MODULE 7. WATER

AUTHORS:

NOELIA CRUZ-PÉREZ

JOSELIN S. RODRÍGUEZ ALCÁNTARA

ANABELA DURÃO

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ABSTRACT

Comprehensive water resource management, encompassing groundwater, surface water, water footprint, and wastewater, is essential to ensure the sustainable availability of this vital resource in a constantly growing urban and population-centric world. Furthermore, the implementation of sustainable urban drainage systems has become critical in addressing flooding and contamination issues in cities, promoting practices such as green roofs and permeable pavements that reduce runoff and enhance water quality, thus contributing to the preservation of our ecosystems and human well-being in an ever-expanding urban environment.

COMPETENCES

The students should acquire the following competencies:

- Diagnosing: The ability to effectively assess and evaluate water-related issues.
- Water Cleaning: Proficiency in techniques and methods for purifying water.
- Field-Worthy Water Safety: Being capable of ensuring water safety under field conditions.

In addition to these skills, it would be beneficial for the students to develop knowledge in the following areas:

- Water Resources: Understanding the availability, distribution, and management of water sources.
- Natural Resources Management: Knowledge of sustainable practices for managing natural resources, with a specific emphasis on water.
- Water Reuse: Familiarity with the concept of reusing water and its implications in various contexts.
- Hydric Footprint: Awareness of the impact of individual and collective water consumption on the environment.
- Good Practices: Adopting and promoting best practices in water management and conservation.

1. INTRODUCTION

Guaranteeing access to drinking water and energy production are two of the main difficulties facing the world's population today. Both sectors, water and energy, require extensive economic deployment and infrastructures that not all countries are able to guarantee. In addition, supplying people with the drinking water necessary for all human activities, as well as offering them a stable energy service, nowadays require sustainable management, otherwise we will increasingly face uncertainties associated with climate change (pandemics, natural disasters, reduced rainfall, increased temperatures, etc.).

Climate change threatens the availability of water resources in many ways, for example, the following could be expected: (i) a reduction in water availability if global temperatures continue to rise and periods of drought lengthen in the more arid and semi-arid regions of the world; (ii) an increase in flooding if extreme heavy rainfall events increase; iii) eutrophication and deterioration of surface water quality due to runoff and nutrient entrainment into the surface water body ; and iv) reduced natural recharge of the aquifer, due to less infiltration into the subsoil, both in the event of less rainfall and torrential rainfall (which would take the form of runoff rather than infiltration) (Figure 1).

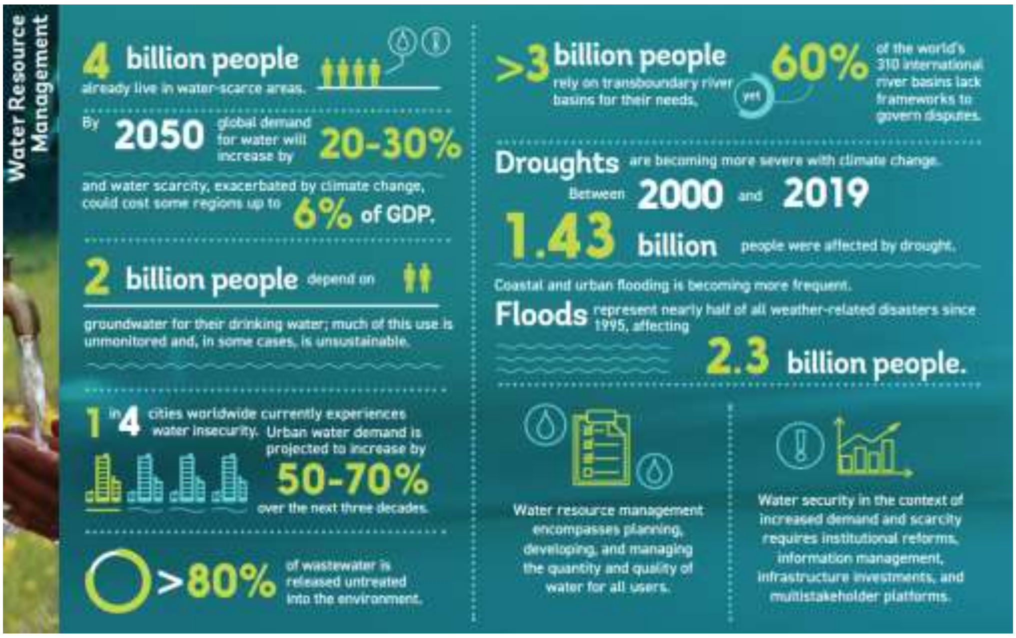


FIGURE 1. MAIN WATER MANAGEMENT ISSUES IN THE WORLD. SOURCE: WORLDBANK (HTTPS://DOCUMENTS1.WORLDBANK.ORG/CURATED/EN/978191614167678978/PDF/WATER-RESOURCE-MANAGEMENT-WORKING-TO-IMPROVE-WATER-SECURITY.PDF)

With regard to the distribution of water on the planet, the most relevant data are shown below:

- The Earth contains approximately 1,386 million cubic kilometres of water. Neither the amount nor the distribution of water has changed significantly over the last two billion years.
- Ninety-seven per cent of the water is found in the oceans, and two per cent remains frozen.
- Eighty per cent of the water found on the continents is on the surface. The remaining 20% is underground or in the form of atmospheric water vapour.
- Only 2.5% of the water on Earth is fresh water. Of this amount, 0.5% is found in underground reservoirs and 0.01% in rivers and lakes.
- Although water is distributed across the Earth, 90% of the planet's available freshwater resources are in Antarctica.
- Another interesting fact about the distribution of water on Earth is that only 0.007% of the Earth's water is drinkable. And that amount is decreasing year by year due to pollution. In fact, more than 1.1 billion people in the world do not have direct access to clean water sources, so they suffer from water stress.

Moreover, more than 768 million people do not have access to safe drinking water, according to the United Nations Children's Fund (UNICEF). Most of these people live in poverty, in remote rural areas or in urban slums. This shows that the distribution of water on Earth is very unequal when it comes to access to drinking water.

2. GROUNDWATER

Groundwater accounts for about 30% of the world's freshwater. Of the remaining 70%, almost 69% is part of the ice and glacier ice sheets, and only 1% is found in rivers and lakes. Groundwater accounts on average for one third of the fresh water consumed by mankind, but in some parts of the world this percentage is as high as 100%. Groundwater is found almost everywhere and its quality is generally very good. The fact that groundwater is stored underground, and sometimes deep underground, helps it to remain uncontaminated and to retain its quality.

Groundwater is contained in aquifers, which are geological formations underground that hold water reserves (Figure 2). The water that is incorporated into aquifers is called "recharge" and is a percentage of the water that infiltrates into the ground when precipitation occurs. Infiltration depends on the type of rainfall, the presence or absence of vegetation, and the percentage of this infiltration that is converted into recharge also varies depending on soil structures.

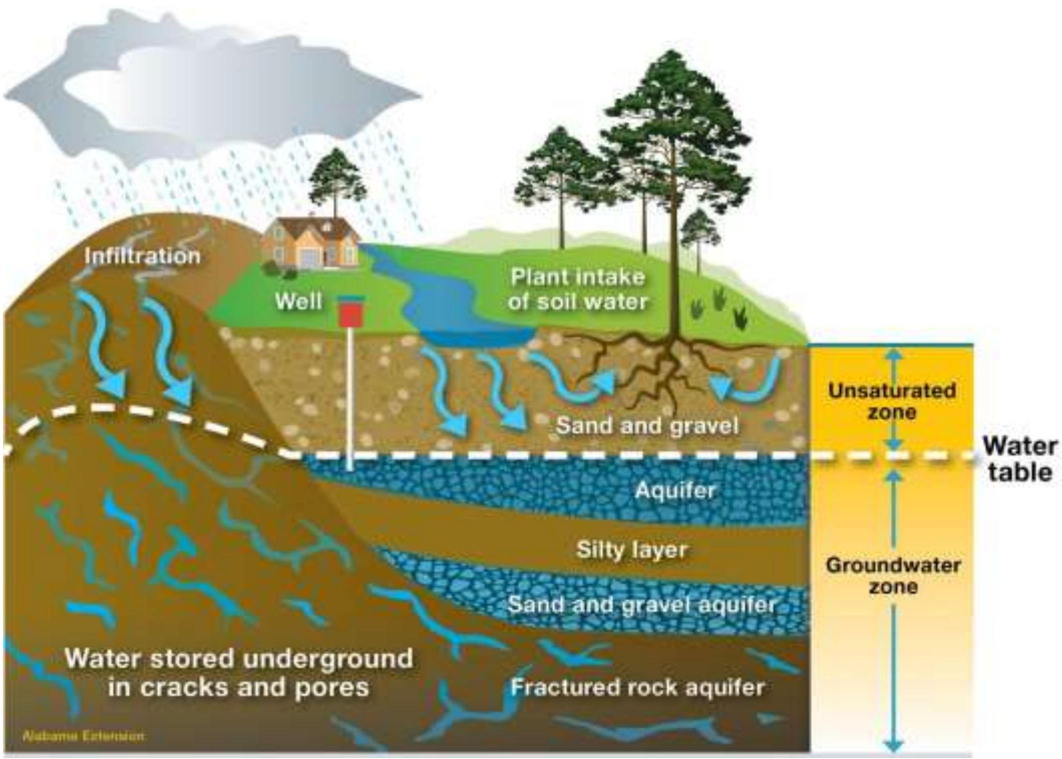


FIGURE 2. AQUIFER AND ITS RELATIONSHIP WITH INFILTRATION. SOURCE: [HTTPS://WWW.ACES.EDU/BLOG/TOPICS/FISH-WATER/WHAT-IS-AN-AQUIFER/](https://www.aces.edu/blog/topics/fish-water/what-is-an-aquifer/)

Aquifers can consist of different materials, e.g. loose sand, gravel, permeable sedimentary rocks such as sandstones or mudstones, fractured volcanic lava, crystallised rocks, etc.

Groundwater recharged with rainwater, water from melting snow or water infiltrating from the bottom of lakes, rivers, and other surface water bodies. Aquifers can also be recharged when crops are irrigated with too much water (it is important to note that this water may then be contaminated by nitrates from fertilisers used in agriculture, if it is not organically farmed). There are also techniques to manage the artificial recharge of aquifers and thus increase the amount of water infiltrating into the ground, by specific management and not relying solely on natural precipitation. In addition, this artificial recharge water can be treated and purified wastewater, which is returned to the system, thus extending the life of the resource.

One of the main challenges in protecting groundwater is that it is, of course, underground. Groundwater levels are not easily monitored with the naked eye and therefore supplies can be unknowingly contaminated or even over-used, meaning that more is extracted from the ground than can be sustainably replenished. Groundwater can be contaminated by landfills, septic tanks, leaking underground gas tanks, and overuse of fertilisers and pesticides.

3. SURFACE WATER

Surface water occupies 71% of the planet, 97.5% of which is salt water and the remaining percentage is fresh water. Of the available fresh water, only 1% is easily accessible in the form of lakes, lagoons, rivers, streams, among others.

In addition to climate change, surface waters are threatened by potential pollution. Pollution can be caused by chemical spills, micro-organisms, sewage, etc. Surface water pollution affects the quality of water and may make it unusable for people and animals.

A wide variety of chemicals are constantly being introduced into our environment. The toxicological consequences of exposure to these compounds and their impact on the health of the population are a growing concern (Plattard et al., 2021). The so-called contaminants of emerging concern (CECs), are defined as a group of substances, mostly organic compounds, that have been detected in water, soil, and air at trace concentrations but are not yet subjected to restrictions of any kind. Despite the lack of any current regulation, special concerns have grown around them because of their potential effects on ecosystems and living organisms upon long-term exposure (Calvo-Flores et al., 2017). For many years, most of these chemicals were undetected by traditional techniques, but the advancement in analytical instrumentation has aided in their identification.

Pharmaceuticals, personal care products (PCPs) and endocrine disrupting chemicals (EDCs) from other groups of substances are classified as CECs because they may have significant adverse environmental and human health effects, although the occurrence of these pollutants in the environment is usually in a very low concentration range, from μg L^{-1} to ng L^{-1}. PCPs and EDCs in water and wastewater have been detectable as a result of advances in analytical chemistry theory and instruments and have raised awareness in the fields of environmental protection, legislation, and public health (Jiang et al., 2013; Zhou et al., 2019).

In addition to CECs, microplastics (MPs) are another issue that has just recently attracted increased concern and research. Environmental concern regarding small plastic particles known as microplastics ("MPs", i.e., plastic particles < 5 mm) has received a great deal of attention due to their potential pollution risk and threat to aquatic organisms (Franco et al., 2020). Today, the production of plastics has reached nearly 359 million tons per year worldwide, with polypropylene (PP) and polyethylene (PE) being the resins with the highest production mainly used for packaging – most plastics are currently used for this purpose. Such high production of plastics, their sometimes-irrational use (i.e., single-use plastics), inadequate management of their residues and their low biodegradability, among others, are the main causes of their presence in the environment (Hernández-Sánchez et al., 2020).

4. HYDRIC FOOTPRINT

According to the report entitled "Progress in the level of water stress", the global water situation is as follows: 32 countries are between 25 and 70% water stressed, 22 countries are above 70%, 15 countries are above 100% and 4 of them have a water stress of more than 1,000% (FAO, 2018). These data present us with an unflattering situation, which invites us to become aware of the use we make of water resources, due to their non-renewable nature. Furthermore, the decrease in water resources in some areas of the planet may lead to migratory movements that, added to those produced by climate change itself, could generate the need for effective policy responses.

In the manufacture of a product and/or the development of an activity, the indicator known as the water footprint counts the volume of freshwater used (differentiating its origin into blue or green footprint), as well as the volume of water polluted in the process, by type of pollution (grey footprint).

The ***blue water footprint*** refers to the consumption of surface water and/or groundwater, i.e. the drinking water we obtain from a natural source to be used in a process. Specifically, it focuses on consumptive water use, which covers any of these four processes: evaporation of water, water incorporated into a product, water that does not return to the same catchment area or water that does not return in the same period.

The ***green water footprint*** is rainwater that becomes part of the soil due to infiltration or evapotranspiration (water that becomes surface runoff is not counted). Its greatest impact is observed when agricultural and/or livestock products are studied.

The ***grey water footprint*** is the one that considers water pollution, counting the volume of freshwater needed to dilute the load of pollutants present, for example, in a wastewater.

All processes of the product system that contribute significantly to the overall water footprint should be included in the calculation of the water footprint. Also, it is important to select the appropriate methodology to calculate the hydric footprint. In this case, the selected methodology was proposed by the Water Footprint Network (WFN)[1], where an assessment of the water footprint components is made. Within the water footprint assessment, the direct and indirect water footprint are counted, as a global study of water consumption gives a more accurate picture of the resources consumed within each activity.

The three dimensions of direct or indirect water footprint are:

4.1. Blue water

Consumptive water use, which encompasses any of four processes: evaporation of water, water incorporated into a product, water that does not return to the same catchment area or water that does not return in the same period. The formulation used in this case would be as follows (Eq.1):

$$WF_{blue} = \textit{blue water evaporation} + \textit{blue water incorporation} + \textit{lost return flow}, \quad \textit{(Eq. 1)}$$

In the case of the blue water footprint, several considerations have been made. For water galleries and wells, all water abstracted from the aquifer by the installation has been accounted for, only to indicate the total volume abstracted. However, this would be the blue water footprint attributed to the end user and not to the operator. For this reason, freshwater losses have only been accounted for as blue water footprint in the groundwater facilities. To this end, the percentage of water lost from the total captured by these groundwater collection facilities has been requested.

Only the percentage of water in the distribution network that is identified with the losses along the distribution route has been counted, since it is water that has been obtained from a specific source and does not reach the end user (is lost along the way).

For water processing facilities, only the consumptive use of blue water in the industrial process has been accounted for in desalination plants. However, in water treatment plants, blue water has not been included, as the values for water evaporation are not known and, since the electricity mix of the suppliers does not have hydropower or biofuel source, the

[1] Hoekstra, A.Y.; Chapagain, A.K.; Aldaya, M.M.; Mekonnen, M.M. 2011. The Water Footprint Assessment Manual. London: Earthscan.

remaining water that can be used in energy production is considered minimal and is not counted here.

4.2. Grey water

The amount of water that remains contaminated after or during the industrial process. It is defined as the volume of fresh water necessary to assimilate the pollutant load until it reaches the levels required by current ambient water quality regulations (Eq.2). It is calculated by dividing the pollutant load (L) by the difference between the environmental water quality standard for that pollutant and its natural concentration in the receiving water body.

$$WF_{grey} = (L \times C_{wat}) / (C_{max} - C_{nat}), \text{ (Eq. 2)}$$

Where:

L = Volume of polluted water; C_{wat} = Concentration of the pollutant in the polluted water; C_{max} = Maximum concentration of the pollutant; C_{nat} = Natural concentration of the pollutant.

The values of L and C_{wat} were obtained from the information provided by the private water companies, and the values of C_{max} and C_{nat} were obtained from the current regulations applicable in the study area. Since several pollutants can typically be found in water, the grey water footprint is determined by the most critical pollutant associated with the largest grey water footprint of the critical substance, in this case BOD_5 (mg/l).

4.3. Green water

This indicator is particularly important in the agricultural and forestry sector but is practically negligible in the rest of the water footprint calculations (Eq.3):

$$WF_{green} = \text{evaporation of green water} + \text{incorporation of green water}, \text{ (Eq. 3)}$$

5. WASTEWATER RECLAMATION

Decades of misuse, poor management, overextraction of groundwater and contamination of freshwater supplies have exacerbated water stress. In addition, countries are facing growing challenges linked to degraded water-related ecosystems, water scarcity caused by climate change, underinvestment in water and sanitation and insufficient cooperation on transboundary waters. To achieve universal access to drinking water, sanitation, and hygiene by 2030, the current rates of progress would need to increase four-fold. Completing these targets would save 829,000 people annually, who die from diseases directly attributable to unsafe water, inadequate sanitation and poor hygiene practices (https://www.un.org/sustainabledevelopment/water-and-sanitation/)

Improving water quality by reducing pollution, eliminating dumping, and minimizing release of hazardous chemicals and materials, halving the proportion of untreated wastewater, and substantially increasing recycling and safe reuse, among others is one of target to achieve, by 2030 (Sustainable Development Goal 6 –Water and sanitation).

Water reuse is also commonly known as water recycling or water reclamation, reclaims water from a variety of sources then treats and reuses it for beneficial purposes such as: agriculture and irrigation; potable water supplies, groundwater replenishment; industrial processes, and environmental restoration. It can provide alternatives to existing water supplies and be used to enhance water security, sustainability, and resilience (https://www.epa.gov/waterreuse/basic-information-about-water-reuse)

As is well known, the discharge of wastewater without any treatment causes considerable problems for the environment.

Most conventional wastewater treatment plant are processed by biological treatments (aerobic and anaerobic) and are associated with the removal of organic compounds, which can contribute to the emission of greenhouse gases (CO_2 and methane, nitrous oxide).

The discharge of organic matter and nutrients into the water mass accelerates the eutrophication process, with negative impacts on the aquatic ecosystem. So, it is very important to have wastewater treatment. The constituents of wastewater are removed by physical, chemical, and biological methods whose are usually classified as physical unit operation, chemical process, and biological process.

The combined approach with control of discharges and control pollution (of diffuse and/or point) is essential to prevent the deterioration of the Environment and promote the integrated management of ecosystems and can contribute for wastewater reclamation.

There are different kinds of wastewater:

5.2. Wastewater sources

5.2.1. Domestic wastewater

Domestic wastewater is usually characterized by a grey colour, musty odour and it has solids content (about 0.1%). The solid material is a mixture of feces, food particles, toilet paper, grease, oil, soap, salts, metals, detergents, sand, and grit, that's why domestic wastewater contain pathogenic organisms (fecal coliform)! So, can become dangerous to public health, and are also aesthetically repulsive!

Personal cleanliness	
Clothes washing	
Food preparation	
Utensil washing	 

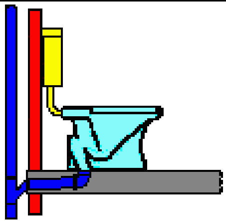
Defecation and urine	
Floor washing	

FIGURE 1- ACTIVITIES THAT PRODUCE DOMESTIC WASTEWATER

5.2.2. Industrial wastewater

Industrial wastewater is wastewater from industrial activities, can contain metals, fat, radioactive substances, and many different chemicals. Its composition depends on the industrial activity in question.

5.2.3. Wastewater from livestock activities

Livestock effluents depend on several variables, namely: animal species, feeding and excretion of nutrients, water consumption, method of cleaning facilities, quantity of straw and/or other materials used in bedding, among others, by that its physicochemical and microbiological characteristics confer potential damage to the environment.

The wastewater from the slaughterhouse has a high content of: (1) organic compounds: 5,000 and 3,000 mg/L for chemical oxygen demand (COD) and Biochemical oxygen demand (BOD5) respectively; nutrients, 450 and 50 mg/L of nitrogen and phosphorus respectively; suspended solids (TSS) around 3,000 mg/L; oils and fats; pathogenic microorganisms (Durão et al, 2023).

FIGURE 2- *LIVESTOCK ACTIVITIES*

5.2.4. Wastewater from agri-food activity

Olive oil production is a fundamental sector of agricultural production in southern European countries. In mainland Portugal, olive oil mills are, for the most part, small and medium-sized production units, private or cooperatives that are located throughout the country. The liquid effluents from olive oil production, were for many years discharged into municipal collectors, and even directly into water bodies, causing considerable environmental problems. Effluents from dairy industries have high organic loads, with BOD_5 and COD concentrations reaching up to 100 g/L, fat contents ranging between 0.08 and 5.7 g/L (Durão et al., 2023).

Cheese factory	
Tomato	 
Wine production	
Olive-oil	
Russet waters	

FIGURE 3- AGRI-FOOD ACTIVITY

5.2.5. Urban wastewater

Urban wastewater its mixture of domestic wastewater with industrial wastewater and/or rainwater. So, its composition varies according to untreated domestic wastewater and the characteristics of the contributors to the wastewater collection system.

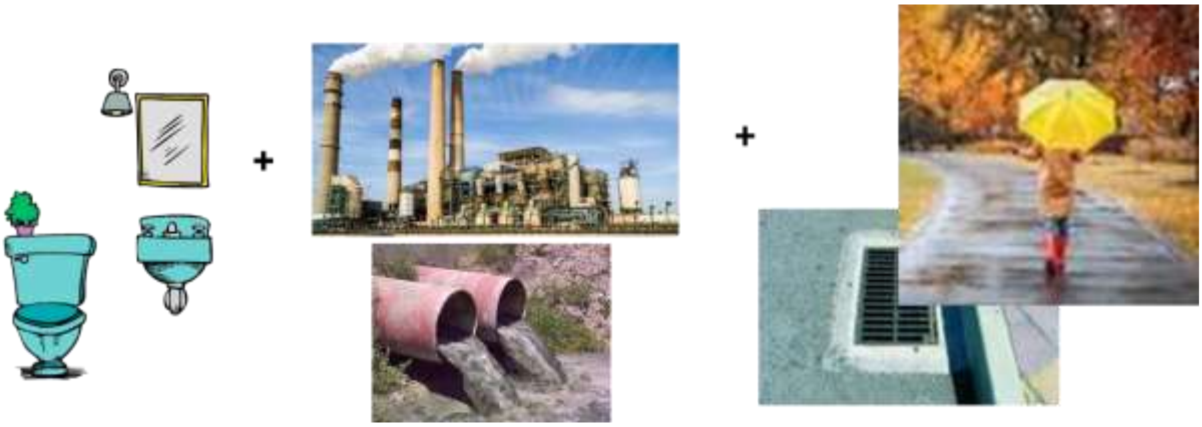


FIGURE 4 - *URBAN WASTEWATER*

5.3. Legislation

The application of Directive 91/271/EEC related to urban wastewater treatment was a prerequisite for Water Framework Directive (WFD) (2000/60/EC) whose main aim was to achieve good chemical and ecological status in the water masses by 2015 and established an integrated approach on management and protection of Europe's aquatic environment.

The urban wastewater treatment in the European Union is governed by Directive 91/271/EEC as subsequently amended by Directive 98/15/EC. Each country in the European Union transposes the mentioned directives into the internal legislation. These Directives were transposed into Portuguese law by Decree-Law shown in Figure.5. As an example, in Portugal the limit values for discharged treated wastewater are those shown in the Table 1.

FIGURE 5 - LEGISLATION

TABLE 1- DISCHAGE LIMITES VALUES OF TREATED WASTEWATER

Discharge Limits Values of Treated Wastewater
(Portuguese Legislation)

Parameter	Unit	Value	
		Decree-Law no. 152/97 [1]	Decree-Law no. 236/98 [2]
COD	mg O_2/L	125	150
BDO_5	mg O_2/L	25	40
TSS	mg/L	35	60
Total N	mg/L	15[3]; 10[4]	15
NO_3^-	mg/L	-	50
NH_4^+	mg/L	-	10
Total P	mg/L	2[3]; 1[4]	10; 3[5]; 0.5 [6]

1- Sensitive area; 2- Limit value; 3- 10000<P<100000; 4- Pop>100000
5- streams discharges to reservoir; 6- discharges directly reservoir

The discharge Limits Values of treated wastewater are dependent of the receiving environment that means that it depends on the classification area; as sensitive or not sensitive. There are also minimum percentage reductions that must be met.

Sensitive areas include waters subject to eutrophication (in which case significant reductions of nitrates and/or phosphates are required); surface waters with high nitrate levels intended for the abstraction of drinking water; and other waters where higher treatment standards are necessary to fulfil the legal emission limit values.

Despite the evolution observed in the number of wastewater treatment plants, by country (Figure 6), especially in Poland, Portugal, and Czech Republic, in terms of treatment processes it is still below what is desired.

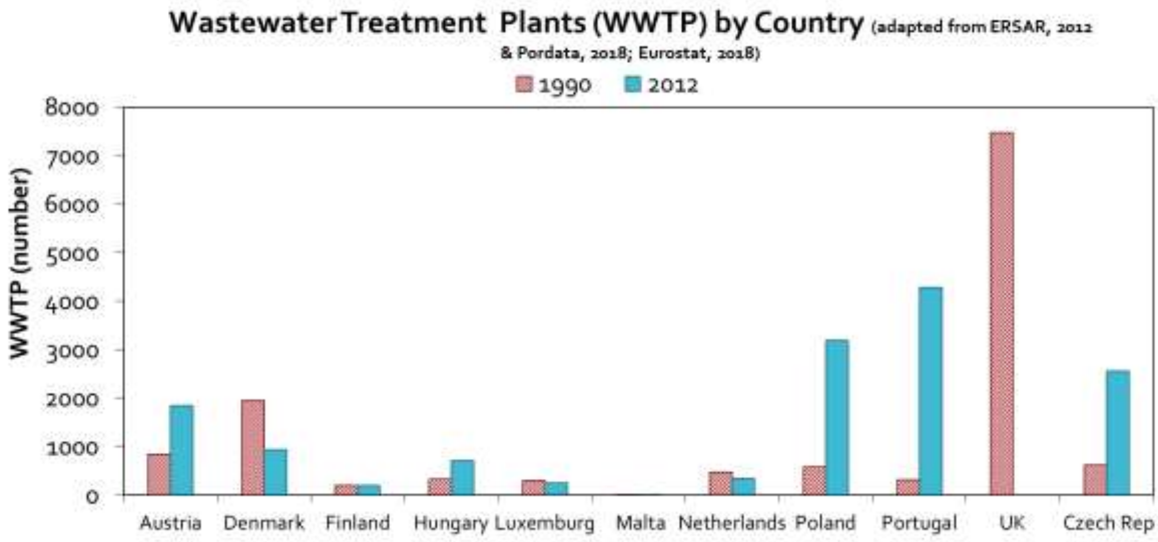


FIGURE 6- EVOLUTION OF WASTEWATER TREATMENT PLANT (WWTP), BY COUNTRY (FONTE).

5.4. Wastewater treatment phases and process

The aim of wastewater treatment plant is to provide a wastewater treatment system that is capable of coping with a wide range of probable wastewater conditions. The characterization of raw wastewater involves: (1) quantitative characterization (flowrates); (2) qualitative characterization (chemical, physical, microbiological parameters).

The flowrate is necessary to determine the design capacity as well as the hydraulic requirements of the wastewater treatment plant.

The wastewater can be divided in 4 groups:

- Organic matter (sugars, proteins, lipids or fats, surfactants volatile organic compounds, pesticides and chemical products for agricultural use)
- Inorganic mater (pH, chlorides, alkalinity, nitrogen and its various forms, phosphorus, sulfur, heavy metals)
- Gas (nitrogen, oxygen, carbon dioxide, hydrogen sulfide, ammonia and methane)
- Biological - pathogens (bacteria, viruses, protozoa and helmints).

Pathogens are defined as microscopic organisms, including viruses, bacteria, fungi, and parasites that can cause diseases in humans, animals, and plants. Pathogenic organisms are capable of infecting or transmitting diseases to humans.

The Table 2 shows some infectious agents potentially present in raw domestic wastewater (Metcalf & Eddy, 2016) and Table 3 depicts the typical composition of domestic untreated wastewater.

Table 2- Some infectious agents potentially present in raw domestic wastewater

	organism	Disease	Remarks
Bacteria	Escherichia coli	gastroenteritis	Diarrhea
	Legionella pneumophila	legionellosis	Acute respiratory ilness
	Vibrio cholerae	cholera	Extremely heavy diarrhea, dehydration
Viruses	Adenovirus	Respiratory disease	
	Hepatitis A	Infectious hepatitis	Jaundice, fever
	Enteroviruses	Gastroenteritis, heart anomalies, meningitis	Jaundice, fever

Table 3- Typical composition of domestic untreated wastewater (Metcalf & Eddy, 2016)

Constituent	Unity.	Concentration		
		Weak	Mediun	Strong
Suspended Solids (ST)	mg/L	537	806	1612
Dissolved Solids (SDT)	mg/L	374	560	1121
Fixed Volatile	mg/L	224 150	336 225	672 449
Total Suspended Solids (TSS)	mg/L	130	195	389
Fixed Volatile	mg/L	29 101	43 152	86 304
Settleable solids	mg/L	8	12	23
Biochemical Oxygen Demand (BOD_5)	mgO_2/L	133	200	400
Total Organic Carbon (TOC)	mg/L	109	164	328
Chemical Oxygen Demand (COD)	mg/L	339	508	1016
Nitrogen (total N) Organic Free ammonia Nitrites Nitrates	mg/L	23 10 14 0 0	35 14 20 0 0	69 29 41 0 0
Phosphorous (total P) Organic Inorganic	mg/L	3,7 2,1 1,6	3,7 2,1 1,6	11 6,3 4,7
Chlorides	mg/L	39	59	118
Sulphate	mg/L	24	36	72
Alkalinity (as $CaCO_3$)	mg/L	50	100	200
Grease	mg/L	51	76	153
Total Coliform Fecal Coliform	nº/100ml	10^6-10^8 10^3-10^5	10^7-10^9 10^4-10^6	10^7-10^{10} 10^5-10^8
Potassium	mg/L	11	16	32
Organic Compounds Volatile	mg/L	<100	100-400	>400

The constituent values have a seasonal variation accordingly with domestic flow, however the total mass of Biochemical Oxygen Demand (BDO) and Total Suspended Solids (TSS) the can increase with the volume of water (Q), population served by the system (Figure 7) (Metcalf & Eddy, 2016).

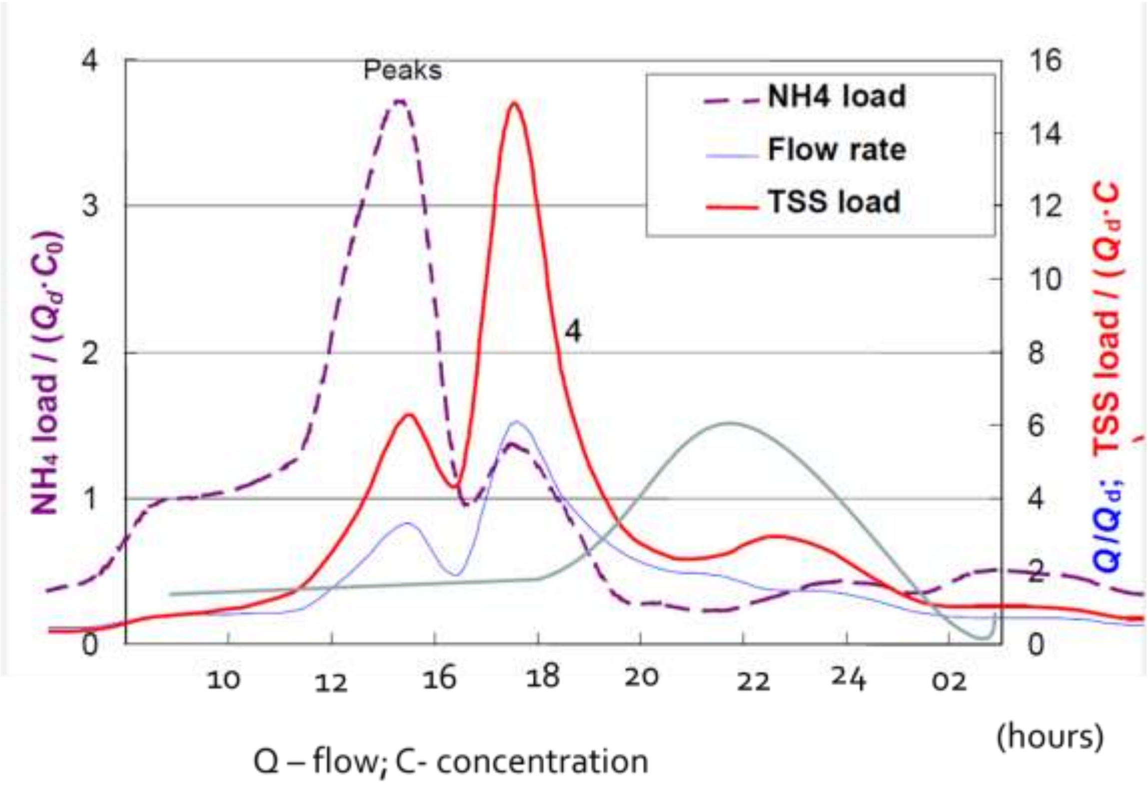


FIGURE 7- DAILY VARIATION OF DOMESTIC FLOWRATE ,TSS AND NH_4 LOAD.

The constituents of wastewater are removed by physical, chemical, and biological methods. These methods are usually classified as physical unit operation, chemical process, and biological process.

The physical unit operations include screening, mixing sedimentation, gas transfer, filtration, and adsorption.

The chemical unit processes include disinfection, oxidation, and precipitation.

Biological unit processes are a treatment method in which the removal constituents are provided by biological activity. It is used to remove the biodegradable organic constituents and nutrients.

The rates of physical, chemical, and biological reactions and conversions occur, and the degree of their completion are important (the constituents involved, the temperature and the type of reactor) and will affect the size of the wastewater treatment plant ((Metcalf & Eddy, 2016)

So, the wastewater treatment plant (WWTP) is composed of a combination unit operations and unit process designed to reduce certain constituents of untreated wastewater to an acceptable level (according to legislation). Whose option for inclusion in a WWTP is defined according to the characteristics of the raw wastewater (influent) to be treated and the receiving environment (effluents) where, it will be discharged and/or recovered, complying the requirements stipulated in the legislation (Figura 8).

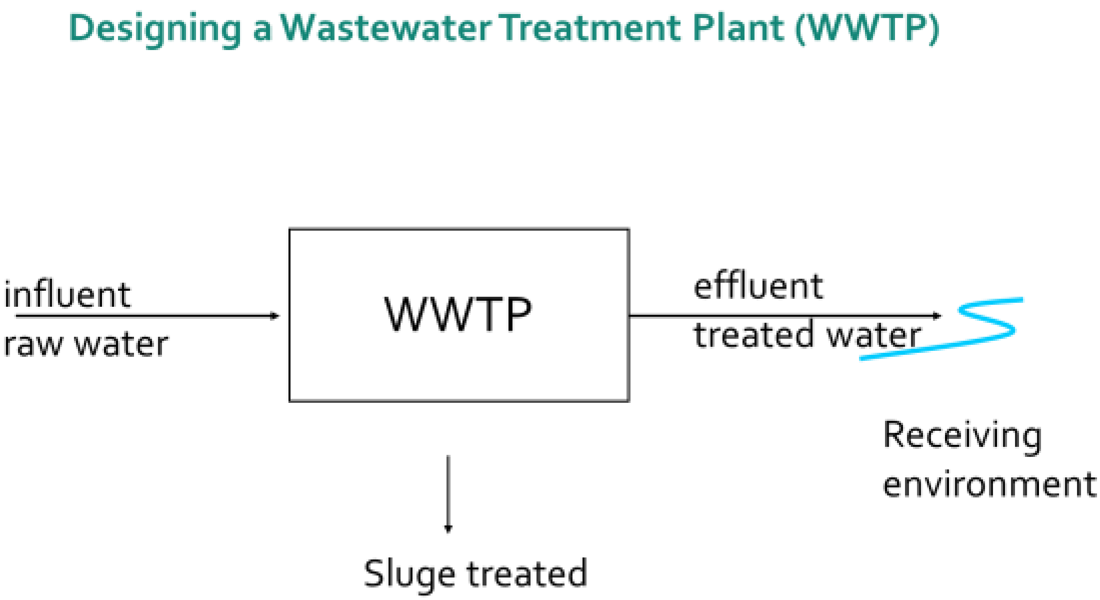
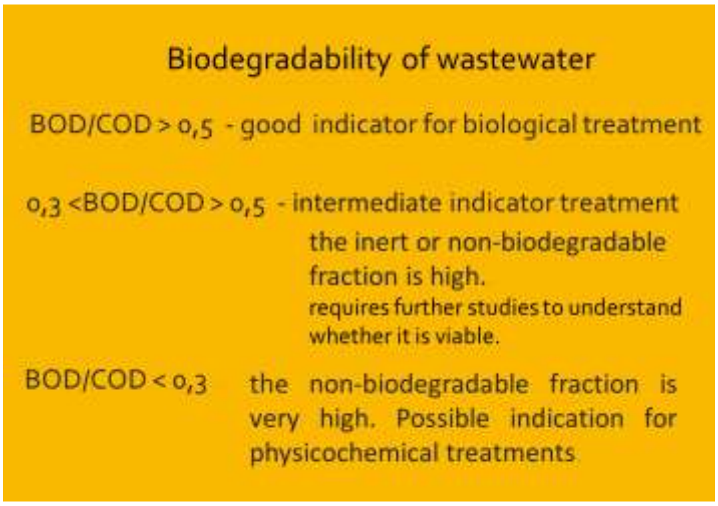


FIGURE 8- LAYOUT OF WASTEWATER TREATMENT PLANT

The WWTP is composed of a combination unit operations and unit process designed to reduce certain constituents of wastewater to an acceptable level, many different combinations are possible, unit operation and process commonly used are listed above.

The most appropriate wastewater treatment process can be defined by evaluating the biodegradability of untreated wastewater:


Biodegradability of wastewater

BOD/COD > 0,5 - good indicator for biological treatment

0,3 <BOD/COD > 0,5 - intermediate indicator treatment the inert or non-biodegradable fraction is high. requires further studies to understand whether it is viable.

BOD/COD < 0,3 the non-biodegradable fraction is very high. Possible indication for physicochemical treatments

When the inert or non-biodegradable fraction is high, requires further studies to understand whether it is viable.

There are several types of wastewater treatment: preliminary, primary, secondary, and tertiary treatment, whose option for inclusion in a WWTP is defined according to the characteristics of the raw wastewater to be treated and the receiving environment (where the treated effluents will be discharged and/or recovered), complying the requirements stipulated in the legislation. So, unit operation and process occur in a variety of combinations in treatment flow diagrams.

5.4.1. Preliminary treatment

Preliminary treatment is the first unitary operation of a WWTP, which serves to remove coarse solids or constituents that could cause operational or maintenance problems in the next stage. This treatment includes sand removal, screening, homogenization and storage, and removal of oils and fats.

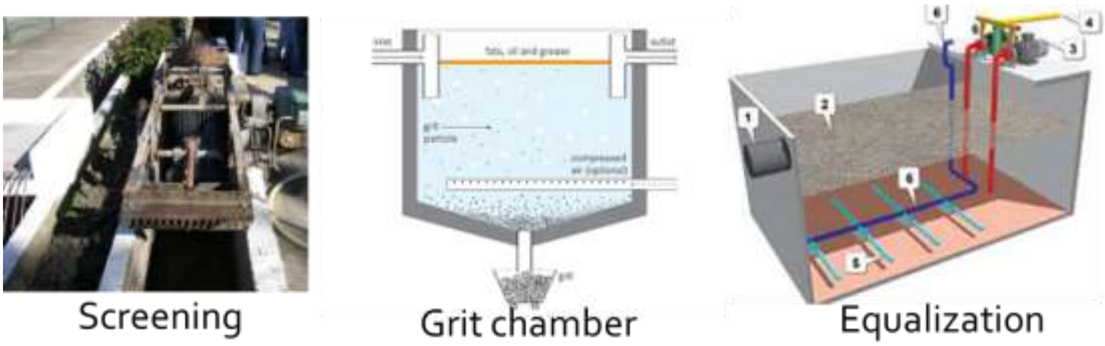


FIGURE 9

5.4.2. Secondary *treatment*

The secondary wastewater treatment involves removing organic matter remaining from primary treatment through biological degradation.

Examples

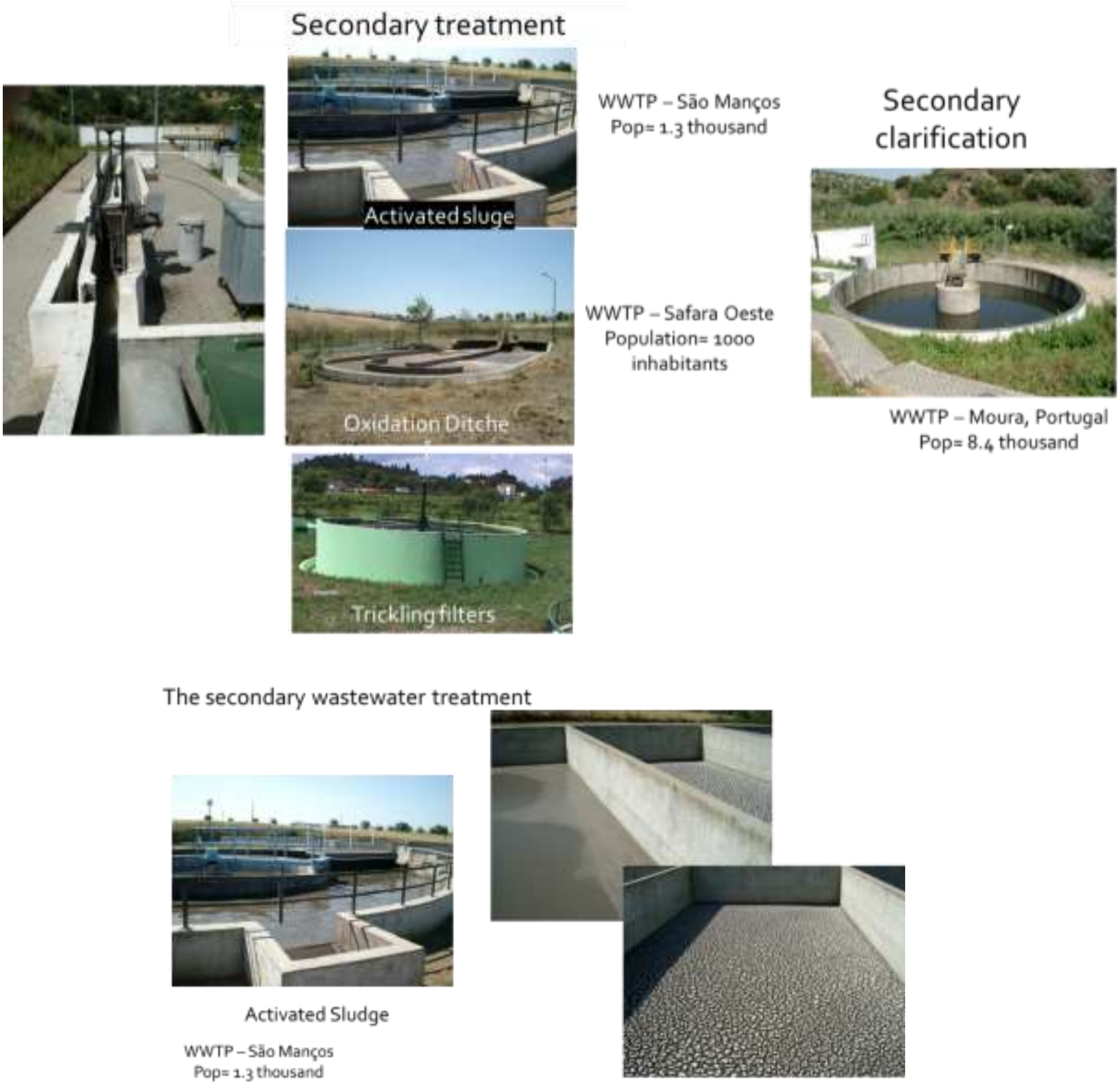


FIGURE 11 – SOME EXAMPLES OF COMBINED WASTEWATER TREATMENTE PLANT

The layout of a wastewater treatment plant (biological treatment) can be observed in the Figure 10

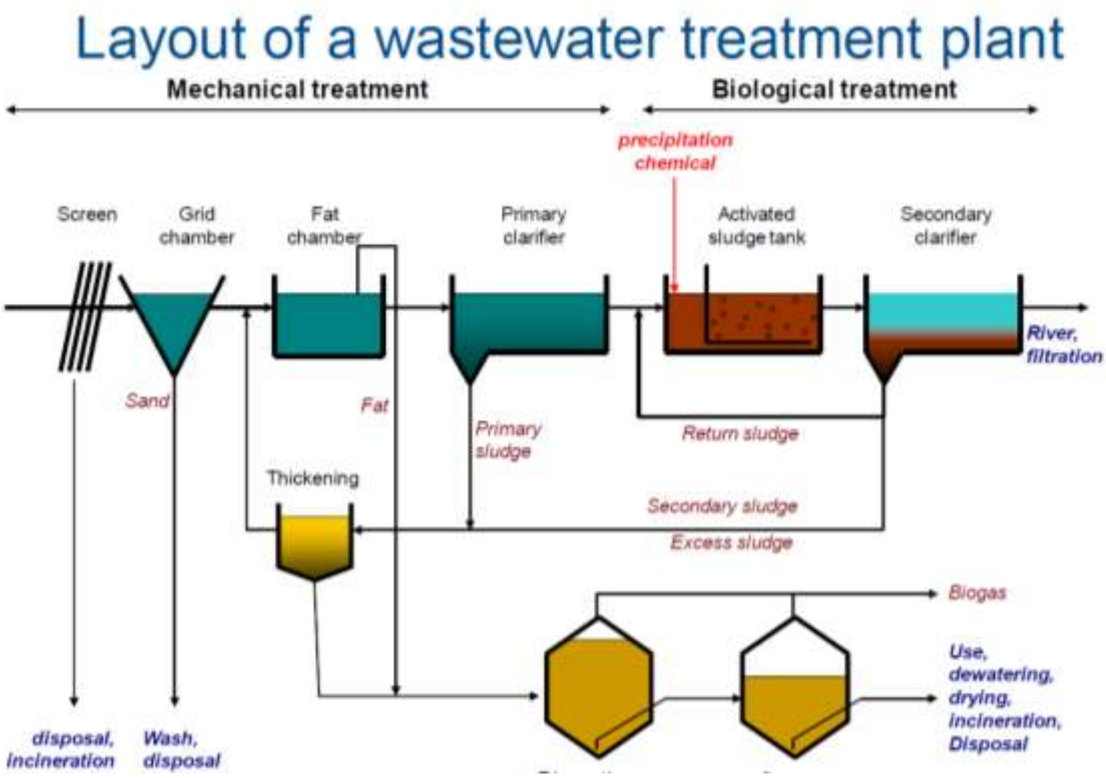


FIGURE 12 –LAYOUT OF A BIOLOGICAL WASTEWATER TREATMENT- ACTIVATED SLUDGE PROCESS (

Biological treatment processed by activated sludge (suspended biomass) the influent is lead into an aeration tank. In this aeration tank the wastewater is mixed with earlier made activated sludge and with the help of the aeration equipment oxygen is added. Under these conditions the activated sludge can remove both the organic as well as other whole or partial contaminates from the wastewater. After the aeration tank the wastewater/activated sludge mixture is lead to a secondary settling tank, in which the biologically activated sludge settles and separates from the treated wastewater.

In the biologic process, the raw wastewater is lead into an aeration tank where wastewater is mixed with earlier made activated sludge and with the help of the aeration equipment oxygen is added. Under these conditions the activated sludge can remove both the organic as well as other whole or partial contaminates from the wastewater. After the aeration tank the wastewater/activated sludge mixture is lead to a secondary settling tank, in which the biologically activated sludge settles and separates from the treated wastewater.

The sludge loading is influenced by a few important factors and processes, such as:

- treatment efficiency
- sludge growth

- sludge age and with that the degree of stabilisation of the sludge
- nitrification and denitrification
- oxygen requirement of the sludge.

Suspended biomass systems are those in which the microorganisms responsible for converting organic matter are kept in suspension in the liquid, while the fixed biomass the microorganisms responsible for converting organic matter are kept in fixed inert material.

5.4.3. Tertiary treatment

Despite removing some organic matter remaining from secondary treatment, serves mainly to remove nutrients (nitrogen and phosphorus). Normally this type of treatment is used to refine the final effluent, that means to produce a better-quality effluent.

The process may include, nitrification, disinfection, filtration, adsorption on activated carbon, ion exchange and reverse osmosis.

There are also diverse mechanisms (physical, chemical, and biological) for wastewater disinfection and types of process: ultraviolet radiation, filtration, activated carbon adsorption (physical); chlorination, ozonation (chemical); phytoremediation, maturation ponds (biological). The choice of disinfection process depends on the efficiency of the process in inactivating pathogens microorganisms.

The level of wastewater treatment plants by country, also needs to be improved (Figure 11), for example in Portugal the most common level of treatment in percentage of load is secondary treatment 80 % , while in Lithuania, check Republic there is no data available.

Level of treatment in % of load entering wastewater treatment plants, by country

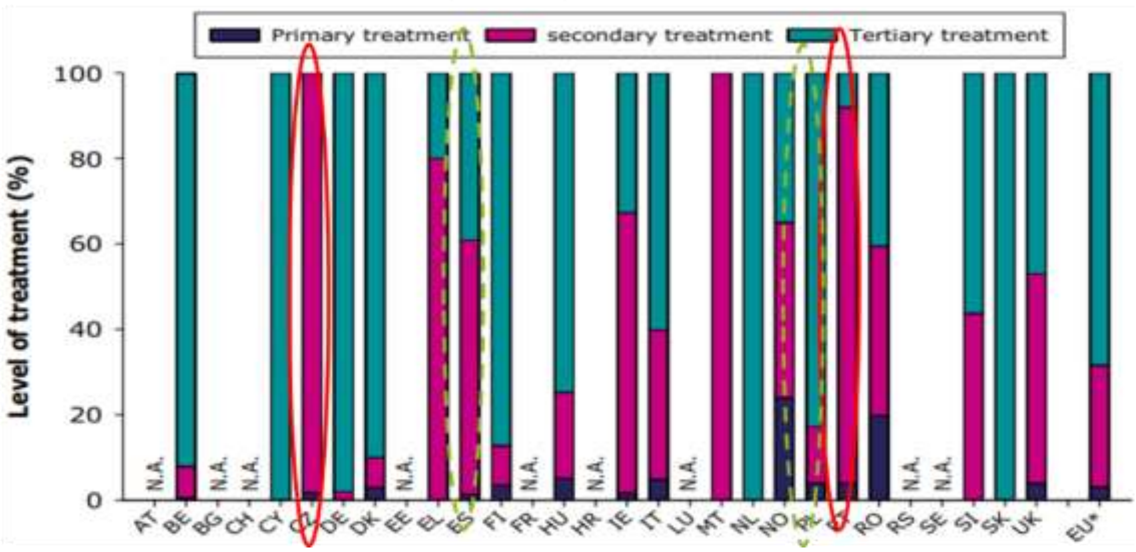


FIGURE 13 - LEVEL OF WASTEWATER TREATMENT PLANT, BY COUNTRY (EUREAU,2017).

Comparing the level of wastewater treatment in percentage regarding solid, carbon, and nutrient removal in WWTP by country in European Union (Figure 12) those with higher percentage of nutrient removal are Austria, Belgium, Hungry, Poland, Italy in opposite in Portugal is 100% of carbon removal. Despite this there is ongoing in Portugal a project called NETA (https://www.projeto-neta.pt/) to optimize and use the Chemical Precipitation Technique, developed by Polytechnic Institute of Beja to treat wastewater, to reuse the effluent for agricultural purposes (Figure 13).

Other example is the WWTP in Beja city that includes the development of a pilot project to reuse the treated wastewater for agricultural irrigation.

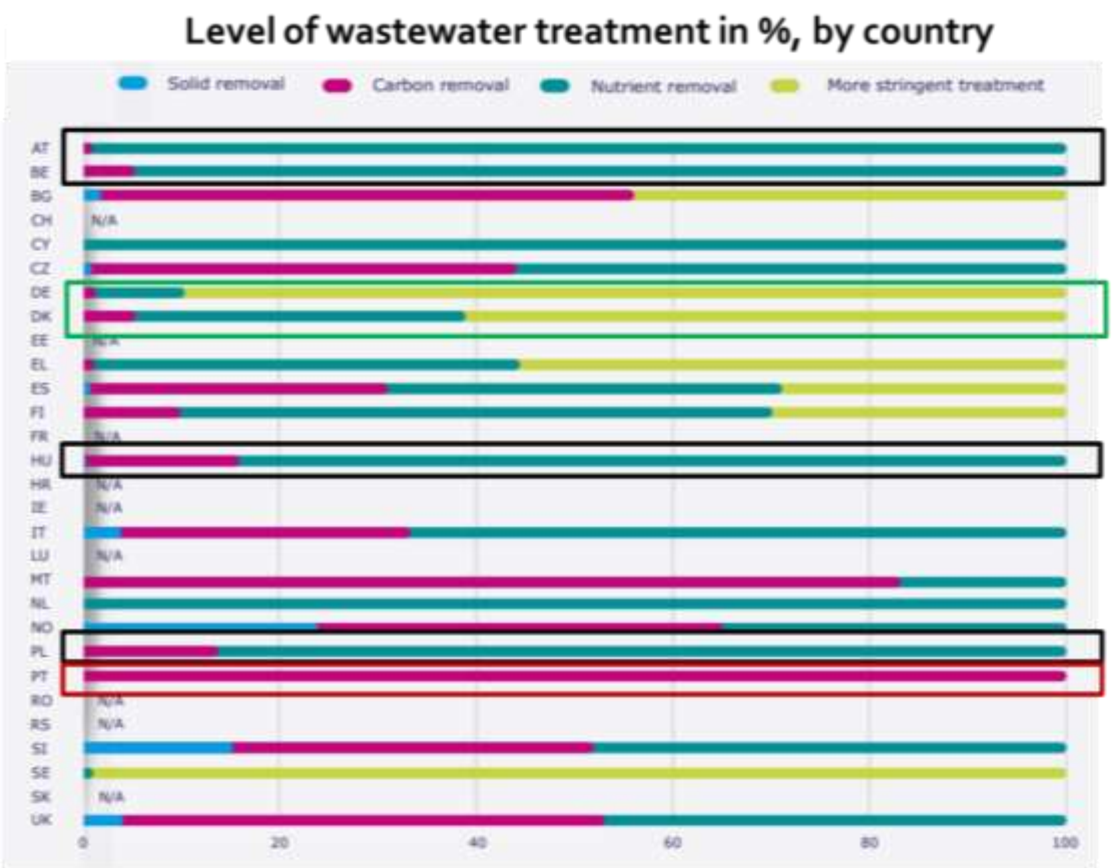
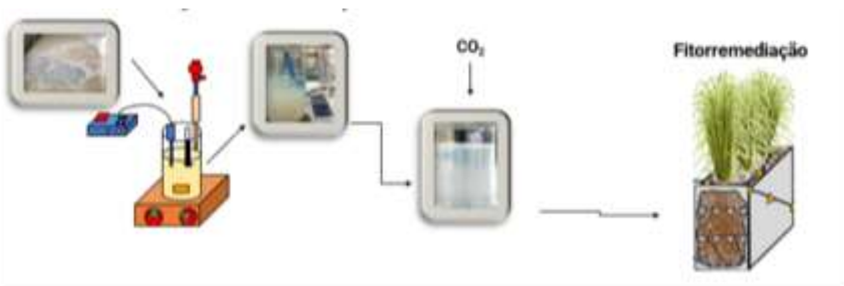


FIGURE 14- LEVEL OF SOLID, CARBON, AND NUTRIENT REMOVAL IN WASTEWATER TREATMENT PLANTS BY COUNTRY (EUREAU,2021)

The Chemical Precipitation Technique (Figure15) is a new technology patented, that covers a wide range of wastewater, with high concentrations of organic matter, nutrients, phenols. (Flor et al, 2022).

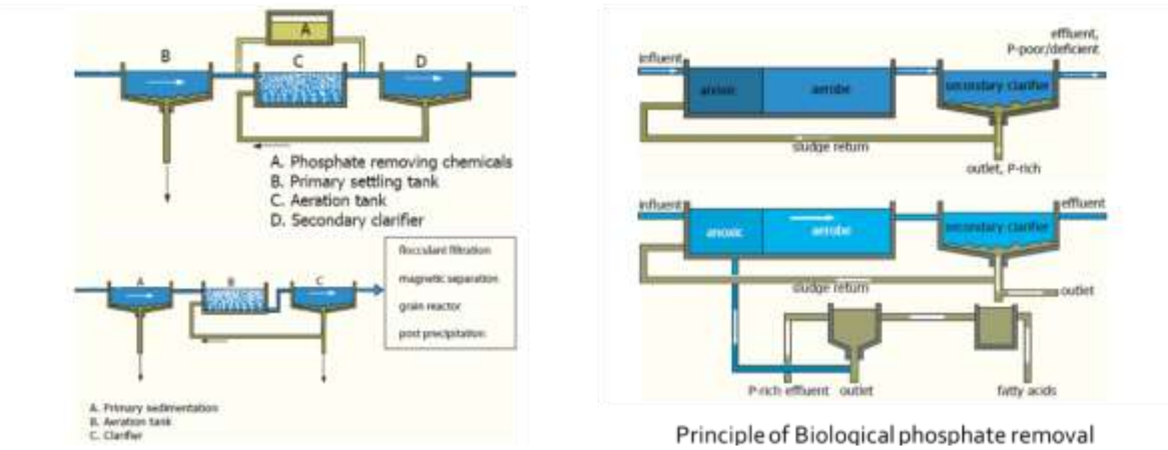


Efficiency removal COD and Nitrogen around 25% and 72% (Flor et al., 2022)

FIGURE 15- NEW TECHNOLOGY USING CHEMICAL PRECIPITATION TECHNIQUE

A layout of tertiary wastewater treatment to remove nutrients (phosphate and nitrogen) is shown in Figure 10.

Tertiary wastewater treatment



Principle of Biological phosphate removal

FIGURE 16 –LAYOUT OF TERTIARY WASTEWATER TREATMENT CHEMICAL AND BIOLOGICAL

6. SUSTAINABLE URBAN DRAINAGE SYSTEMS

The traditional method of draining surface water runoff from a built area is using underground pipe, tank storage systems to protect public health and prevent local flooding by taking the water away from source as quickly as possible. Those systems can be defined as unitary, separative, pseudo separative.

Sustainable Urban Drainage Systems (SUDS) are a set of sustainable techniques for controlling and managing rainwater and emerged as an alternative to the traditional rainwater drainage system in urban areas. This system was designed to manage the environmental risks of urban runoff and contribute whenever possible to the improvement of the urban environment (Ballard et al., 2007). It represents the set of management practices, structures of control and strategies designed to collect the runoff in an efficient and sustainable way, in addition, to minimize pollution in the receiving water environment (Susdrain, 2012). SuDs is a way of managing rainfall that minimizes the negative impacts on the quantity and quality of runoff whilst maximizing the benefits of amenity and biodiversity for people and environment.

The main objectives of designing SUDS are to: (1) create a shared vision around the delivery of SUDS using nature-based approaches for all involved in designing and evaluation; (2) enable the designing of SUDS to meet agreed standards; (3) ensure that SUDS are maintainable now and, in the future (McCloy Consulting & Robert Bay Association, 2021).

The four pillars of SuDS design are: water quantity, water quality, amenity, and biodiversity (SuDS Manual, 2015)

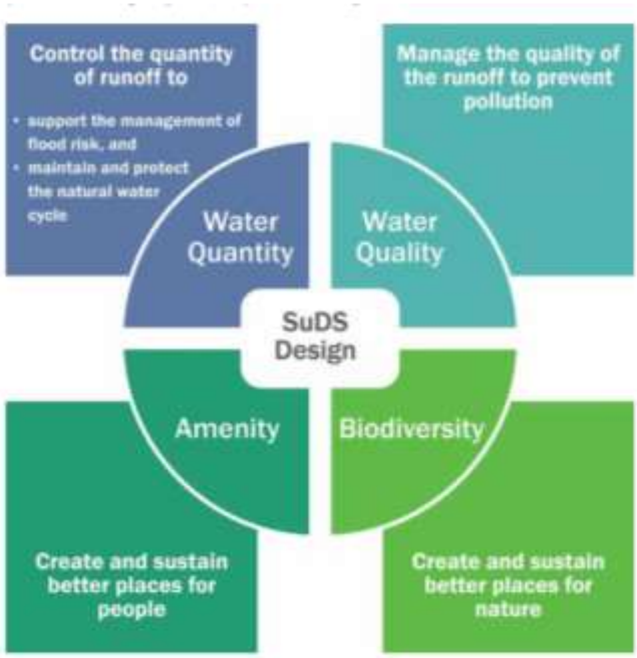


FIGURE 17- FOUR PILLAR OF SUSTAINABLE URBAN DRAINAGE SYSTEMS (SUDS MANUAL, 2015)

The SUDS properly designed, constructed, and maintained are more sustainable than the conventional system and it has the following objectives: (1) reduce the peak flows and runoff volume, (2) minimize the transportation of pollution from urban areas to the receiving water; (3) improve water quality; (4) improve flow regimes in watercourses or steam; (5) collect rainwater to replace mains water in applications that do not require high levels of water quality; (6) integrate stormwater treatment into the landscape; (7) improve urban landscape); (8) promote the natural recharge of aquifers/groundwater (when water is appropriate); (9) create recreation and leisure areas (take into account the natural environment and community needs); (10) provide better habitat for wildlife.

7. GOOD PRACTICES

In order to achieve a reduction in the water footprint, the following aspects are proposed:

- Remote monitoring of the supply network, as real-time repairs of network deficiencies are key to reducing the blue water footprint.
- Renewal of the supply network in municipalities with significant losses to prevent municipal "water wastage." In addition to representing water savings, water is closely tied to energy. Therefore, by reducing the amount of potable water extracted from various sources (in a scenario with no losses in the network or minimal losses), energy savings are achieved by maximizing the network's efficiency.
- Use of recirculating trucks for cleaning and maintenance of the sewer network.
- Reuse of water in industrial processes where possible, to avoid excessive use of potable water for all purposes when the physicochemical characteristics of the water permit it.
- In wastewater treatment facilities, it is proposed to reuse as much treated water as possible instead of diverting treated flows to the municipal sewer system.
- Use of reclaimed water: actively incorporating reclaimed water is considered urgent and necessary in response to various water uses that are currently being supplied with drinking water, leading to the excessive extraction of groundwater.
- Use of managed aquifer recharge wells to increase underground reserves on islands and reduce reliance on seawater desalination where possible.

8. REFERENCES

Calvo-Flores, F.G., Isac-García, J., Dobado, J. A. (2017). *Emerging Pollutants: Origin, Structure, and Properties*. Wiley.

Durão A., Rehan,I. Moreira, O., Carvalho F., Almeida A. (2023) Situação atual das águas residuais em Portugal continental. Entregável E.1.1 do Projeto NETA - Novas Estratégias no Tratamento de Águas Residuais.

Flor, C, Durão A, Almeida A., Carvalho F. (2022) Ecoinovação em Processos de Tratamento de Efluentes Agroindustriais e Reutilização de Águas Residuais na Indústria Alimentar. CNESA, Santarem

Franco, A. A., Arellano, J. M., Albendín, G., Rodríguez-Barroso, R., Zahedi, S., Quiroga, J. M., & Coello, M. D. (2020). Mapping microplastics in Cadiz (Spain): Occurrence of microplastics in municipal and industrial wastewaters. *Journal of Water Process Engineering*, *38*(June), 101596. https://doi.org/10.1016/j.jwpe.2020.101596

Hernández-Sánchez, C., González-Sálamo, J., Ortega-Zamora, C., Jiménez-Skrzypek, G., & Hernández-Borges, J. (2020). Microplastics: An Emerging and Challenging Research Field. *Current Analytical Chemistry*, *17*(7), 894–901. https://doi.org/10.2174/1573411016999201029194655

Jiang, J. Q., Zhou, Z., & Sharma, V. K. (2013). Occurrence, transportation, monitoring and treatment of emerging micro-pollutants in waste water - A review from global views. *Microchemical Journal*, *110*, 292–300. https://doi.org/10.1016/j.microc.2013.04.014

Marecos Do Monte, H., Santos, T., Barreiros, A. & Albuquerque, A. (2016). Tratamento de águas residuais – Operações e processos de tratamento físico e químico. CT05, ERSAR, Lisboa, Portugal, 544 p. (ISBN 978 989 8360 32 8).

Metcalf, & Eddy (2016). Wastewater Engineering: Treatment, Disposal and Reuse (International edition ed). MacGraw-Hill., New York.

Plattard, N., Dupuis, A., Migeot, V., Haddad, S., & Venisse, N. (2021). An overview of the literature on emerging pollutants: Chlorinated derivatives of Bisphenol A (ClxBPA). *Environment International*, *153*. https://doi.org/10.1016/j.envint.2021.106547

Zhou, S., Di Paolo, C., Wu, X., Shao, Y., Seiler, T. B., & Hollert, H. (2019). Optimization of screening-level risk assessment and priority selection of emerging pollutants – The case of pharmaceuticals in European surface waters. *Environment International*, *128*(April), 1–10. https://doi.org/10.1016/j.envint.2019.04.034