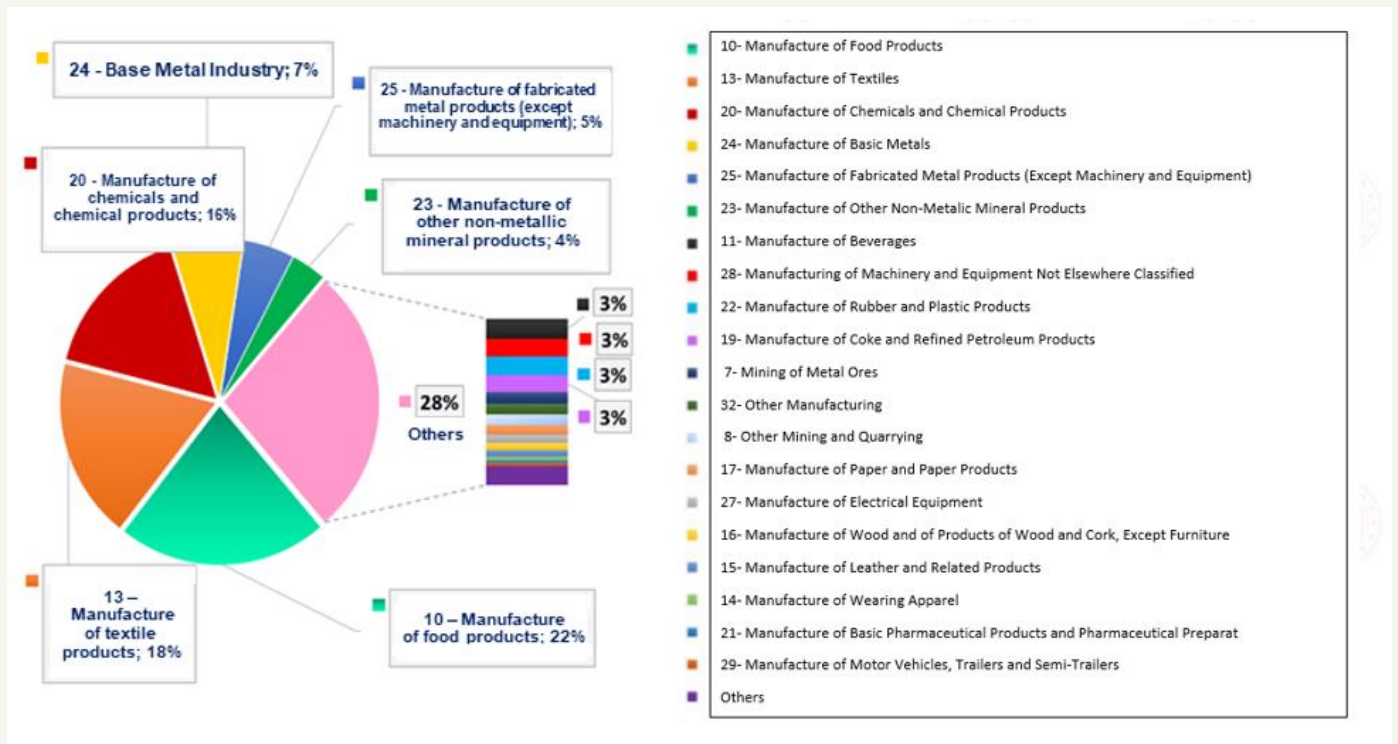
In the European Green Deal Action Plan prepared by our country within the scope of the European Green Deal Action Plan, in which member countries agreed on the objectives such as implementing a clean, circular economy model with a carbon neutral target, expanding the efficient use of resources and reducing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

The "Industrial Emissions Directive (IED)", 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 systematise the applicability of cleaner production processes and to 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, organising 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 categorised 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, especially food, textile, chemical, basic metal industry, which represent production areas of different capacity 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 Türkiye

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 Water Efficiency BATs, (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 prioritised 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 prioritised 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.

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)
- Manufacture of electrical equipment (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)

Installation and repair of machinery and equipment

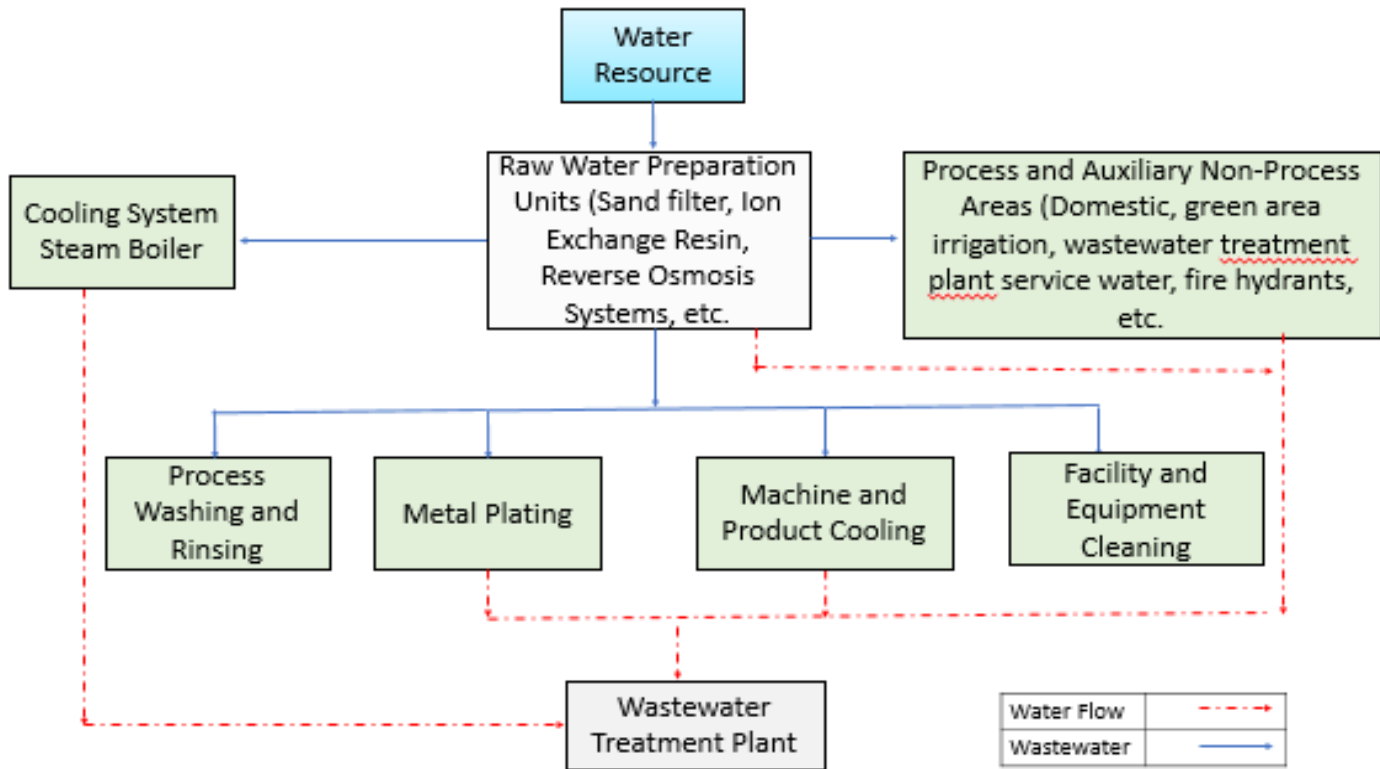
Under the installation and repair of machinery and equipment sector, the sub-production branches for which guidance documents have been prepared are as follows

33.16 Maintenance and repair of aircraft and space vehicles

33.20 Installation of industrial machinery and equipment

2.1 Maintenance and Repair of Aircraft and Space Vehicles (NACE 33.16)

Flow Chart for Maintenance and Repair Sector of Aircraft and Space Vehicles



	Minimum	Maksimum
Specific Water Consumption of Facilities Visited bitin the Scope of the Project (L/person.day)	549,3	
Reference Specific Water Consumption (L/person.day)	There is no specific water consumption value	

Percentage Distribution of Water Efficiency Practices



In the maintenance and repair of aircraft and spacecraft sector, technical maintenance, repair and renovation services of cargo and passenger aircraft, installation and repair of in-cabin entertainment systems, production and repair of data cables for aircraft, etc. are carried out.

Within the scope of the related activities, assembly of metal materials and metal coating processes are carried out. Water is consumed in the metal coating process and for machine cooling. The water used for product cooling in the sector is used recirculated and is added as it decreases as a result of evaporation. If there are raw water preparation units such as activated carbon filter, ion exchange resin, reverse osmosis used to produce soft water to be used in production processes, water consumption is also significant for filter washing, resin regeneration and membrane cleaning processes. Water consumption also occurs in auxiliary processes such as cooling system and steam boilers. If the final product to be obtained is subjected to dyeing process, water consumption occurs in the dyeing process

There is no reference specific water consumption value in the maintenance and repair of aircraft and space vehicles sector. The specific water consumption of the production line analysed within the scope of the study is 549.3 L/piece. Sector-specific measures, implementation of good management practices, general water efficiency BATs and measures related to auxiliary processes are implemented in the sector. It is possible to provide 51 - 69% water recovery.

33.16 Maintenance and Repair of Aircraft and Space Vehicles NACE code within the scope of the proposed priority water efficiency implementation techniques are presented in the table below.

NACE Code	NACE Code Description	Prioritised Sectoral Water Efficiency Techniques
33.16	Maintenance and repair of aircraft and space vehicles	<p>Sector Specific Measures</p> <ol style="list-style-type: none"> 1. Wastewater treatment plant effluent is treated by coagulation, flocculation, sand filtering and activated carbon filtering after being blended with rainwater or well water to obtain good quality water to be used in cooling tower (Galeão Airport, Brazil) 2. Replacement of conventional sanitary fittings with more efficient ones, e.g. fittings with two-stage flushing mechanisms or waterless urinals 3. Rainwater drainage system discharges rainwater from aprons, de-icing areas, roads, car parks and roofs, collects it in ponds and feeds it to the irrigation system, fire control system and toilet flushes through separate systems (Frankfurt International Airport, Germany) 4. Use of reclaimed water or rainwater for car and aircraft washing 5. Use of treated wastewater for car washing and sending wastewater from car washing to treatment plant (Dubai Airport, UAE) 6. Treatment of wastewater with membrane bioreactor system and utilisation in green area irrigation and fire control (Qingdao Airport, China) 7. Use of seawater in siphons and cooling systems at airports close to the sea (Hong Kong Airport, China) 8. Reducing irrigation requirements by using appropriate plant material by making soil / climate analysis in landscape areas 9. Use of sanitary, kitchen and restaurant wastewater for landscape irrigation or fire control after activated sludge system + disinfection (Fiumicino Airport, Rome) 10. Use of leak detection programme and advanced real-time water demand monitoring system 11. Use of rainwater collected from terminal roofs or satellite buildings to dilute crude glycol for de-icing aircraft or runways (Heathrow Airport, London) 12. Providing flow with a mixture of water and air by using tap aerators, and installing flow restriction devices on taps that cannot be equipped with aerators 13. Use of rainwater cisterns for plant irrigation in landscape areas 14. Grey water collected from aircraft catering facilities and terminal building kitchens is treated together with water from aircraft washing activities used in irrigation systems (Hong Kong Airport, China)

NACE Code	NACE Code Description	Prioritised Sectoral Water Efficiency Techniques
33.16	Maintenance and repair of aircraft and space vehicles	<p>15. Treatment of wastewater from restaurant kitchens in passenger terminals and feeding it to toilet flushing systems (Narita Airport, Japan)</p> <p>16. Irrigation only when necessary, using sensors to monitor soil moisture instead of timed or manually controlled devices</p> <p>Good Management Practices</p> <p>1. Preparing a water efficiency action plan to reduce water use and prevent water pollution</p> <p>2. Providing technical trainings to personnel for the reduction and optimisation of water use</p> <p>3. Determination of water efficiency targets</p> <p>General Water Efficiency BATs</p> <p>1. Minimising spillages and leakages</p> <p>2. Recovery of water from rinsing solutions and reuse of recovered water in processes appropriate to its quality</p> <p>3. 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.</p> <p>4. Use of pressure washing systems for equipment cleaning, general cleaning, etc.</p> <p>5. Reducing water consumption by reusing filter wash water in filtration processes, reusing relatively clean cleaning water in production processes and using clean-in-place systems (CIP)</p> <p>6. Avoiding the use of drinking water in production lines</p> <p>7. Use of cooling water as process water in other processes</p> <p>8. Identification and minimisation of water losses</p> <p>9. Use of automatic control-close valves to optimise water use</p> <p>10. Documented production procedures are kept and used by employees to prevent water and energy wastage</p> <p>11. Reuse of pressurised filtration backwash water prior to water softening at appropriate points</p> <p>12. Optimising the frequency and duration of regeneration (including rinses) in water softening systems</p> <p>13. Construction of closed storage and impermeable waste/scrap sites to prevent the transport of toxic or hazardous chemicals for the aquatic environment</p> <p>14. Preservation 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</p> <p>15. Prevention of mixing of clean water flows with polluted water flows</p> <p>16. Determination of wastewater flows that can be reused with or without treatment by characterising the wastewater quantities and qualities at all wastewater generation points</p>

NACE Code	NACE Code Description	Prioritised Sectoral Water Efficiency Techniques
33.16	Maintenance and repair of aircraft and space vehicles	<p>17. Use of closed loop water cycles in appropriate processes</p> <p>18. Use of computer aided control systems in production processes</p> <p>19. Untreated reuse of relatively clean wastewater from washing, rinsing and equipment cleaning in production processes</p> <p>20. Determination of the scope of reuse of washing and rinsing water</p> <p>21. 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.)</p> <p>22. Implementation of time optimisation in production and arrangement of all processes to be completed as soon as possible</p> <p>23. Collecting rainwater and utilising it as an alternative water source in facility cleaning or in suitable areas</p> <p>24. Preventing the need for rinsing between activities by using compatible chemicals in sequential processes</p> <p>25. Reuse of nanofiltration (NF) or reverse osmosis (RO) concentrates with or without treatment depending on their characterisation</p> <p>Precautions for Auxiliary Processes</p> <p>1. Saving water by reusing steam boiler condensate</p> <p>2. Ensuring water saving by insulating steam and water lines (hot and cold), preventing water and steam losses in pipes, valves and connection points in the lines and monitoring them with a computer system</p> <p>3. Replacement of old equipment in the aeration system with ion exchange resins based on the principle of reverse osmosis (systems producing demineralised water) and water reuse</p> <p>4. Re-use of the liquid formed by condensation from the ventilation system</p> <p>5. Avoiding unnecessary cooling processes by identifying processes that need wet cooling</p> <p>6. Reducing water consumption by increasing the number of cycles in closed loop cooling systems and improving the quality of make-up water</p> <p>7. Reduction of evaporation losses in closed loop cooling water</p> <p>8. Increasing the number of cycles by using corrosion and scale inhibitors in systems with closed water cycle</p> <p>9. Prevention of flash steam losses due to boiler discharge</p> <p>10. Use of air cooling systems instead of water cooling in cooling systems</p>

NACE Code	NACE Code Descriptio	Prioritised Sectoral Water Efficiency Techniques
33.16	Aircraft and spacecraft maintenance and repair	<ol style="list-style-type: none"> 11. Installation of water softening systems for the healthy operation of cooling water recovery systems <hr/> 12. Use of a closed-loop cooling system to minimise water use <hr/> 13. Local dry air cooling in some periods of the year when the cooling requirement is low <hr/> 14. Collecting the water generated by surface runoff with a separate collection system and using it for purposes such as cooling water, process water, etc. <hr/> 15. Reducing the amount of blowdown by using degassers in steam boilers <hr/> 16. Minimisation of boiler discharge water (blowdown) in steam boilers <hr/> 17. Re-use of the energy produced from the steam condenser

A total of 61 techniques have been proposed in this sector.

Maintenance and Repair of Aircraft and Space Vehicles NACE Code;

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

2.1.1 Sector Specific Measures

- ***Treatment of wastewater with membrane bioreactor system and utilisation in green area irrigation and fire control (Qingdao Airport, China)***

The global trend in the treatment and reuse of domestic wastewater has led to the increasing adoption of similar practices at airports (Carvalho et al., 2013). At Qingdao Airport in China, membrane bioreactors are used for wastewater treatment. The airport has a wastewater treatment capacity of 1,000 m³/day. The treated wastewater is used for maintenance of the airport complex, afforestation, green area irrigation and fire control systems (Liu et al., 2007).

It is recommended to strengthen the pre-treatment in order to reduce membrane fouling in the installed system. MBR effluent is suitable for various consumption in terms of quality and can be used for afforestation, fire fighting and landscaping areas (Liu et al., 2007).



Landscaping and Green Space Application at Qingdao Airport

- ***Use of treated wastewater for car washing and sending wastewater from car washing to treatment plant (Dubai Airport, UAE)***

Dubai Airport has a wastewater treatment plant with a daily treatment capacity of 80 m³ and an oil-water separator system. Wastewater treatment plant effluent is reclaimed and used for washing vehicles and engineering works. All vehicles operated by the Engineering Services Department are cleaned using recycled water and all drainage water is sent back to the wastewater treatment plant. Domestic wastewater is treated and reused for green area irrigation in the airport complex to minimise water consumption (Carvalho et al., 2013).

- ***Use of sanitary, kitchen and restaurant wastewater for landscape irrigation or fire control after activated sludge system + disinfection (Fiumicino Airport, Rome)***

As an example of this method, at Fiumicino Airport in Rome, grey water from terminal restaurants and the company responsible for the preparation of food served on board is collected and treated together with domestic wastewater using an activated sludge/biological treatment system after physical treatment to remove the oil. The treated grey water is subjected to ultraviolet disinfection and reused in landscape irrigation, air conditioning systems and fire control systems (Carvalho et al., 2013).

- **Wastewater treatment plant effluent is treated by coagulation, flocculation, sand filtering and activated carbon filtering after being blended with rainwater or well water to obtain good quality water to be used in cooling tower (Galeão Airport, Brazil)**

At Galeao Airport in Brazil, the wastewater treatment plant effluent is subjected to physical pre-treatment with sand filtration, coagulation and activated carbon filtration processes. Afterwards, reverse osmosis membranes are used to obtain good quality water that can be used in cooling towers.



Galeao Airport Physical Treatment System and Reverse Osmosis Membranes

- **Use of reclaimed water or rainwater for car and aircraft washing**

The "Sustainable Airports Handbook" was published by the Chicago Department of Aviation in 2018 and the best techniques that can be applied at airports are presented. With this technique, recycled water or rainwater is used for vehicle and aircraft washing, reducing the amount of drinking water needed for vehicle washing (CDA, 2018).

- **Use of rainwater collected from terminal roofs or satellite buildings to dilute crude glycol for de-icing aircraft or runway (Heathrow Airport, London)** Approximately 85% of the rainwater collected at London Heathrow Airport is reused.

potential of the terminal and satellite buildings. Collected from the roofs of terminal and satellite buildings

rainwater can be used for dilution of "raw" glycol in the de-icing process. With this water, water needs other than drinking water can be met (AMEC, 2014).

- **Treatment of wastewater from restaurant kitchens in passenger terminals and feeding it to toilet flushing systems (Narita Airport, Japan)**

Within the scope of this method, wastewater from restaurants in the terminals of Narita Airport is treated and reused as flushing water in airport toilets. In addition to water saving in terminals, drinking water use was reduced by using treated rainwater and grey water from kitchens. With the studies carried out, drinking water use was reduced by 9.1% (28.1 L/passenger) in 2019 (NAA, 2021).

- ***Rainwater drainage system discharges rainwater from aprons, de-icing areas, roads, car parks and roofs, collects it in ponds and feeds it to the irrigation system, fire control system and toilet flushes through separate systems (Frankfurt International Airport, Germany)***

Frankfurt International Airport has a rainwater pond at the west end of the runway system to collect rainwater. During winter, rainwater from taxiways, runways and de-icing area is temporarily stored in these ponds. The collected rainwater is treated depending on the COD concentration (Born & Ermel, 2007). The collected water is used for green area irrigation, fire control system and toilet flushing (Fraport AG, 2019).



Frankfurt International Airport Rainwater Retention Pond (Born & Ermel, 2007)

- ***Grey water collected from aircraft catering facilities and terminal building kitchens is treated together with water from aircraft washing activities and used in irrigation systems (Hong Kong Airport, China)***

At Hong Kong Airport, grey water collected from catering facilities and terminal building kitchens is collected and treated together with water from aircraft washing activities. The treated water is reused for green area irrigation (Carvalho et al., 2013).

A membrane biological reactor has also been installed at the airport to improve the quality of treated water. Grey water passes through dissolved air flotation, membrane bioreactor, submerged biological aeration filter and UV disinfection stages. Up to 800 m³ of water obtained from this plant is used for green area irrigation (Kilburn, M, 2013).

- ***Reducing irrigation requirements by using appropriate plant material by making soil / climate analysis in landscape areas***

The "Sustainable Airports Handbook" was published by the Chicago Department of Aviation in 2018 and sets out the best techniques that can be applied at airports. One of these techniques is to conduct a soil/climate analysis to determine the appropriate plant material and landscape design with native or adapted plants to reduce or eliminate irrigation requirements. Soil and climate analysis is recommended to determine the appropriate landscape strategy (CDA, 2018).

- ***Use of rainwater cisterns for plant irrigation in landscape areas***

It is recommended to use rainwater cisterns for irrigation during the plant growing season. Rainwater from collection systems is directed to cisterns for storage. The collected water can be used for irrigation during dry periods (CDA, 2018).

- ***Irrigation only when necessary, using sensors to monitor soil moisture instead of timed or manually controlled devices***

A soil moisture monitoring system is recommended to reduce the dependence on manual control and timed devices in irrigation systems and also to detect leaks (CDA, 2018).

- ***Replacement of conventional sanitary fittings with more efficient ones, e.g. fittings with two-stage flushing mechanisms or waterless urinals***

To reduce the amount of wastewater, it is recommended to use high-efficiency dry systems such as composting toilet systems and waterless urinals (CDA, 2018). At Frankfurt Airport, the installation of waterless urinals in taps saved 4.2 million litres of drinking water annually (Carvalho et al., 2013).

- ***Providing flow with a mixture of water and air by using tap aerators, and installing flow restriction devices on taps that cannot be equipped with aerators***

At Frankfurt Airport, thousands of cubic metres of water are saved each year through the use of flow limiting equipment in taps (Carvalho et al., 2013).

- ***Use of leak detection programme and advanced real-time water demand monitoring system***

Initiatives such as leakage control and water demand monitoring are widely used at airports. Sydney, London Heathrow and Manchester Airports have leak detection programmes (Carvalho et al., 2013). At Paris Airport, the drinking water distribution network is continuously monitored for both leakage control and water quality, and operational data is transmitted to an information technology centre using fibre optic cables. In the event of a leak, an emergency telephone is signposted to take action quickly (Carvalho et al., 2013).

- ***Use of seawater in siphons and cooling systems at airports close to the sea (Hong Kong Airport, China)***

One of the alternative water sources at airports is sea water. It is utilised for airports close to the coast. For example, 41% of the water demand of Hong Kong Airport is met from seawater. A large portion of this water is used in the cooling system (HKIA, 2011).

2.1.2 Good Management Practices

- ***Providing technical trainings to personnel for the reduction and optimisation 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 plants, 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 (MAF, 2021). Therefore, it is important to train staff on water use reduction, optimisation and water saving policies. It is important that the personnel are involved in water saving activities.

water use before and after water efficiency initiatives.

Practices such as creating regular reports on quantities and sharing these reports with the staff support participation and motivation in the process. Obtained through staff training technical, economic and environmental the benefits pay off in the medium or long term (TUBITAK MAM, 2016; MAF, 2021).

- ***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 characterisation should be carried out (MAF, 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 (MAF, 2021).

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

The first step in achieving water efficiency in industrial facilities is to set targets (MAF, 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 (MAF, 2021).

2.1.3 General Water Efficiency BATs

• **Identification and minimisation 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).

• **Minimising 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 (MAF, 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).

• **Determination of the scope of reuse of washing and rinsing water**

In industrial plants, relatively clean wastewaters such as washing-final rinse wastewaters and filter backwash wastewaters can be reused without treatment in floor washing and garden irrigation processes that do not require high water quality (Öztürk, 2014). Thus, it is possible to save between 1-5% in raw water consumption (MAF, 2021).

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

By determining the wastewater generation points in industrial facilities and characterising the wastewater, wastewater with high pollution load and relatively clean wastewater can be collected in separate lines (TUBITAK MAM, 2016; MAF, 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; MAF, 2021). Separation of wastewater streams generally 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 characterising the wastewater quantities and qualities at all wastewater generation points***

It is possible to reuse various wastewater streams with or without treatment by identifying and characterising the wastewater generation points in industrial facilities (Öztürk, 2014; TUBITAK MAM, 2016; MAF, 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 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; MAF, 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; MAF, 2021).

- ***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 pressurised nozzles (TUBITAK MAM, 2016). Reducing water consumption, wastewater generation and wastewater pollution load through the use of water pressure optimised nozzles in technically appropriate processes are the main environmental benefits of the application.

- ***Use of automatic control-close valves to optimise 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 unnecessary 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). With the monitoring and control of water consumption on process basis, 3-5% savings can be achieved in process water consumption (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 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 (NOM)) 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 oxidising 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).

- ***Collecting rainwater and utilising it as an alternative water source in facility cleaning or in suitable areas***

Nowadays, when water resources are decreasing, rainwater harvesting is frequently preferred especially in regions with low rainfall. There are different technologies and systems for rainwater collection and distribution systems. Cistern systems, ground infiltration, surface collection and filter systems are used. Rainwater collected with special drainage systems can be used for production processes, garden irrigation, tank and equipment cleaning, surface cleaning, etc. if it meets the required quality requirements (Tanik et al., 2015).

In various examples, roof rainwater collected in industrial facilities was stored and used inside the building and in landscape areas, resulting in 50% water saving in landscape irrigation (Yaman, 2009). Perforated stones and green areas can be preferred in order to increase the permeability of the ground and to allow rainwater to pass and absorb into the soil on the site (Yaman, 2009). Rainwater collected on building roofs can be used for car washing and garden irrigation. It is possible to recover and reuse 95% of the collected water by biological treatment after use (Şahin, 2010).

- ***Optimising 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 (MAF, 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 optimised and excessive washing rinsing or backwashing with salt water can be prevented by using online hardness sensors.

- **Reuse of pressurised 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 pressurised 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".

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

Depending on the wastewater characterisation 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 characterisation. 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 (MAF, 2021).



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

Reverse Osmosis System

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

Since inefficient resource utilisation 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 organisation 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. Utilising computerised monitoring systems as much as possible in order to maximise the efficiency of the application increases the technical, economic and environmental benefits to be obtained (TUBITAK MAM, 2016).

- ***Preservation 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***

In industrial plants, water recovery is achieved by using dry cleaning techniques and preventing leaks to prevent the mixing of chemicals that pose a risk to the aquatic environment such as oils, emulsions and binders into wastewater streams (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***

Closed and impermeable waste/scrap storage sites can be constructed in industrial facilities in order 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.

- ***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.



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

Computer Aided Control System

- ***Reducing water consumption by reusing filter wash water in filtration processes, reusing relatively clean cleaning water in production processes and using clean-in-place systems (CIP)***

The wastewater from backwashing of activated carbon filters and softeners usually contains only a high content of suspended solids (TSS). Backwash water, which is one of the easiest types of wastewater to recover, can be recovered by filtration with ultrafiltration plants. In this way, water savings of up to 15% can be achieved (URL - 1, 2021).

Regeneration wastewater generated after the regeneration process are soft waters with high salt content and constitute approximately 5-10% of total water consumption. Regeneration wastewater is collected in a separate tank and utilised in processes with high salt requirements, plant cleaning and domestic use. For this purpose, a reserve tank, water installation and pump are required. By reusing regeneration wastewater, water consumption, energy consumption, wastewater amounts and salt content of wastewater are reduced by approximately 5-10% (Öztürk, 2014). The payback period varies depending on whether the regeneration wastewater is consumed in production processes, plant cleaning and domestic use. The potential payback period is estimated to be less than one year if regeneration waters are reused in production processes that require high salt (since both water and salt will be recovered). For facility and equipment cleaning and domestic use, the payback period is estimated to be over one year (MAF, 2021).

In our country, reverse osmosis (RO) concentrates are combined with other wastewater streams and discharged to the wastewater treatment plant channel. The concentrates formed in TO systems used for additional hardness removal can be used in garden irrigation, in-plant and tank-equipment cleaning (TUBITAK MAM, 2016; MAF, 2021). In addition, with the structuring of monitoring for raw water quality, it is possible to feed TO concentrates back to raw water reservoirs and re-evaluate them by mixing (MAF, 2021).

- ***Implementation of time optimisation 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 labour 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 inefficiencies, inefficiency 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).

- ***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; MAF, 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; MAF, 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; MAF, 2021).

- ***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 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 mixture of water, soap and air at the right rate.

- ***Recovery of water from rinsing solutions and reuse of recovered water in processes appropriate to its quality***

Rinsing wastewaters in industrial plants are relatively clean wastewaters that can be reused without treatment in floor washing and garden irrigation processes that do not require high water quality (Öztürk, 2014). Recycling of rinsing wastewater reduces raw water consumption.

Savings between 1-5% can be achieved.

- ***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. These blowdown waters can be reused in appropriate production processes.

- ***Preventing the need for rinsing between activities by using compatible chemicals in sequential processes***

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

Various chemicals are used in industrial plants to increase washing and rinsing efficiency. The fact that these chemicals are compatible and act as solvents shows a positive trend in increasing the efficiency. Therefore, the dirt on the material can be removed in a shorter time and more effectively and the amount of water used in washing processes can be significantly reduced. In this case, even if the amount of wastewater can be reduced, there may be an increase in the chemical loads carried by wastewater. These negative effects can be minimised by reusing the washing water containing solvents used in washing rinsing processes.

Water savings of 25-50% are possible by reusing wash water. The application may require reserve tanks and new pipework. In alternative cases, the washing solution can be kept directly in the system and used repeatedly until it loses its properties.

2.1.4 Precautions for Auxiliary Processes

BATs for Steam Generation

- **Ensuring water saving by insulation of 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**

Failure to design steam lines properly in the facilities, routine maintenance and maintenance of steam lines repairs, mechanical problems occurring in the lines and the lines are not properly repaired.

If the steam lines and hot surfaces are not fully insulated, steam losses may occur. 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 minimise steam losses are used in many plants with high 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.), routine inspection and cleaning of heat treatment units (including chimneys) in specified periods, effective maintenance-repair, cleaning and loss control practices can save 1-6% in water consumption (Hasenbeigl, 2010; Öztürk, 2014; MAF, 2021).



https://hohwatertechnology.com/wp-content/uploads/2021/03/boiler_175594851-1024x688.jpeg

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 flash steam losses due to boiler discharge***

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 vapour 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.

- ***Minimisation 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-analysed 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 optimising the steam boiler blowdown process, operating costs are reduced by saving on boiler water consumption, waste costs, treatment and heating.

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

With a simple modification to the pipework system, the water supplying the water resting/decarbonising unit can be obtained from the outlet of the turbine condenser unit. This water has a sufficient temperature for the resting/decarbonising unit. Therefore, it is not necessary to heat this water by means of the steam produced by the heat exchanger system. Significant vapour 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; MAF, 2021).

BATs for cooling systems

- ***Use of a closed-loop cooling system to minimise 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 optimising 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 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 undesirable 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 (MAF, 2021).

- ***Avoiding unnecessary cooling processes by identifying processes that need wet cooling***

The boundaries of the plant site affect design parameters such as cooling tower height. In cases where it is necessary to reduce the tower height, a hybrid cooling system can be applied. Hybrid cooling systems are a combination of evaporative and non-evaporative (wet and dry) cooling systems. Depending on the ambient temperature, the hybrid cooling tower can be operated as a fully wet cooling tower or as a combined wet/dry cooling tower (TUBITAK MAM, 2016). In regions where there is not enough cooling water or where water costs are high, the evaluation of dry cooling systems or hybrid cooling systems can be an effective solution to reduce the amount of cooling booster water (TUBITAK MAM, 2016).

- ***Use of air cooling systems instead of water cooling in cooling systems***

Industrial cooling systems are used for cooling heated products, processes and equipment. For this purpose, closed and open circuit cooling systems can be used, as well as industrial cooling systems using a fluid (gas or liquid) or dry air (IPPC BREF, 2001b; MAF, 2021). Air cooling systems consist of finned pipe elements, condenser and air fans (IPPC BREF, 2001b; MAF, 2021). Air cooling systems can have different operating principles. In industrial air cooling systems, the heated water is cooled by air in closed circuit cooling condensers and heat exchangers (IPPC BREF, 2001b; MAF, 2021). In water cooling systems, the heated water is taken into a cooling tower and the water is cooled in drip systems. However, although water-cooled systems operate in closed circuit, a significant amount of evaporation occurs. In addition, since some water is discharged as blowdown in cooling systems, water loss also occurs in this way (IPPC BREF, 2001b; MAF, 2021). The use of air cooling systems instead of water in cooling systems is effective in reducing evaporation losses and also in reducing the risk of contamination of cooling water (IPPC BREF, 2001b; MAF, 2021).

- ***Local dry air cooling in some periods of the year when the cooling requirement is low***

In cases where the cooling requirement is low, it is possible to save water by cooling with dry air.



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

Cooling Systems (Chiller)

- ***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; MAF, 2021). In these systems, more than 95% of the circulating water can be recovered (TUBITAK MAM2016). 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; MAF, 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 stabilise 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 (MAF, 2021).

- ***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 optimising cooling systems. In addition, the amount of blowdown can be reduced by 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 formed in the cooling system is generally discharged directly to the wastewater channel. By reusing the 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 (MAF, 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 of 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 ventilation and air conditioning systems

- ***Re-use of the liquid formed by condensation from the ventilation system***

Condensate with good water quality can be produced in the system during the aeration cycle. For example, in a plant in Spain, condensate from the aeration system with a conductivity of about 200 μS is collected in a tank and used to flush an automatic galvanising line (MedClean, n.d.).

- ***Replacement of old equipment in the aeration system with ion exchange resins based on the principle of reverse osmosis (systems producing demineralised water) and reuse of water***

Conductivity of the final effluent using ion exchange resins in the aeration system is brought to a conductivity level suitable for use in cleaning equipment. Example In a facility in Spain, by replacing the equipment in the aeration system with ion exchange resins, effluent with a conductivity value of approximately 1000 μS is obtained and reused in the system (MedClean, n.d.).

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Reşitpaşa District Katar Street
Anı Technopolice 1 2/5, D:12, 34469
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