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Theme:

Application of microalgae in wastewater treatment

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Dedications

I dedicate this modest dissertation:

To whom I bear his name, my dear father Abdelmadjid

No dedication can express my respect, love and consideration for the sacrifices made for my well-being. You are the closest person to my heart, the friend and supporter of my long journey.I am here thanks to your prayers, advices and encouragement. May Allah keep you, bless you and grant you a long and healthy life full of happiness so that you will be proud of me.

To my dear mother Ait oubeli Dalila

You are my angel in my life and the fountain of love and tenderness. May Allah watch over you Preserve your health and grant you a long life full of happiness.I wish you healing and speedy recovery and may God give you strength and patience,You are the candle that lights my long way.

To my brothers

I wish you every success in your journey.

To my big sister

Inès, I wish you a life full of success, happiness and prosperity.

To my friends, my comrades and all my enssmalian family

I wish you a life full of success and prosperity in your lives and careers.

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Abreviations

ATP : Adénosine Triphosphate.

BOD : Biological Oxygen Demand

Cd : Cadmium.

Co : Cobalt.

CO_2 : Carbon dioxide.

COD : Chemical Oxygen Demand.

CU : Copper.

DWS : Drinking Water Supply.

Fe : Iron.

Hg : Mercury.

MS : Mineral Solids.

$NADPH_2$: Nicotinamide adénine Dinucléotide hydrogen Phosphate.

NH3 : Ammonia.

NH^{4-} : Ammonium.

NI : Nickel.

NO^{2-} : Nitrogen dioxide.

NO^{3-} : Nitrates.

O_3 : Ozone.

pH : potential of Hydrogen.

$PO_4{}^{3-}$: Phosphate.

SO_4: Sulphate.

TN: Total Nitrogen.

TOC: Total Organic Carbon.

TP : Total Phosphorus.

TSS : Total Suspended Solids.

UV : Ultraviolet.

VO: Volume.

VSS : Volatile Suspended Solids.

WHO : World Health Organization.

WRD : Water Ressources Department.

WWTP : wastewater treatment plant.

Zn : zin

General introduction

The concept of sustainable development focuses on satisfying current needs while preserving the means for future generations to do the same. Yet our reality falls short of this goal, as humanity's impact on the planet and its ecosystems has been devastating, particularly over the last century. The major contributor to this problem is the exponential increase in the world's population, which is having a detrimental effect on food security.

Human domestic, agricultural and industrial activities generate a plethora of waste and debris, likely to pollute and disturb the receiving environment. These discharges and wastes constitute what is known as wastewater **(Mecheref & Mahfouf, 2016).**

Treating this water, which is essential for preserving our environment, helps to limit the impact of various forms of pollution on human health.

Today, there are multiple physico-chemical and biological treatment techniques, but their implementation is both costly and cumbersome. In addition, they are known to have adverse effects on the environment.

Biological wastewater treatment is a crucial technique for eliminating dissolved pollutants, which involves their degradation and decomposition by various micro-organisms, including microalgae.

Microalgae are photosynthetic microorganisms that first appeared on Earth three billion years ago. They continue to attract the attention of scientists around the world, thanks to their remarkable potential in a variety of fields, which has aroused growing interest over the years.

In the environmental field, microalgae play a key role in wastewater treatment, using their capacity to fix carbon dioxide and certain heavy metals during their development.

It is also important to point out that wastewater from our study area is discharged into bodies of water, causing a major ecological imbalance for terrestrial and aquatic flora and fauna.

The aim of this work is to demonstrate the role of microalgae in wastewater treatment by building a microalgae treatment plant, in order to treat wastewater and thus resolve the inconveniences caused by it.

The reuse of purified water, and the exploitation of microalgae biomass, are prospects from which farmers can benefit from.

My study will be organized into the following chapters:

- The first chapter provides on the first part an overview of generalities about microalgae, their classification, cultivation and applications, while on the second part it provides a general description of wastewater treatment processes, the composition of this water, its origins and the use of microalgae in its treatment.
- The second chapter, we pass to the Methodology where i give a presentation of the study area, the methods of calcculation of the pollutant and hydraulic loads and the sizing of the various compartments of the proposed treatment plant.
- The third chapter, will be devoted to results and discusion of the necessary calculations we need for sizing the WWTP, a comparison between the proposed wastewater treatment process and activated sludge, and the final result in the form of a Three-dimensional plan.

Chapter 1: Generalities

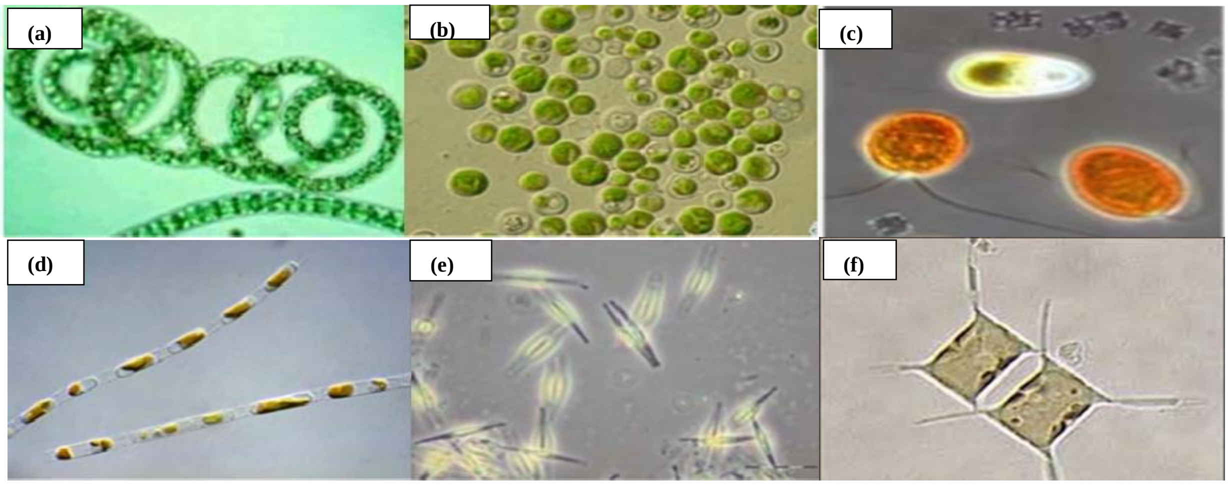
1.1. Generalities on microalgae

Photosynthetic organisms are attracting growing interest, thanks to their interesting biological and metabolic properties. The term "microalgae" has gradually gained acceptance in the scientific and industrial worlds. In recent years, microalgal biotechnology has become a key area of research, enabling us to explore and exploit the enormous potential of these microorganisms in a wide range of systems and industrial sectors.

1.1.1. Definition

Microalgae are microscopic algae ranging in size from a few microns to a hundred microns **(Cadoret & Bernard, 2008),** photosynthetic, they can be unicellular or undifferentiated multicellular. Thanks to their great adaptability and high growth rate, they thrive in a variety of habitats, mainly in aquatic environments **(Tebbani *et al.*, 2014).**

Microalgae are thallophytes, possessing chlorophyll as well as other pigments to carry out the process of photosynthesis **(Becerra, 2009)**, a process by which they convert light energy from the sun into electrochemical energy to split the water molecule (with release of O_2) and synthesize organic compounds (biomass) from carbon dioxide and mineral elements **(Fischer *et al.*, 2016),** they are also considered the main primary producers of the biosphere.



(a): *Spirulina platensis*, (b): *Chlorella vulgaris*, (c): *Dunaliella salina*

(d): *Skeletonema marinoi*, (e): *Phaecodactylum tricornutum*, (f) :*Chaetoceros calcitrans*

Figure 1: Diversity of microalgae **(Wahbi, 2017).**

1.1.2. Classification of microalgae

The biodiversity of microalgae is immense, reflected in the variety of shapes, sizes, colors and habitats of these microorganisms. It has been estimated that there are around 200,000 species of microalgae on the planet. Some authors even put the figure at over a million species, of which only 35,000 have been described **(Rajkumar & Zahira, 2013; in Mortonen, 2017).**

The genetic diversity and physiological plasticity of microalgae enable them to adapt to variable environmental conditions, which explains the variety of species **(Thruman & Burton, 1997).**

1.1.2.1. Classification criteria

Microalgae are classified according to several criteria such as: the organization of their photosynthetic membranes, the chemical nature of the reserve products derived from photosynthesis **(Carlsson *et al.*, 2007),** life cycle, basic cell structure and variation in pigmentation **(Chen *et al.*, 2015).** Table (1) lists some of the criteria used to classify microalgae.

Table 1: Classification of some microalgae species **(Wahbi, 2017).**

Habitat	**Reserves**	**Pigments**	**Representatives**	**Number of Species**	**Common name**	**Type of microalgae**	**Phylum**
Fresh, brackish and salt water	Carbohydrates, lipids and Proteins	Chlorophyll a and b. xantophyll and carotenes.	*Chlorella,sp* *Scenedesmus sp*	7500	Green algae	Eukaryote	Chlorophyte
Fresh, brackish and salt water	Lipids and silica	Chlorophyll a, C1 and C2. Xantophylls. Carotenes Fucoxanthin	*Dinobryon sp* *Surirella arctica*	6000	Brown-yellow, green-yellow algae and diatoms	Eukaryote	Chrysophyte
Fresh, brackish and salt water	Starch, lipids and proteins	Chlorophylls a, C1, C2, carotenes, Fucoxanthin	*Gymnodinium litoralis* *Ceratium fusus* *Alexandrium minitum*	1100	Dinoflagellates, dinophytes	Eukaryote	Pyrrhophyte
Brackish and salt water	Complex and sulfated polysaccharides	Chlorophyll a Phycoerythrin Phycocyanin,	*Rhodosorus marinus*	7000	Red algae	Eukaryote	Rhodophyte
Fresh and salt water	Polysaccharides, lipids and iron	Chlorophyll a and b allophycocyanin, phycoerythrocyanine	*Anabaena azollae* *Spirulina platensis* *Microcystis aeruginosa*	2000	Cyanobacteria, blue-green algae	Prokaryote	Cyanophyte

1.1.2.2. Different groups of microalgae

There are two main groups of microalgae:

- **Eukaryotes:** These are unicellular or multicellular organisms with a complex structure containing a membrane-bound nucleus and several internal organelles.
- **Prokaryotes:** unicellular organisms also known as cyanobacteria. They are considered prokaryotes due to the absence of a membrane-bound nucleus inside their cells **(Filali, 2012).**

Table 2: Diversity of eukaryotic and prokaryotic microalgae, marine and freshwater **(Sharma & Rai, 2011).**

Domain	**Class**
Prokaryota	Cyanophyceae
	Prochlorophyceae
Eukaryota	Bacillariophyceae
	Charophyceae
	Chrysophyceae
	Chlorophyceae
	Cryptophyceae
	Dinophyceae
	Euglenophceae
	Glaucophyceae
	Haptophyceae
	Phaeophyceae
	Rhodophyceae

1.1.3. Reproduction of microalgae

The life cycle of microalgae comprises two processes of sexual and/or asexual reproduction:

- **Asexual reproduction**: microalgae can reproduce either by scissiparity in cyanophyceae and mitosis in eukaryotes, or by sporulation.
- **Sexual reproduction:** This is the least frequent and most random mode in which reproduction is based on the interaction of male and female gametes **(Gayral, 1975; in Amirouche & Benachrine, 2012).**

1.1.4. Biochemical composition of microalgae

The interest of microalgae lies in the diversity of their biochemical compositions. The main difference between this biomass and other plants is their richness in lipids, proteins, polysaccharides, vitamins, pigments and antioxidants **(Dejoye Tanzi, 2013).**

Table 3 lists the biochemical composition of some microalgae.

Table 3: Biochemical compositions of microalgae **(Becker, 2007).**

Microalgae	**Proteins (%)**	**Polysaccharides (%)**	**Lipids (%)**
Chlorella vulgaris	51-58	12-17	14-22
Dunaliella salina	57	32	6
Porphyridium cruentum	28-39	40-57	9-14
Spirulina platensis	46-63	8-14	4-9
Scenedesmus obliquus	50-56	10-17	12-14
Synechococcus sp	63	15	11

1.1.5. Mechanism of photosynthesis in microalgae

Microalgae are photosynthetic organisms that have the ability to capture light via the absorption of photons by photosynthetic units and convert this light energy into chemical energy through their main pigments: chlorophyll(a), chlorophyll(b), xanthophyll and carotene **(Geetanjali & Sen, 2017).**

Photosynthesis is represented globally by the following equation:

$$nCO_2 + nH_2O \longrightarrow (CH2O)\ n + nO_2$$

This global reaction takes place in two stages (light reaction and dark reaction) separated in space and time (Figure 2).

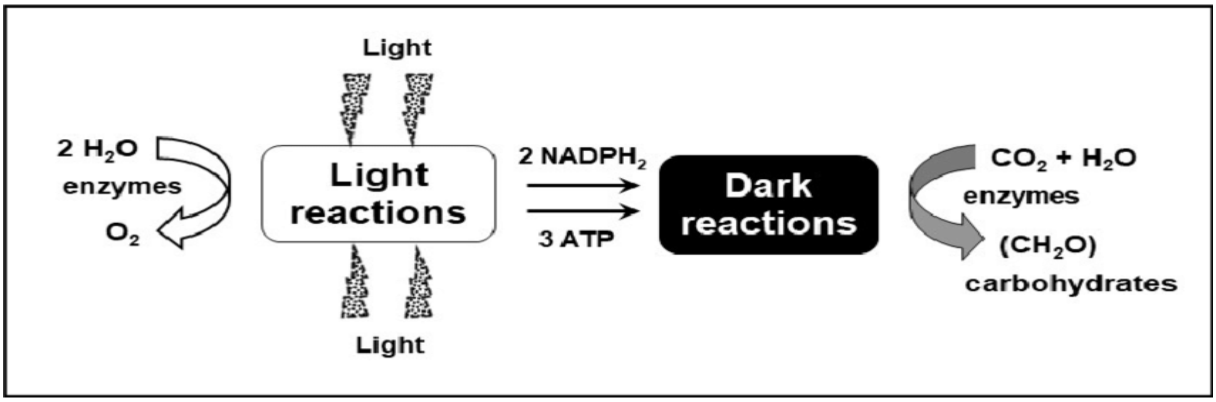


Figure 2: Light and dark reactions of photosynthesis **(Masojídek *et al.*, 2021).**

- **Light reaction**: A rapid reaction taking place in the chloroplast membrane. It enables light energy to be converted into chemical energy to produce $NADPH_2$ and ATP. The oxygen released results from the dissociation of the consumed water molecule.
- **Dark reaction:** This reaction takes place in the stroma, where the products of the light reaction are used to reduce CO_2 into carbohydrates. This stage is significantly slower than the previous one. **(Sialve & Steyer, 2013).**

1.1.6. Microalgal growth dynamics

The growth of microalgae follows a curve (Figure 3) that describes the evolution of algal biomass over time. This curve is divided into several phases that reflect changes in the biomass and its environment **(Yuan-Kun &Hui, 2004).**

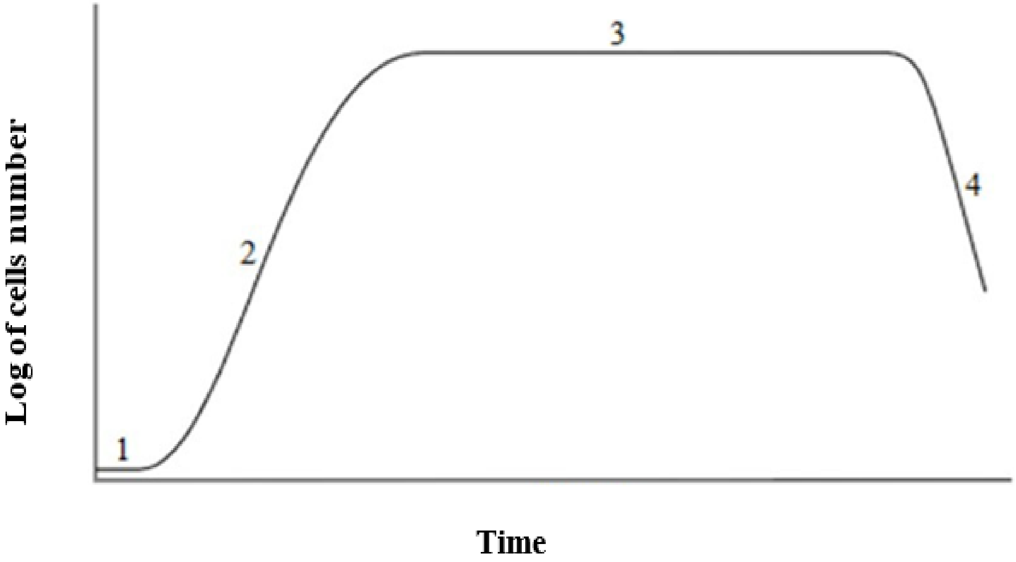


Figure 3:Model of growth curve of microalgae culture **(According to FAO, 1996).**

Acccording to the curve shown in figure 3, the growth of microalgae is divided into four phases that are:

1. Lag phase: it corresponds to the time needed for microalgae to adapt to new environmental conditions. The growth rate during this period is very low **(Yuan-Kun & Hui, 2004).**

2. Exponential phase: during this phase, the growth rate of microalgae is at its maximum, thanks to optimal environmental conditions **(Andersen, 2005).**

3. Stationary phase: is the period when the microalgae population reaches equilibrium and undergoes no net growth, the rate of growth is being balanced by the rate of cell death or inactivation **(Yuan-Kun &Hui, 2004).**

4. Death phase: After a complete halt in cell division, cells that die will not be replaced **(Fernandez-Reiriz *et al.*, 1989).**

Microalgal growth can be influenced by a number of factors and parameters that affect the growth and productivity of microalgal biomass (Figure 4).

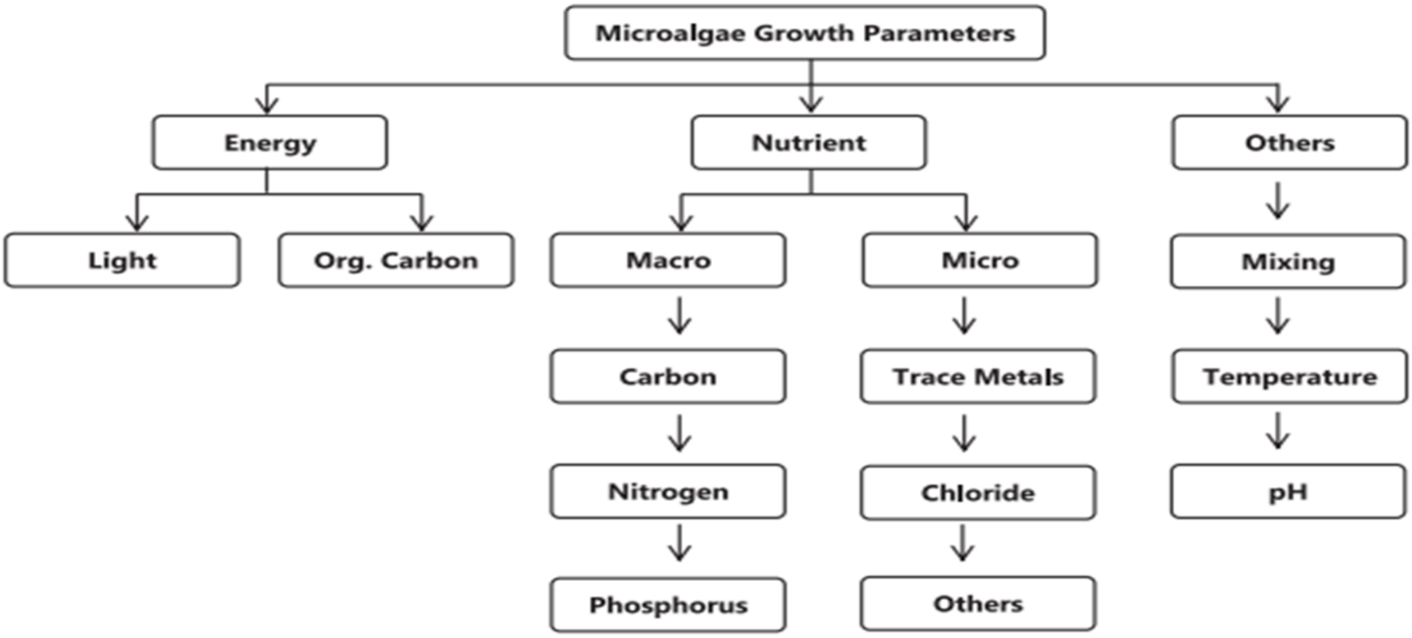


Figure 4: Schematic diagram of microalgae growth parameters **(Razzak *et al.*, 2017).**

1.1.7. Microalgae culture systems

There are several microalgae cultivation systems used for commercial production or laboratory research. Among the main cultivation systems, we distinguish:

1.1.7.1. Open systems: raceway

In recent decades, the industrial cultivation of microalgae has mainly relied on the open-system operating system, which refers to a system in which microalgae are grown in an open environment using natural light exclusively and thus eliminating the need for artificial lighting expenditure during the growth of microalgae **(Razzak *et al.*, 2013).**

The raceway pond (figure 5) is mainly used for cultivating microalgae: *scenedesmus sp, Chlorella sp* and *Spirulina platensis*. The idea is to circulate the algae over a long distance, but with a shallow width. Paddle wheels are used to facilitate mixing and circulation **(Tebbani *et al.*, 2014).**

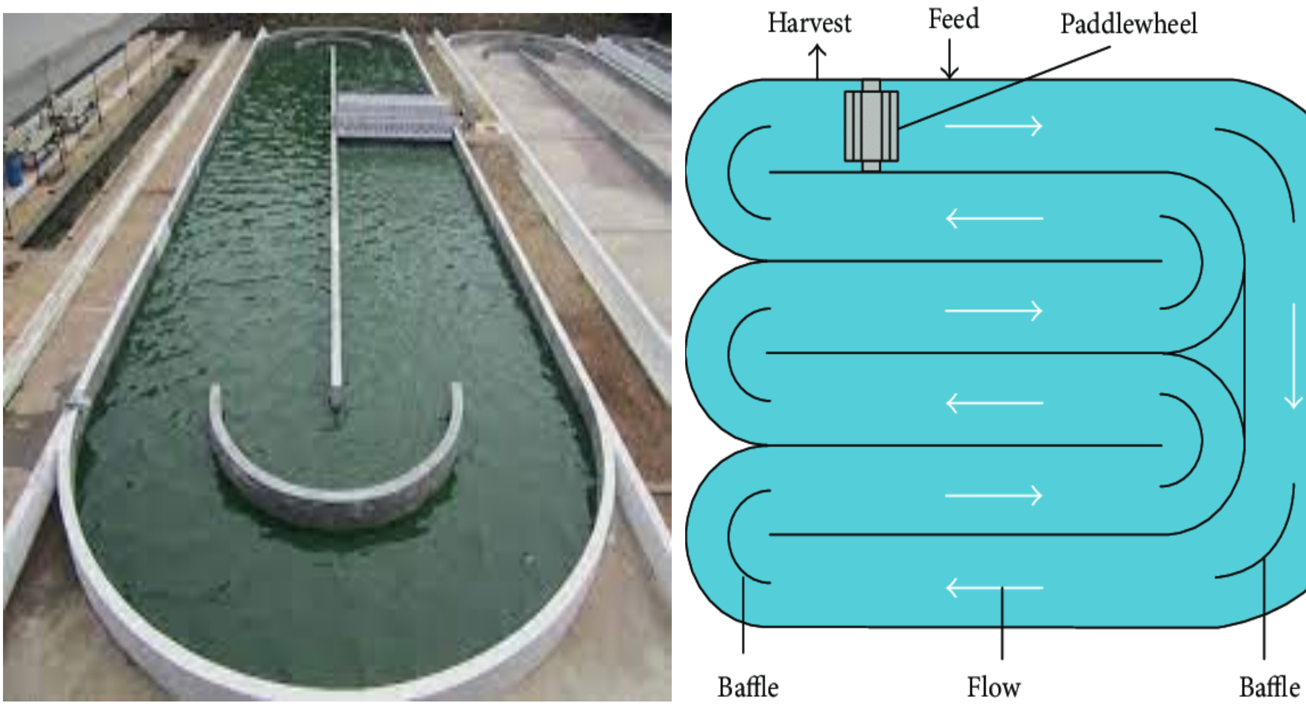


Figure 5: Raceway pond **(Dalgleish, 2017).**

1.1.7.2. Closed systems: Photobioreactors

Biological growth systems known as closed photobioreactors were used to grow microalgae indoors, isolating them from the outside elements.

They were often tubular in shape (Figure 6) to maximize the surface/volume ratio so that microalgae cells could receive sufficient light. Although these controlled environments allowed cultures in sterile medium, the expenses associated with their construction were quite high. **(Ugwu *et al.*, 2008).**

Figure 6: Tubular Photobioreactor **(De Vree *et al*., 2015).**

1.1.8. Biomass harvesting

Harvesting is a crucial step in separating microalgae from the culture medium. The adoption of a harvesting technique would mainly depend on the nature of the microalgae itself (Density and size), the application of the produced biomass and the energy requirements per unit of production **(Abu Hasan et *al*., 2017).**

The methods used to harvest microalgae biomass, their principles as well as their advantages and disadvantages are summarized in Table 4.

Table 4: Harvesting technique of microalgae biomasse **(Kim 2007 in Chisti, 2016).**

Technique	Principle	Advantages	Disadvantage
Centrifugation	-Using centripetal force, a separation between the culture medium and the microalgae can be obtained thanks to the disparity of density.	-Rapid and efficient with 95% removal efficiency.	-High energy and maintenance cost.
Sedimentation	-Subjected to gravity, the cells in the medium cause sedimentation.	-Low cost and energy efficient as microalgal biomass are left to settle naturally.	-Takes long time to settle. -Ineffective for small sized microalgae.
Filtration	-pass the suspension through a filter designed to retain cells while allowing other substances to pass through.	-Effective recovery for small sized microalgae.	-High cost, algal species specific . -Clogging/fouling of filters.
Flocculation	-Particles in solution unite to create clusters or "flocs".	-Cost effective.	-Biomass unsuitable for further use (animal feed or anaerobic digestion). -Chemical flocculant contamination.
Flotation	-A gravity-based process in which gas bubbles are attached to micro-algae cells so that they can float to the surface.	-Able to process large volumes of biomass as air bubbles adhere to microalgae, making them buoyant.	-Contamination with flocculation agent.

1.1.9. Microalgae applications

Microalgae have a wide variety of applications in different fields (Figure 7). They can be used in food and feed, cosmetics, biofuels, wastewater treatment, agriculture and pharmaceuticals production. Microalgae are a source of nutrients, bioactive compounds and renewable biomass, making them a sustainable and environmentally friendly alternative.

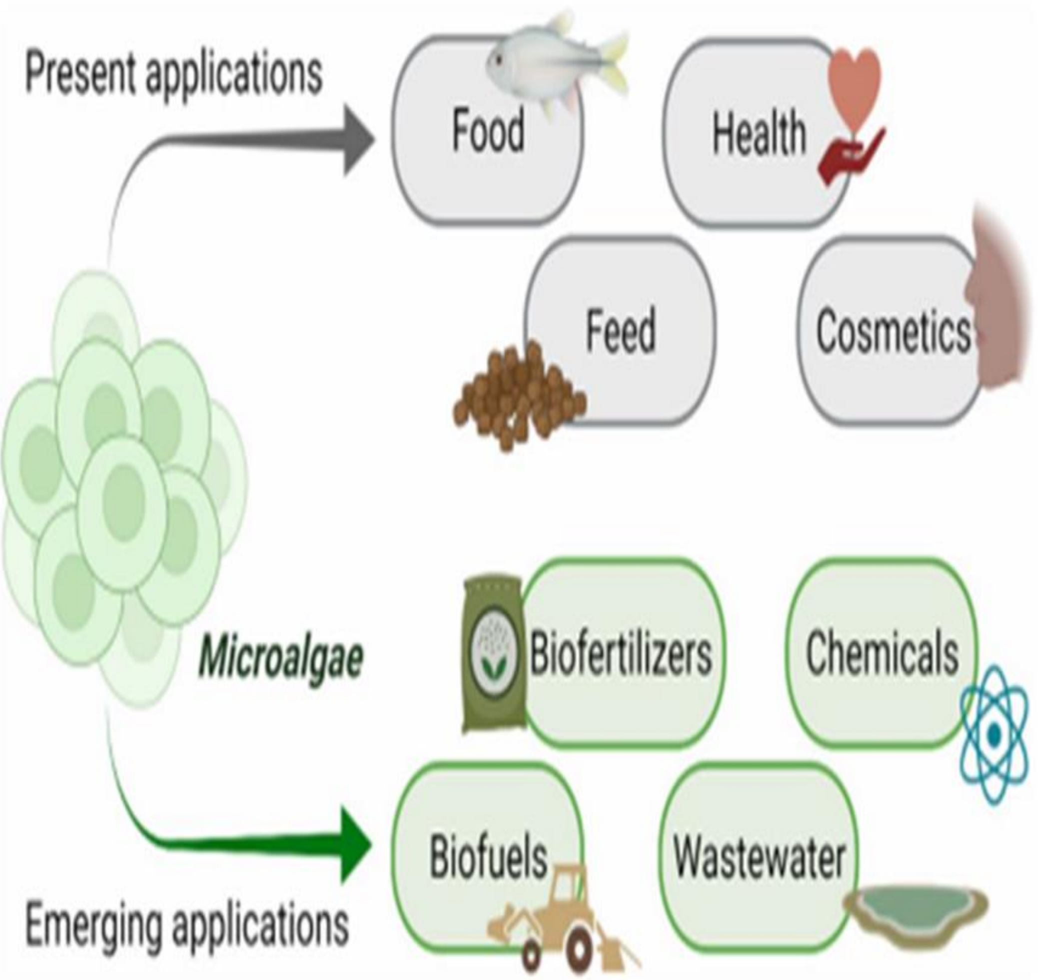


Figure 7: Applications of microalgae **(Dagnaisser, 2022).**

Microalgae used in various fields are listed in Table 5.

Table5: Some microalgae Species with high relevance for biotechnological applications**(Rizwana, 2018) .**

Species	Product	Field of application	Growing system
Spirulina platensis	Phycocyanin, biomass	Health food and cosmetics	Closed system
Chlorella vulgaris	Biomass, Ascorbic acid	Health food and food supplement	Closed and open system
Dunaliella salina	powders β-carotene	Human nutrition	Open system
Haematococcus pluvialis	Astaxanthin	Nutraceutical, cosmetics, food and feed industries	Closed and open system
Nostoc muscorum	Vitamin B12	Growth promoting	Closed and open system
Porphyridium cruentum	Polysaccharides	Pharmaceuticals, cosmetics and nutrition	Closed system
Phaedactylum tricornutum	Lipids and Fatty acids	Food and energy	Open system

1.1.9.1. Food applications

Microalgae are used in human and animal nutrition, and even in aquaculture. These microorganisms provide a real nutritional contribution, and the biomass produced can take several forms (powder, capsules and pellets) **(Pulz &Gross, 2004).**

β-carotene is a pigment synthesized by the alga Dunaliella and used as a colorant in the food industry. Polysaccharides derived from microalgae are exploited in the food industry as gelling or thickening agents **(Tebbani *et al.*, 2014).**

Microalgae are an important source of food for aquatic organisms such as fish, shrimp and oysters **(Person, 2010).** They are also used to improve water quality in fish farms.

1.1.9.2. Pharmaceuticals

Microalgae produce a wide variety of bioactive compounds (antioxidants, pigments and fatty acids) and toxins that can be used to produce drugs and pharmaceutical products. Polysaccharides extracted from microalgae enable the synthesis of antioxidant, anticoagulant, antiviral and anti-tumor agents. Microalgae also have the capacity to synthesize vitamins (For exemple Vitamine B12 and E) **(Tebbani *et al.*, 2014).**

1.1.9.3. Cosmetics

Several species of microalgae, mainly Spirulina and Chlorella, are used industrially in cosmetics. Due to their diverse natures (moisturizer, antioxidant, etc.), their extracts can be found in various products such as refreshing or regenerating skincare products, anti-aging creams, emollients as anti-irritants in exfoliating scrubs and also in hair care and sun protection products **(Person, 2010).**

Figure 8: Varied applications for microalgae in key areas (food, pharmaceuticals, cosmetics) **(Legrand, 2002).**

1.1.9.4. Energy sector

Microalgae are used in the energy sector (Figure 9) for the production of new and renewable energies. Thanks to their rich lipid content and rapid growth, microalgae are used to produce biofuels such as biodiesel and ethanol, using photosynthesis to convert sunlight into energy **(Kherarba, 2013).**

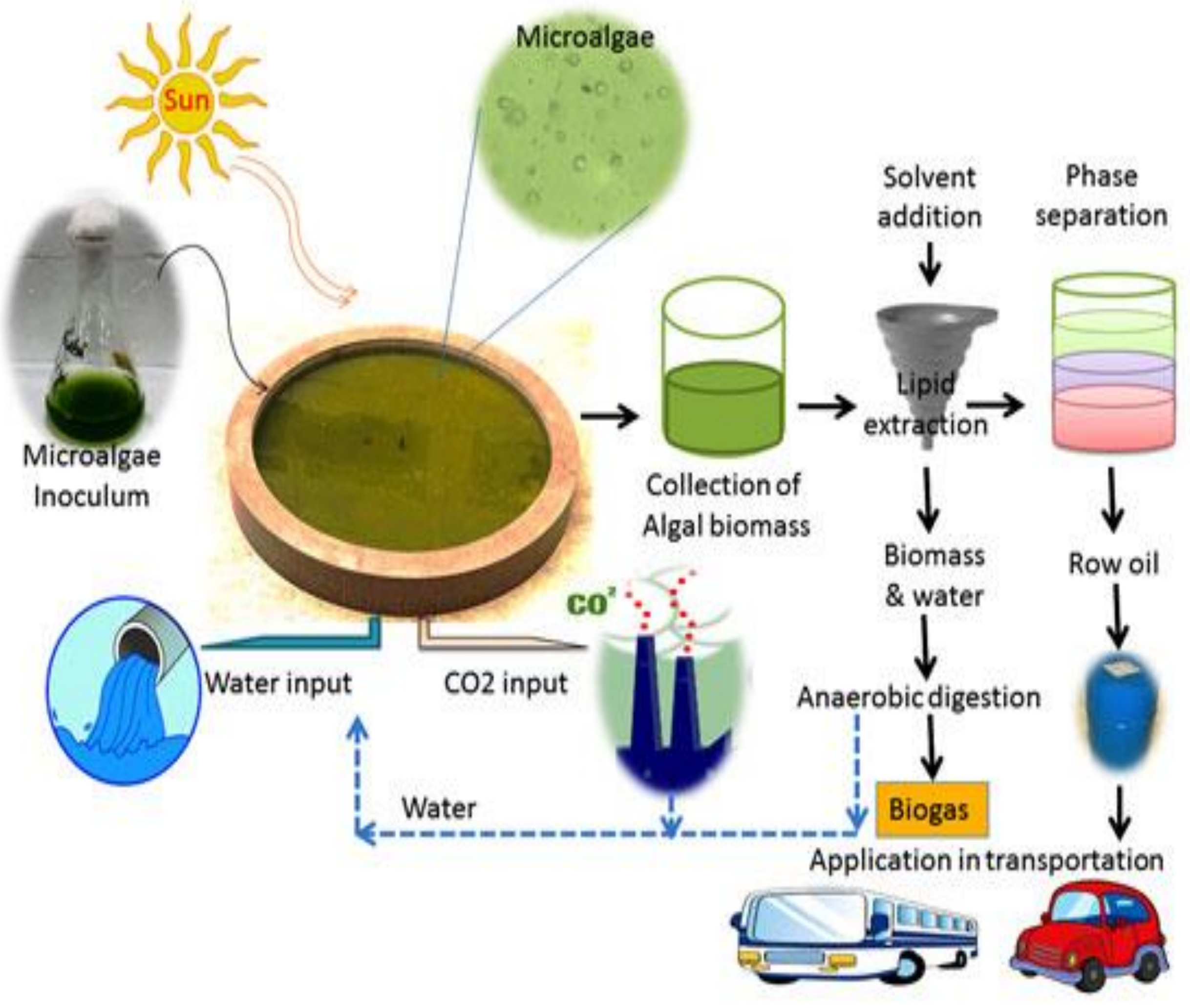


Figure 9: Overview of the Biofuel Production from Microalgae **(Oves *et al.*, 2022).**

1.1.9.5 Environmental applications

The main environmental applications of microalgae are :

- **Wastewater treatment:** microalgae are used in wastewater treatment thanks to their ability to assimilate numerous nutrients and fix heavy metals present in wastewater.

- **Agriculture:** the algal biomass produced is rich in essential nutrients for plant growth can be used as fertilizer and soil stabilizer in agriculture.
- **CO_2 sequestration**: microalgae are extremely efficient in this process, as during photosynthesis they can absorb up to 5 times more CO_2 than terrestrial plants **(Tebbani *et al.*, 2014).**

1.2. Generalities on Wastewater treatment processes

The aim of wastewater treatment is to obtain purified water that meets the discharge standards laid down by legislation and that can be used as part of the measures required for good water management (recycling), Depending on the nature and extent of the pollution, different processes can be used to purify urban and industrial wastewater, depending on its characteristics and the degree of purification required.

1.2.1. Waste water

1.2.1.1. Definition of wastewater

Wastewater is water which has undergone a deterioration and transformation of its natural properties after use, and which has become laden with soluble or insoluble pollutants **(Bliefert & Perraud, 2001)**. It represents a danger for users and receiving environments, which involves going through a treatment chain to remove all toxic elements.

1.2.1.2 Wastewater composition

The composition of wastewater can vary according to its origin (Domestic, agricultural, industrial or rainwater). It may contain several substances, in dissolved or solid form (figure 10), as well as numerous microorganisms.

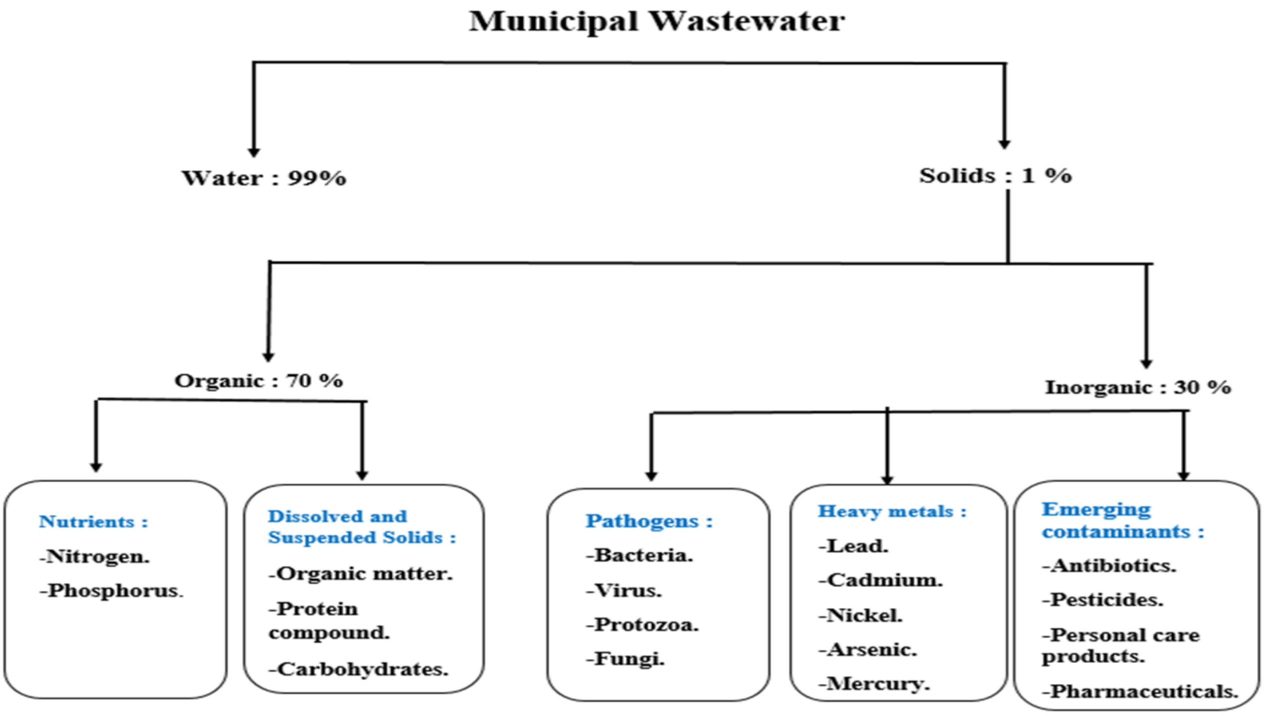


Figure 10*:* Composition of municipal wastewater (According to Academic Library, 2023).Consulted the 03/03/2023. Source***:* https://ebrary.net/htm/img/14/2050/12.png**

1.2.1.3 Wastewater origin

The origin of wastewater refers to the specific source from which it is generated. Depending on the origin of the polluting substances, wastewater can be classified into four categories:

1.2.1.3.1. Domestic wastewater

This comes from the various domestic uses of water. It essentially comprises toilet wastewater and household wastewater from bathrooms and kitchens. This wastewater contains organic waste, household chemicals and pathogens such as bacteria, viruses and parasites **(El Hachemi, 2012).**

1.2.1.3.2. Industrial wastewater

Industrial wastewater is the water generated by various industrial plants. Its composition is directly related to the type of industry considered.

Independently of the load of mineral or organic pollution, its putrescible or non-putrescible nature, it may also have its own toxicity characteristics linked to the chemicals transported **(Rodier *et al.*, 2005).**

1.2.1.3.3 .Agricultural wastewater

It includes drainage and farm wastewater. It is characterized by the presence of high concentrations of fertilizers, pesticides and insecticides, as well as a very high fertilizing value **(Kellogg *et al.*, 2000).**

1.2.1.3.4. Storm water

Stormwater, also known as urban stormwater, is runoff water from atmospheric precipitation. That picks up impurities when it comes into contact with the air (industrial fumes), then as it runs off residues deposited on city pavements and roofs (fuels, tire residues and heavy metals, waste oils...) **(Mecheref & Mahfouf, 2016).**

1.2.1.4 .Main characteristics of wastewater

In the field of wastewater treatment, the measurement of water quality is based on a number of parameters, which must be taken into account in: the design of the treatment plant, the choice of treatment process, the dosage of reagents and/or the measurement of pollutant removal. The main characteristics of wastewater are :

- **potential of Hydrogen (pH):** pH plays an important role in effluent purification, as it has the ability to decrease or increase the mobility of elements such as metal ions in bioavailable solution and thus their toxicity **(Merair & Salmi, 2014).**
- **Temperature:** an important ecological factor affecting pH, solubility of salts and especially gases, as well as determining the origin of water and any mixtures **(Rodier *et al.*, 2005).**
- **Suspended Solids (SS):** include insoluble matter suspended in the liquid, such as large organic and mineral matter.
- **Chemical Oxygen Demand (COD):** represents the quantity of oxygen required to oxidize chemically organic compounds present in wastewater. The value of the COD/BOD ratio indicates the biodegradability coefficient of an effluent **(Rodier *et al.*, 2005**). COD values generally vary :
    - COD = 1.5 to 2 times BOD For urban wastewater.
    - COD = 1 to 10 times BOD For all wastewaters.
    - COD> 2.5 times BOD for industrial wastewater **(Metahri, 2012).**

- **Biological Oxygen Demand (BOD)**: is a measure of the quantity of oxygen required for the biological degradation of organic matter by aerobic microorganisms over a specific period, generally 5 days at a temperature of 20°C.
- **Nutrients:** such as nitrogen and phosphorus. The excessive presence of these nutrients can lead to eutrophication of water bodies.
- **Pathogenic microorganisms**: such as bacteria, viruses and parasites. These pathogens of fecal origin can be transmitted by direct contact or contamination of water resources, and cause disease for humans.
- **Chemical contaminants:** wastewater can contain a variety of chemical contaminants such as heavy metals, hydrocarbons, pesticides and so on. These contaminants can have harmful effects on human health and the environment. **(Abouzlam, 2006).**

1.2.1.5. Discharge standards

Wastewater discharge standards refer to regulatory limits and criteria established to control the quality of wastewater discharged into the environment.

Table 6:physico-chemical discharge standards applied in Algeria,according to the WHO(World Health Organization) **(JORAD, 2012).**

Parameter	Standard used(WHO)
Temperature	30°C
pH	6,5-8,5
BOD	30 mg/l
COD	90 mg/l
TSS	35 mg/l
Nitrogen	30 mg/l
Total phosphorus	10mg/l
NH_4^+	20 mg/l
NO_2^-	1 mg/l

NO_3^-	<1mg/l
PO_4^{3-}	2mg/l

1.2.2. Wastewater treatment

1.2.2.1 .Wastewater treatment processes

The main aim of treatment is to reduce and eliminate suspended solids, biodegradable organic matter, pathogens and toxic compounds present in wastewater, so that the water finally discharged into the natural environment does not degrade it. This process involves obtaining purified water that complies with the discharge standards set by legislation, while preserving public health and the environment **(Martonen, 2017).**

1.2.2.1.1. Pre-treatment

Pretreatment or preliminary treatment is the first stage of treatment, which consists of removing the coarsest materials from the effluent, as well as elements likely to interfere with subsequent stages of treatment. **(Grosclaude, 1999).** This treatment removes around 35% of pollutants **(Moulin *et al.*, 2013).** Pre-treatment stages include screening, grit removal, oil removal and degreasing.

- **Screening**

This involves separating the most voluminous solid debris from the raw water, by passing the inlet effluent through a screen with bars spaced at varying distances to remove the most voluminous matter. The spacing of the bars is determined by the nature of the solids to be removed as well as the requirements of the treatment system **(Merair & Salmi, 2014).**

- **Grit removal**

Grit removal is a step carried out by reducing the flow speed to allow sedimentation of particles: sand, gravel and more or less fine mineral particles present in wastewater to eliminate them so as to avoid deposits in channels and pipes, thus protecting pumps and other equipment against abrasion and avoiding overloading subsequent treatment steps **(Merair &Salmi, 2014).**

- **De-oiling and degreasing**

De-oiling removes floating oils from the surface of the wastewater (liquid-liquid separation) using the dissolved air flotation method, while degreasing removes fats and grease suspended or dissolved in the wastewater (solid-liquid separation) by adding certain chemical agents. The aim of these two processes is to eliminate oils and greases that can hinder the effectiveness of the biological treatment that follows **(Metahri, 2012 in Mechref & Mahfouf, 2016).**

1.2.2.1.2. Primary treatment (Physico-chemical treatments)

Primary treatment in the strict sense is a physico-chemical treatment that aims to eliminate a large proportion of suspended mineral or organic matter by decantation or flotation (physico-chemical sludge) **(Moulin *et al.*, 2013).**

Settling performance can be improved by adding chemicals (ferric chloride, alumina sulfate...) that will neutralize charged particles, thus increasing the probability of collision between particles: coagulation and flocculation, (Figure 11), as well as the formation of flocs that are subsequently easily settleable **(Mecheref & Mahfouf, 2016).**

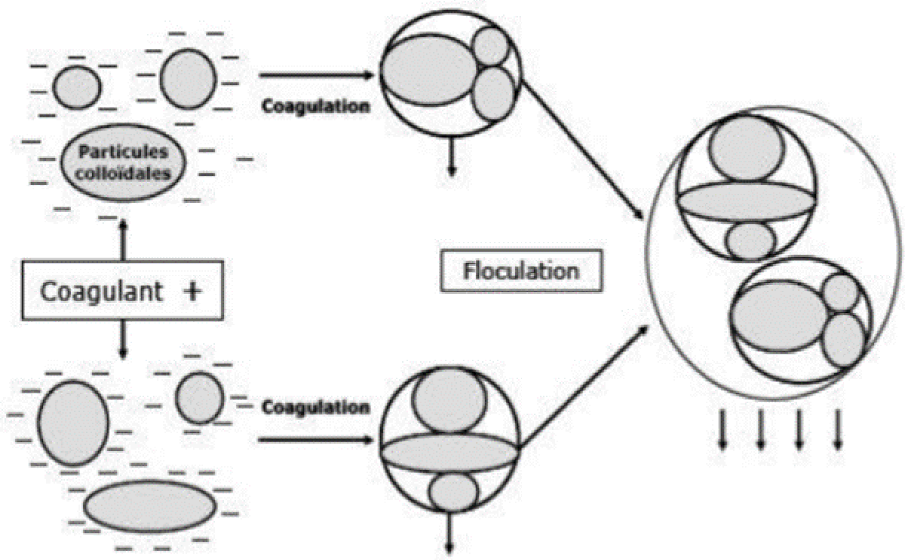


Figure 11: Ilustration of Coagulation and floculation process to remove colloidal poluants **(Adewale 2014).**

1.2.2.1.3. Secondary treatments (Biological treatments)

The main objective of these treatments is to eliminate the soluble and organic fractions of pollution, by exploiting the activity of microorganism's populations capable of consuming them **(Moulin *et al.*, 2013).**

Biological treatment processes are based on the ability of a purifying biomass of microorganisms (essentially bacteria) to oxidize mineral matter (NH_3) and the constituent materials of COD and BOD on the one hand, and to reduce oxygen-bearing molecules on the other: NO_3, SO_4 and CO_2. Depending on the type of bacteria present in the water, biological treatments are classified into two groups **:**Anaerobic treatments and aerobic treatments **(Grosclaude, 1999).**

- **Anaerobic treatment**

  This biological treatment is based on anaerobic fermentation or methanization processes. It consists on putting the wastewater to be treated into contact with a biomass of microorganisms mainly methanogenic bacteria that are capable of degrading organic matter under anaerobic conditions (absence of oxygen) to produce methane-rich biogas (50-70%) **(Bernet, 2015).**
- **Aerobic treatment**

Aerobic biological treatment involves the degradation of organic matter by microorganisms in the presence of oxygen, while controlling temperature and pH. A distinction can be made between:

- ✓ **Free culture (activated sludge)**

Activated sludge is the most common aerobic biological treatment.It involves the development of a bacterial culture dispersed in flocculent form in the form of flakes (activated sludge), in a brewed and aerated basin (aeration tank) supplied with water to be treated . In this tank, the purpose of mixing is to prevent deposits and homogenize the mixture of bacterial flakes and wastewater (mixed liquor); aeration can be based on oxygen from water, oxygen-enriched gas, or even pure oxygen, the aim being to dissolve this gas in the mixed liquor, in order to meet the needs of aerobic purification bacteria. After a sufficiently long contact time, the mixed liquor is sent to a clarifier also known as a secondary clarifier, designed to separate the purified water from the sludge. Sludge is recycled to the aeration tank to maintain a sufficient concentration of purifying bacteria **(Rejsek, 2002).**

According to the National sanitation office, biological wastewater treatment using activated sludge is the most widely used treatment in Algeria.

The advantages and disadvantages of activated sludge are summarized in the following table

Below.

Table 7: Advantages and disadvantages of activated sludge **(Grosclaude, 1999).**

Process	**Advantages**	**Disadvantages**
Activated sludge	- Suitable for all community sizes (except very small ones). - Good elimination of all pollution parameters (SS, COD, BOD_5, by nitrification and denitrification). - Suitable for protecting sensitive receiving environments. - Slightly stabilized sludge. - Easy to implement simultaneous simultaneous dephosphatization.	-Substantial investment costs. - High energy consumption. -Need for qualified personnel and regular monitoring. - Sensitivity to hydraulic overloads. - Sludge settleability not always easy to control. - High sludge production must be concentrated.

✓ **Fixed culture**

Fixed culture biological treatment is based on contact between wastewater and purifying biomass fixed on a mineral or synthetic support. We can distinguish :

- **Bacterial beds**

This process consists of attaching a bacterial culture to a substrate such as crushed stone, pozzolan (volcanic sand) or plastic. The bacterial film developed on the substrate surfaces forms a biofilm that degrades organic matter **(Abouzlam, 2006).**

Figure 12: Bacterial beds **(Bouchentouf &Abdarrahmane, 2021)**.

- **Biological disks**

This aerobic biological process consists in feeding wastewater that has been previously decanted or screened into a structure in which disks fixed on a horizontal axis are rotated at slow speed. These disks support the development of purifying microorganisms (biofilm), which draw the oxygen they need from the water to be treated, absorbing the dissolved pollution on which they feed. When the biofilm exceeds a thickness of a few millimeters, it detaches and heads towards a clarifier, where it separates from the purified water**. (Boutin *et al.*, 2016).**

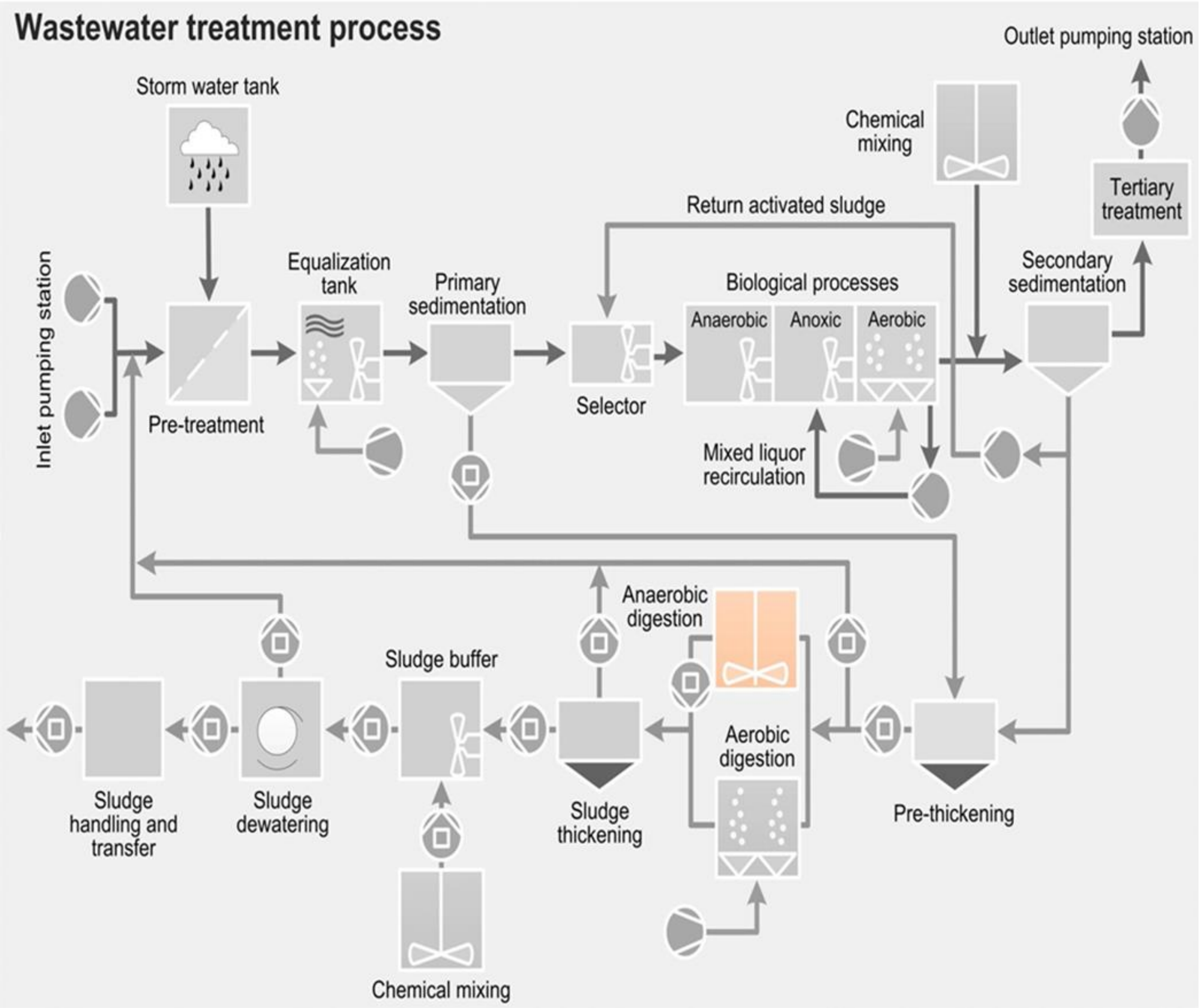


Figure 13: A descriptive schema of wastewater treatment process.

Consulted the: 03/03/2023.

Source: https://www.sulzer.com/-/media/images/applications/water-wastewater/municipal-wastewater/municipal-wastewater

1.2.2.1.4. Microalgae treatment process

Traditional wastewater treatment systems are generally costly, energy-intensive and often still unable to solve all the challenges posed by the wastewater they produce, which is why researchers have been looking for alternative solutions.

The ability of microalgae to thrive in nutrient-rich waters by utilizing organic and inorganic carbon, nitrogen and phosphorus while simultaneously accumulating biomass and reducing N, p and The chemical oxygen demand and removing heavy metals in wastewater has made them a potential candidate for a sustainable alternative to wastewater treatment **(Pittman *et al.*, 2010).**

The idea of using algae for wastewater treatment dates back over 60 years, when Oswald and Gotaas (1957) pioneered the use of microalgae for wastewater treatment. Since then, a great deal of research has been carried out into the potential of microalgae for treating wastewater from a variety of sources **(Oswald & Gotaas, 1957).**

In the 1970s, there was renewed interest in microalgae as a means of wastewater treatment due to growing concerns about eutrophication (excessive nutrient enrichment) of water bodies. Researchers recognized that microalgae could play a crucial role in reducing nitrogen and phosphorus levels in wastewater due to their photosynthetic abilities to convert solar energy into useful biomass and incorporate nutrients that cause eutrophication **(De la Noue & De Pauw, 1988).**

In the 1980s and 1990s, several pilot-scale projects were launched to test the feasibility of using microalgae for wastewater treatment. These studies demonstrated that microalgae-based wastewater treatment systems could effectively remove nutrients, organic matter and suspended solids from wastewater while producing valuable biomass **(Al-Homaidan *et al.*, 2012).**

In recent years, there has been growing interest in the use of microalgae as a sustainable and cost-effective solution for wastewater treatment. Several large-scale projects have been launched in different parts of the world, including Europe, Asia and America, to explore the bio-remediation potential of these microorganisms **(Plohn *et al.*, 2021).**

To reduce the economic costs of wastewater treatment processes using microalgae, the biomass produced is used to produce high-value-added molecules, biogas, biodiesel and hydrogen, etc. **(Filali, 2012).** These processes are generally coupled with the removal of CO_2 from industrial off-gases, leading to integrated processes (Figure 14).

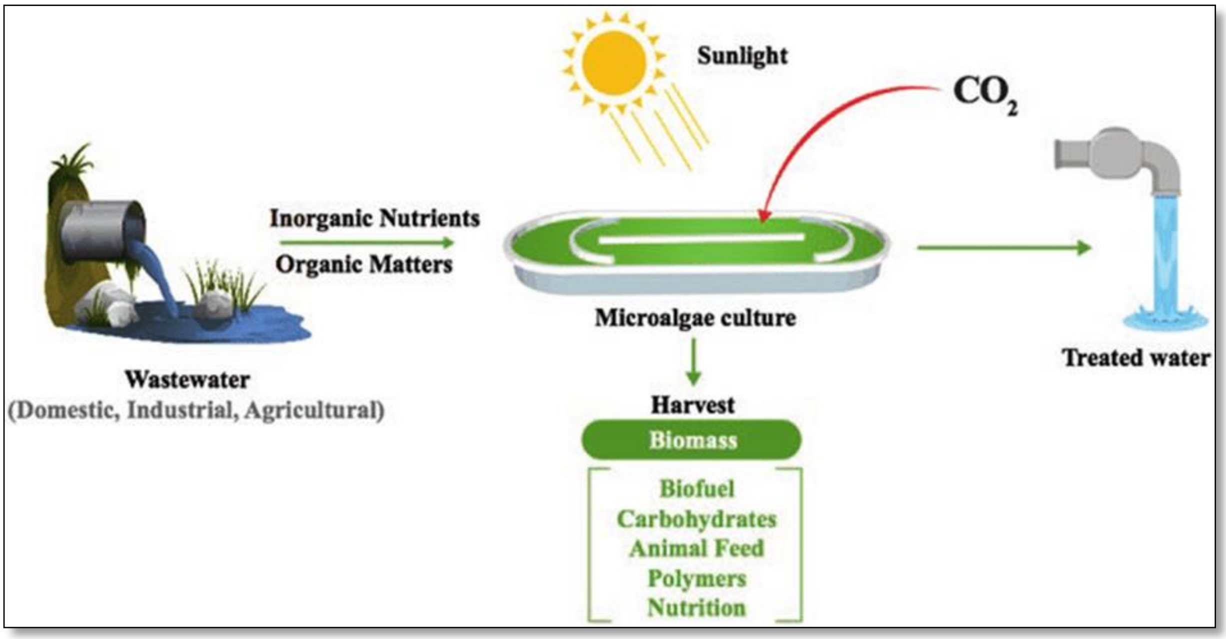


Figure 14: Principles of microalgae production integration with watewater treatment **(Zerrouki & Henni 2019).**

Overall, the history of microalgae use in wastewater treatment is marked by a steady progression from laboratory experiments to pilot-scale projects to large-scale commercial applications. Although challenges remain, microalgae-based wastewater treatment systems hold great promise for the future.

1.2.2.1.4.1. Challenges associated with wastewater treatment using microalgae

- **Selection of Strains**

The selection of suitable microalgae strains for wastewater treatment and biomass production is very important, and is based on a number of factors, including:

- Strain tolerance to environmental conditions (pH, temperature and high ammonium concentrations.) **(Waern, 2016).**
- Purification capacity: the selected microalgae strain must have a high capacity to eliminate nutrients from wastewater.
- Growth rate: it is preferable to choose a microalgae strain that grows rapidly. This allows results to be obtained in the short term.
- Ease of cultivation: the microalgae strain must be relatively easy to cultivate on a large scale, including factors such as growth parameters and compatibility with other species.
- The characteristics of the wastewater to be treated.

- The desired level of treatment efficiency required.
- The cost and energy requirements of harvesting the biomass produced and valorizing it **(Al-Jabri *et al.*, 2021).**

- **The Necessity of Pretreatment of Wastewater**

  Pretreatment is an essential step before introducing microalgae, as the presence of certain compounds at high concentrations in wastewater can inhibit microalgal growth **(Tyagi & Couillard, 1988)**, Similary the turbidity and pH of wastewater could inhibit this growth **(Das *et al.*, 2018).** Growing microalgal biomass in wastewater that has undergone pretreatment could reduce residual nutrients and turbidity in treated wastewater, and improve microalgal growing conditions **(Chen *et al.*, 2016).**

  Among the most widely used pretreatment methods in wastewater, treatment is electrocoagulation **(Bellebia *et al.*, 2012)**, This method has proven its effectiveness by removing various chemical additives, turbidity and pathogens from wastewater **(Symonds *et al.*, 2015).**

- **Biomass harvesting**

Harvesting microalgae biomass from wastewater presents a number of technical and operational challenges:

- Fouling and clogging: microalgae harvesting systems can be prone to fouling and clogging due to the presence of organic matter, mineral deposits or other particles in the wastewater, which can reduce harvesting efficiency and lead to the need for frequent cleaning operations.
- Variability in microalgae characteristics: such as size, shape and density. This variability can make harvesting more complex.
- High-energy costs: many microalgae harvesting methods, such as centrifugation, require the use of energy-intensive equipment.

1.2.2.1.4.2. Mechanism of Treating Wastewater

- **Nutrient uptake**

Microalgae could use sunlight, soluble inorganic carbon dioxide, nitrogen and other nutrients to increase their cell numbers while treating wastewater **(Manickam, 2015 in Triantafyllidis, 2018).**

A variety of inorganic (ammonium, nitrate, nitrite and atmospheric nitrogen) and organic (urea and glycine) forms of nitrogen could be assimilated by microalgae strains, although their efficiencies vary according to strain and growth conditions, similarly phosphorus removal from wastewater by these microorganisms could be a superior choice to chemical precipitation and artificial phosphorus removal **(Pizarro *et al.*, 2006).**

The removal efficiencies of nutrients from wastewater of different origins by microalgae are listed in Table 8.

Table 8: Microalgal nutrient removal efficiencies from different wastewater.

Wastewater	**The Concentration of Contaminations in Wastewater (mg /L)**			**Strain**	**Operating conditions**		**Removal Efficiency (%)**			**Reference**
	TN	**TP**	**TOC**		**pH**	**VoL(L)**	**TN**	**TP**	**TOC**	
Municipal sewage water	116,1	212	-	*Chlorella vulgaris*	-	25	94	89,1	-	**(Li *et al.*,2011)**
	130	15	-	*Spirulina platensis*	7,7	0,25	79	93,3	-	**(Zhou *et al.*,2017)**
Agro-industry wastewater	44	88	495	*Scendesmus obliquus*	8,6	0,5	34	65	42	**(De-godos *et al.*, 2010)**
Aquaculture wastewater	9,8	1,56	14	Algal-bacterial flocs	-	400	58	89	71	**(Michels *et al.*, 2014)**

- **Metals Adsorption and Uptake**

The presence of heavy metals in high concentrations in wastewater could inhibit photosynthesis in microalgae **(Miazek *et al.*, 2015).**

Nevertheless microalgae have the ability to concentrate metal pollutants in an efficient way both internally and externally so they could be adopted for the removal of metals from wastewater, and they are also able to concentrate by different mechanisms on various heavy metals such as Ni, Zn, CO. Microalgal cells require trace amounts of metals such as Fe, Cu, and Hg for growth **(Suresh *et al.*, 2015).**

Microalgae eliminate heavy metals with two mechanisms:

- **Adsorption**: A process by which heavy metal ions are attracted and bind to the surface of microalgae cells, forming a complex. This mechanism is generally driven by electrostatic forces. Heavy metals adsorbed on microalgae can be removed by physical separation techniques such as filtration or centrifugation. **(Lau *et al.*, 1999).**
- **Uptake:** A process by which heavy metals are stored inside microalgae cells. This mechanism is driven by transporters or channels allowing heavy metal ions to enter the cell. Once the heavy metals have been taken up by the microalgae, they can be removed by harvesting the biomass **(Yang *et al.*, 2020).**

The removal efficiencies of several metals by selected microalgae are listed in Table 9.

Table 9: Microalgal removal of metals from wastewater.

Metals	**Strain**	**Operating Condition**				**Removal Efficiency (%)**	**Reference**
		Initial consentration (mg /L)	**pH**	**Temperature (°C)**	**Time (Hour)**		
Cadmium	*Chlorella vulgaris*	5	6,2	25	24	66	**(Travieso *et al.*,1999)**
Nickel	*Scenedesmus sp.*	30	6	-	5	97	**(Chong *et al.* ,2000)**
Zinc	*Synechocystis sp*	30	6	-	5	40	**(Chong *et al.*,2000)**
Copper	*Spirulina platensis*	56,6	7,96	28	240	94,9	**(Chan *et al.*, 2013)**

1.2.2.1.4.3. Symbiotic Relationship

Microalgae could also participate in a symbiotic relationship with bacteria (Figure 15), to degrade organic matter **(Subashchandrabose e*t al.*, 2011).**

As a by-product of the photosynthesis process, microalgae produce oxygen, which could be used by aerobic bacteria to mineralize organic matter into carbon dioxide and supply it to microalgae as well as growth-promoting factors and vitamins (B12, B1 and B7) that stimulate microalgae growth, and the process would be repeated when finally treating wastewater **(Ramanan *et al.*, 2015).**

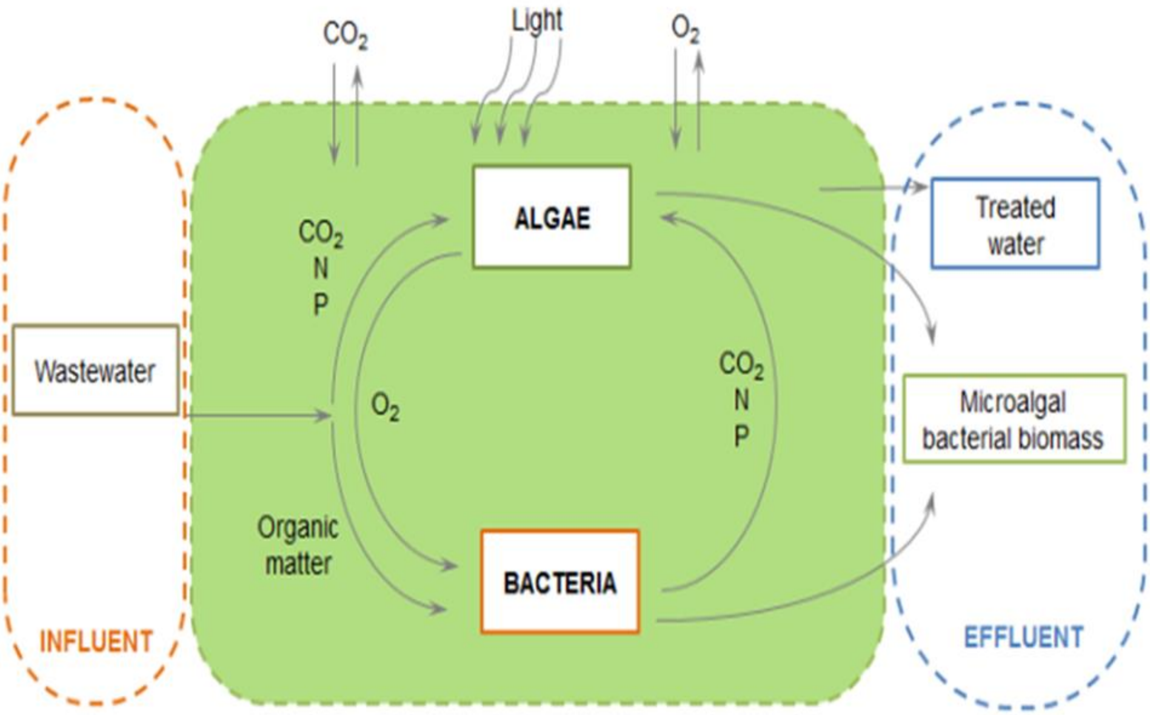


Figure 15: Symbiosis algae-bacteria present in microalgae-based wastewater treatment process **(Oswald & Gotaas, 1957).**

1.2.2.1.4.4 Importance of microalgae in wastewater treatment

Microalgae play key roles in the biological treatment of wastewater because they:

- Feed mainly on nitrogen and phosphorus, contained in large quantities in wastewater, and can even contribute directly to the elimination of certain organic by-products.
- Ensure the elimination, in part, of excess nutrient salts in wastewater.
- Act as bio-absorbents, helping to eliminate heavy metals and other toxic products carried by wastewater.
- Influence negatively the living conditions of certain pathogenic bacteria thanks to their biological activity, leading to their reduction in number and even their disappearance.
- Are used for the degradation and transformation of xenobiotic complexes.
- Are seen as a biological sensor for detecting pollution **(Ghenabzia, 2020).**

A number of pilot plants for wastewater treatment using microalgae have been successfully built around the world, mainly in irradiation zones (Figure 16).

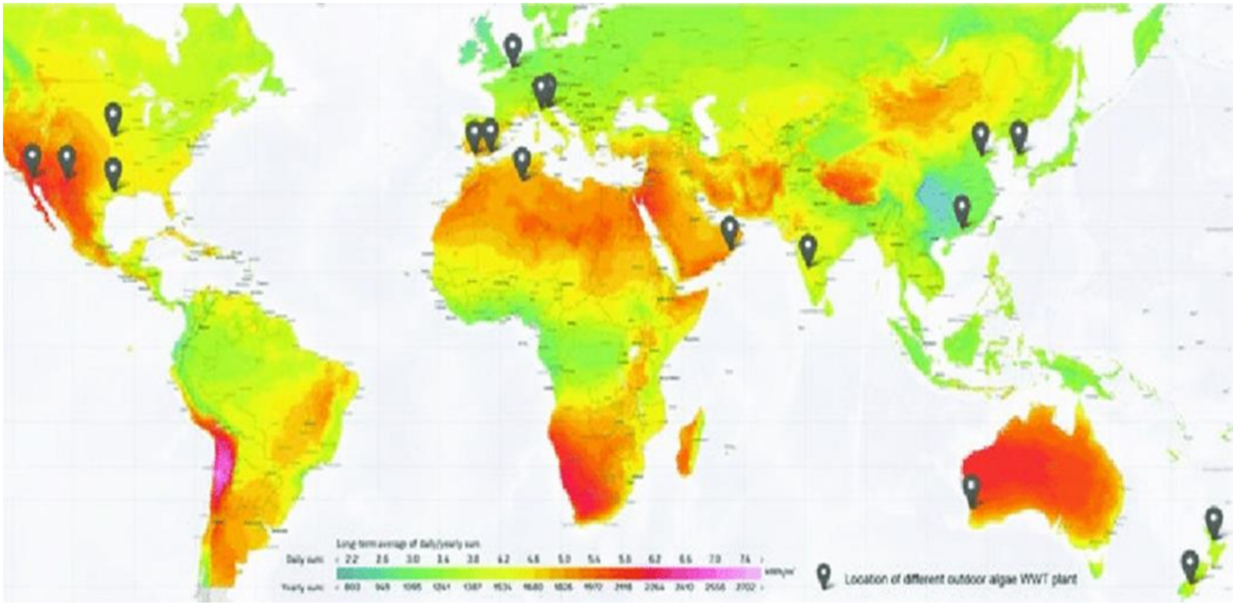


Figure 16: Location of different outdoor algae wastewater treatment plants and direct normal irradiation (kWh/m2) **(Zerrouki & Henni 2019).**

1.2.2.1.5. Tertiary treatment

The tertiary treatment of wastewater includes complementary treatments aimed mainly at eliminating phosphorus (dephosphatation) and pathogens (disinfection).

- **Phosphorus removal**

Phosphorus is eliminated by physical-chemical or biological treatments:

- Biological dephosphatation is based on the succession of anaerobic and aerobic phases during biological treatment to induce the selection of bacteria with the capacity to accumulate phosphorus. The efficiency of this method is generally lower than that of physico-chemical phosphorus removal **(REJSEK, 2002).**
- Physico-chemical phosphorus removal is achieved by adding mineral salts such as ammonium sulfate or ferric chloride, which precipitate the phosphorus **(Groslaude, 1999).**

- **Disinfection**

Disinfection aims to reduce the concentration of pathogens present in effluent before discharging it into the environment. Unlike disinfection standards for drinking water production, which specify the total absence of coliforms, discharge standards for urban wastewater vary according to the nature of the receiving environment. Two categories of treatment can be distinguished :

- Extensive processes such as lagooning.
- Intensive physico-chemical processes such as disinfection with chlorine, peracetic acid, UV and O_3 **(Grosclaude, 1999).**

1.2.2.1.6. Sludge treatment

The biological or physico-chemical treatments used during wastewater treatment generate a significant production of diluted sludge containing fermentable organic matter. Conventional sludge treatment using digestion typically follows these steps is series: Thickening, anaerobic digestion and dewatering before biogas monetisation and biosolids reuse or disposal.

Sludge treatment has two main objectives:

- Stabilization of organic matter to prevent uncontrolled fermentation, which would lead to odor nuisance.
- Eliminate as much water as possible to reduce the volume of sludge to be evacuated. **(Groslaude, 1999).**

Conclusion

Microalgae's significance extends beyond the microscopic scale, as they have far-reaching implications for the environment, industries and human well-being.

Wastewater are cleared of their largest waste, during the pre-treatments, down to the smallest pollutants, during tertiary treatments. Secondary treatments using activated sludge is the most frequently used treatment in Algeria, but this news won't prevent us from saying that this method presents several disadvanteg which can be reduced by the use of new technique presented by the application of microalgae in wastewater treatement, wich have shown their effectiveness according to several studies.

Methodology of work

In order yo apply microalgae in wastewater treatment; we have done a thorough study of wastewater treatment and facilities used during this process. The working methodology we have adopted to complete this research assignment, including visits made, are resumed in the following steps:

- **Step 1:** Planning and defining objectives

The first step in this research was to clearly define the objectives of the study. This involved specifying the main aim of the study, as well as the specific research questions we wished to address.

- **Step 2:** Literature Review and Visit Site Identification

An extensive literature review was conducted to understand previous work in the field of wastewater treatment using microalgae. Based on this review, relevant visit sites were identified, such as:

- Wastewater treatment plants of the following areas of Souk-Ahras state: Sedrata, Hanancha and Souk-Ahras, to learn about the wastewater treatment chain, costs, advantages and disadvantages of the methoods used during wastewater treatment.
- Water Ressources Department of Souk-Ahras state: to get an idea about the waters supply of the study area.
- The weather station of the state of Souk-Ahras: this visit was made in order to collect the necessary informations to identify the cliimate of the study area.
- The department of hydraulic ressources of the state of Souk-Ahras: with the aim of determining the hydraulic loads of wastewater in the study area.

- **Step 3:** Contact and coordination with those responsible for the visit sites

Once the visit sites had been identified, contact was made with the people in charge or managers of these sites. Meetings were organized to discuss the purpose of the visit, obtain the necessary authorization and plan the logistical details.

- **Stage 4:** On-site data collection

Site visits were carried out in accordance with agreed permits and plans. During these visits, relevant data were collected, such as treatment plant operating parameter and treated wastewater characteristics.

- **Step 5:** Analysis and documentation of visit results

After each field visit, detailed notes were taken to document the observations, conversations and data collected. This information was carefully organized for later analysis.

- **Step 6:** Integration of Visit Results into the Study

The results of the visits were integrated into the overall study methodology. This included the use of field data to validate research hypotheses or to better understand microalgae wastewater treatment operations.

- **Step 7:** Global Data Analysis and Synthesis

All the data collected, including those from the visits, were comprehensively analyzed to answer the research questions. The results were synthesized as part of the overall study.

- **Step 8 :** Presentation of results

Finally, the results of the visits were presented in a clear and relevant way in the dissertation, starting with the presentation of the study area, the calculations made during the sizing of the necessary stuctures of the proposed wastewater treatment station untel the final result that is represented in the form of a Three-dimensional plan.

Chapter 2 : Methodology

Introduction:

The treatment of wastewater is a major challenge in the field of sanitation, involving the use of facilities known as wastewater treatment plants.

The introduction of microalgae in wastewater treatment opens the door to an innovative and ecological approach to water purification. By combining the power of microalgae photosynthesis with their ability to absorb nutrients and reduce pollution, this method offers a promising solution to the growing challenges of wastewater management. This introduction will explore the fundamentals of designing a wastewater treatment plant using microalgae, highlighting the key stages and the resulting ecological benefits. The first step in sizing such a plant is to choose the right location.

1. Presentation of the study area

The study area is located in the far north-east of algeria, on the Algerian-tunisian border. it lies 140 km south-east of the city of annaba and 200 km east of constantine. The souk ahras region lies in a transition zone between the tellian atlas and the saharan atlas. After a visit to the Souk-Ahras state, I found a suitable site for a microalgae wastewater treatment plant in the municipality of Taoura, that belongs to the southern souk-ahras mountains. Wastewater from this municipality is currently discharged into water bodies without any prior treatment. This practice is detrimental not only to public health and the surrounding environment, but also to the region's water reserves. The construction of a wastewater treatment plant for this agglomeration will not only protect the environment, but also will provide additional quantities of quality water for irrigation.

The choice of site for the future Taoura WWTP is based on a compromise between the following objectives and constraints:

- Best environmental protection.
- Possibility of reusing effluent for irrigation.
- Budgetary constraints, especially in terms of investment and operation.
- Non-flood zone.
- Surface area.
- Distance from town.

Prior to any hydraulic project, a site survey is necessary to understand the physical characteristics of the site and the factors that can influence the design and success of a project.

In this study, I have examined the environmental environment in which the plant will be located.

2. Geographical location of the plant siting area

The site of the future Taoura WWTP lies to the north of the municipaliti's main town, at a distance of around 5 km. It is located on the north side of the national road N82, with steep to medium slopes. The usable area is approximately 2 to 3 hectares.

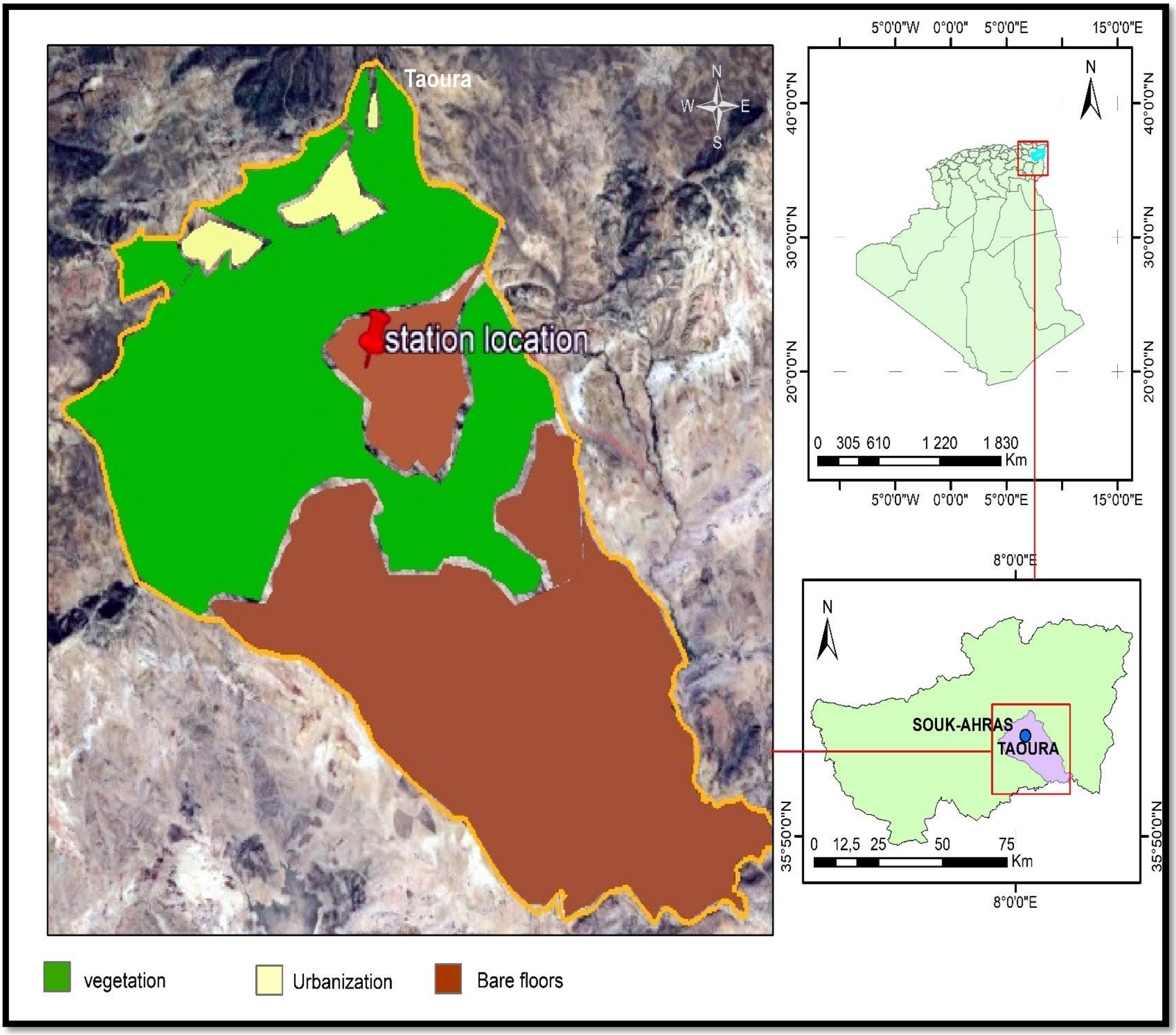


Figure 17: Location of the future wastewater treatment station of Taoura **(Rehamna, 2023*).***

3. Site characteristics

The site of the future WWTP has a relatively flat, sloping morphology, extending over an area of around 3 ha.

3.1. Climate situation

Taoura is characterized by a Mediterranean climate with cold, rainy winters and dry, hot summer. Its climatic regime depends on several main parameters, such as:

3.1.1. Precipitation

Precipitation is a fundamental climatic factor that conditions seasonal runoff and directly influences the regime of rivers and aquifers **(DAVIDE, 1956).**

I have noted the absence of a metrological station in the Taoura region, therefore I will use the monthly rainfall values for the period (2003-2018) recorded at the Souk-Ahras metrological station.

Table 10: Average monthly rainfall **(Period 2003-2018).**

Month	**S**	**O**	**N**	**D**	**J**	**F**	**M**	**A**	**M**	**J**	**J**	**A**
P(mm)	38,8	65,2	91,3	128,7	122,6	126,1	97,6	78,2	52,4	21,7	5,7	17,2

Source : The weather station of the state of Souk-Ahras.

Rainfall amounts are shown in the following figure:

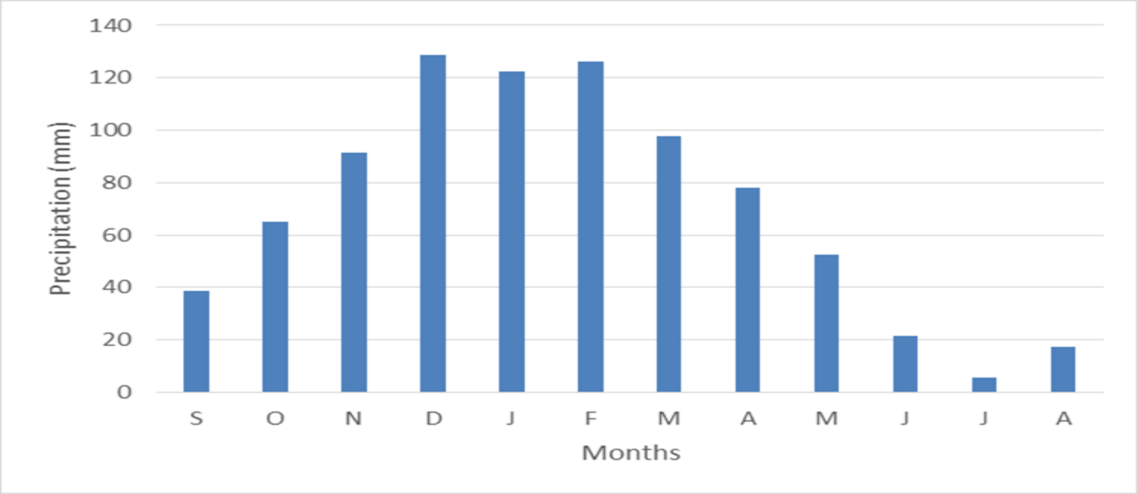


Figure 18: Average monthly precipitation heights **(Period 2003-2018).**

According to Table 10 and the histogram (Figure 18), the average monthly precipitation shows an increase in precipitation from September to December, with a drop in precipitation beginning in February and continuing until August.

3.1.2. Temperature

Temperature is a major factor in determining a region's climate. It determines evapotranspiration and runoff deficit, plays a part in the development of plant biological rhythms and helps establish the water balance **(DAVIDE, 1956).**

Table 11: Average monthly temperatures **(Period 2003-2018).**

Month	**S**	**O**	**N**	**D**	**J**	**F**	**M**	**A**	**M**	**J**	**J**	**A**
T (°C)	20,7	18,4	12,5	8 ,7	8,2	7,7	10,4	13,8	17,3	22,2	26,4	26,1

Source : The weather station of the state of Souk-Ahras.

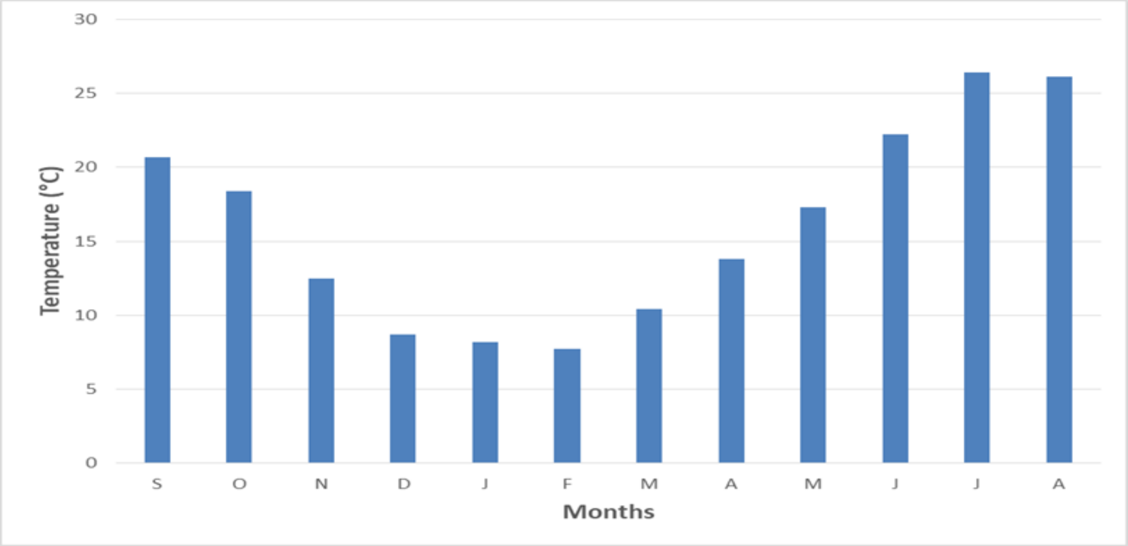


Figure 19: Average monthly temperatures **(Period 2003 -2018).**

The histogram (Figure 19) shows that the lowest values are measured in December, January and February, where the coldest month is February (with a temperature of around 7.7°C). On the other hand, the highest values are found in June, July and August, where the hottest month is July (with a temperature of around 26.4°C).

3.1.3. Wind

Wind is one of the most important determinants of rainfall, evaporation and consequently climate. According to data from the Souk-Ahras state meteorological station, the prevailing winds in the Taoura region are from north to south (Table 12).

They are most active during the rainy season. In summer, these winds blow in the form of the sirocco. They are dry, hot and often quite strong, favoring evaporation**. (Davide, 1956).**

Table 12: Average monthly wind speed **(2003 -2018).**

Month	**S**	**O**	**N**	**D**	**J**	**F**	**M**	**A**	**M**	**J**	**J**	**A**	**Annual average**
Wind speed (m/s)	2,8	2,5	3,3	3,4	3,5	3,8	3,6	3,7	2,9	3,1	3,1	2,9	3,2

Source : The weather station of the state of Souk-Ahras.

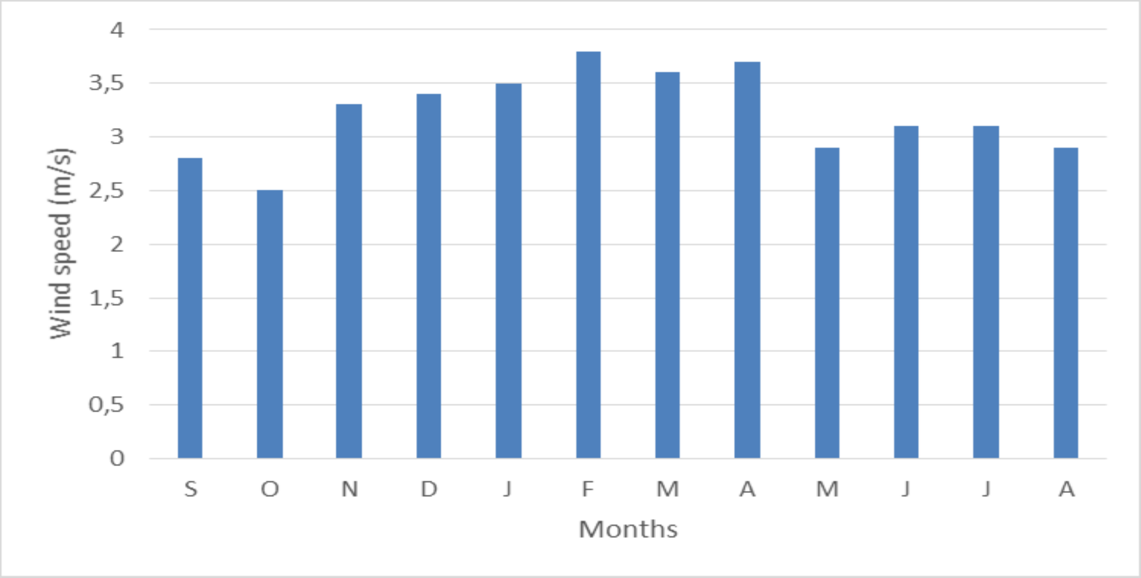


Figure 20: Average monthly wind speed **(2003 -2018).**

According to Table 12, and the histogram (Figure 20), the average annual wind speed is 3.2 m/s. The minimum monthly mean wind speed is 2.5 m/s (October), the maximum monthly mean is 3.7 m/s (April).

3.1.4. Humidity

The relative humidity of air is the ratio of the actual vapor pressure by the saturation vapor pressure at the same temperature. It gives us an idea of whether the atmosphere is close to condensation or not.

Humidity values observed at the Souk-Ahras station are shown in the table below.

Table 13: Average monthly and annual air humidity. **(Period 2003 -2018).**

Month	S	O	N	D	J	F	M	A	M	J	J	A	Annual average
Relative humidity (%)	63,8	67,4	75	79,1	79,4	77,1	73,4	72	66,3	52,7	49,8	52,7	67,7

Source : The weather station of the state of Souk-Ahras.

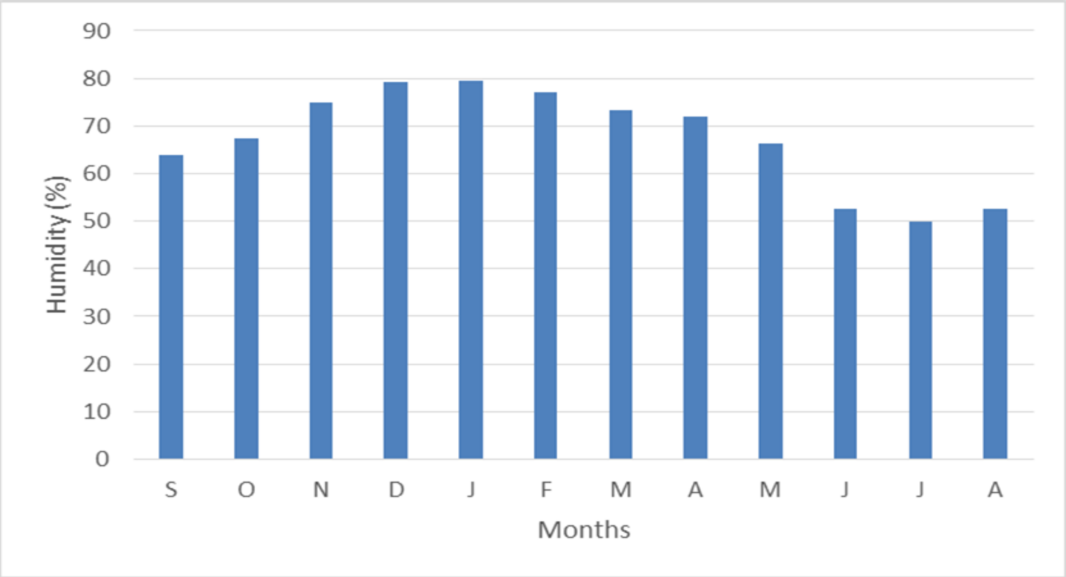


Figure 21: Average monthly air humidity. **(Period 2003 -2018).**

According to Table 13 and the histogram (Figure 21), the driest month of the year is July, with an average relative humidity of 49.8%, while the wettest months are December and January, with relative humidities ranging from 79.1% To 79.4%.

4. Population activities

During my survey of the municipality of Taoura, I found no oil mills and no industrial activity. However, the municipaliti's main activity is agriculture, and there are also other activities such as livestock breeding, catering, car washing and lubrication.

5. Hydraulic situation

5.1. Drinking water supply

The municipality of Taoura is supplied with drinking water from existing DWS (Drinking Water Supply) networks, as well as from others under study or construction.According to the annual report for the year 2023 by the operating department of Algerian waters in the state of Souk-Ahras, only 19205 of the population of the municipality of Taoura are supplied with drinking water, representing 78% of the population's satisfaction rate.

5.2. Sanitation

- **Wastewater**

In order to identify the existing discharges in the area, a survey was carried out on site by a hydraulic engineering firm with the help of the municipaliti's technical services. This revealed that the Taoura municipality as a whole has two major watersheds:

- ✓ **Oued Mellegue**: located to the south of the municipality, this is an effluent of Oued Medjerda in Tunisia.
- ✓ **Oued Medjerda**: Located to the north of the municipality, this is considered to be a main collector, flowing towards the east of the state before emptying into the Mediterranean (Gulf of Tunisia).

These discharges all flow openly into talwegs and watercourses, which are sometimes located close to dwellings, causing inconvenience for the population and pollution of all watersheds, leading to the risk of water-borne diseases. This pollution can also have a major impact on the main activity of the locality.

- **Stormwater**

The locality is characterized by the existence of natural watercourses and talwegs that allow stormwater to drain away, as well as ditches that collect stormwater and discharge it into natural watercourses.

6. Sizing the treatment plant

Sizing a treatment plant is always preceded by determining the origin of wastewater discharges, the quantity of stormwater, as well as the population to be served and the anticipated wastewater flows based on demographic data and growth projections. In addition, wastewater analysis and pollutant load calculations are a very important phase in the design of a treatment plant.

6.1. Estimated population connected to the planned sewerage network

According to the Souk-Ahras state planning department, the latest census data for 2008 indicates that the population of Taoura is 18933 inhabitant, with a growth rate of 1.55%. The future evolution of the population at different horizons is determined by the following formula:

$$\mathbf{P=P_0\,(1+T)^n}$$

With:

P: Future population

P_0: Resident population in the reference year.

n: Number of years between the reference year and the year taken into account.

T: Growth rate.

Population trends up to 2050, set arbitrarily in this study, are summarized in Table 15 (Chapter 3).

6.2 Estimating the municipaliti's drinking water requirements

The evolution of drinking water requirements for the future population of Taoura municipality is estimated on the basis of an average daily per inhabitant upply of: 150 l/inhab/d for the medium and long term 2050.

The average daily flow is calculated using the following formula:

$$Q_{aver.d}=\frac{P\times D}{1000}\ (\mathrm{m^3/d})$$

With :

$Q_{aver.d}$: Average daily flow (m^3/d).

P: Number of inhabitants.

D: Theoretical allocation (l/ inhab/d) (D= 150 l/ inhab/d).

Estimates of the population's drinking water requirements for various time horizons are given in Table 16(Chapter 3).

6.3. Estimated wastewater flows for the 2050 horizon

6.3.1 Estimated domestic wastewater flows

The production of domestic wastewater in the municipality studied is conditioned by the degree of water consumption, and is proportional to the density of the urban fabric. The flow of wastewater is estimated at 80% of the population's water requirements.

It should be remembered that the water supply for the municipality of Taoura is 150 l/inhab/d and the average daily wastewater flow is given by the following formula:

$$Q_{ad.d.ww} = C \times K_r$$

With :

$Q_{ad.d.ww}$: Average daily flow rate of domestic wastewater,

Kr: Discharge coefficient taken as 80% of the quantity of consumed drinking water

C: Average daily consumption (C=P×D), (m^3/d).

From which: D: daily supply (l/inhab/d).

P: number of inhabitants.

Estimates of wastewater flows discharged by the municipality studied at different horizons are summarized in Table 17 (Chapter 3).

6.3.2. Estimating equipment wastewater flows

According to the Souk-Ahras state's water resources department, wastewater flows from equipment have been estimated at around 15% of the average daily flow of domestic wastewater, and they are calculated using the following formula:

$$Q_{Eq.ww} = 0{,}15 \times Q_{Dom.ww}$$

With :

$Q_{Eq.ww}$: Equipment wastewater flow.

$Q_{Dom.ww}$: Domestic wastewater flow.

6.3.3. Estimated total wastewater flows

We have:

$$Q_{T.ww} = Q_{Eq.ww} + Q_{Dom.ww}$$

With :

$Q_{T.ww}$: The total wastewater flow.

$Q_{Eq.ww}$: The flow of equipment wastewater.

$Q_{Dom.ww}$: The flow of domestic wastewater.

6.3.4. Calculation of the inhabitant equivalent

The inhabitant equivalent (IE) is defined as the unit of measurement used in wastewater treatment to assess the pollution load. It allows to standardize the various sources of pollution by comparing it to the quantity of pollution produced by an average inhabitant. This measurement facilitates the design and management of wastewater treatment systems.

Having the total wastewater flow by 2050. The inhabitant equivalent can be determined as follows:

$$[\mathrm{IE}]_{2050} = \frac{Q_{T.ww} \times 1000}{Kr \times D}$$

With :

$Q_{T.ww}$: The total wastewater flow.

D: Theoretical allocation (l/ inhab/d) (D= 150 l/ inhab/d).

K_r : Discharge coefficient ($K_r = 0{,}8$)

6.4. Calculation of hydraulic and pollutant loads

To size the wastewater treatment plant, we need to estimate the hydraulic and pollutant loads for the year 2050.

6.4.1. Calculation of hydraulic loads

- **Average daily wastewater flow ($Q_{aver.d}$)**

This is the new average daily flow for the number of Inhabitant Equivalent ($Q_{aver.d}$), the total wastewater flow calculated previously. Therefor :

$$Q_{aver.d} = Q_{T.ww}$$

- **Average hourly flow ($Q_{aver.h}$)**

The average hourly flow rate per day is the flow rate observed during the day, measured on arrival at the treatment plant, and is given by the following formula:

$$Q_{aver.h} = \frac{Q_{aver.d}}{24}$$

- **Dry weather peak flow ($\mathbf{Q}_{Dwp}$)**

Calculating peak flow is important to ensure that wastewater treatment systems are able to handle seasonal fluctuations and variations in flow. It is given by the following formula:

$$\mathbf{Q}_{Dwp} = \mathbf{C_P} \times (\boldsymbol{Q}_{aver.h})$$

With:

Cp : The peak coefficient given by the following formula :

$$C_P = 1{,}5 + \left(\frac{2{,}5}{\sqrt{Q_{aver.h}}}\right) \qquad \text{If : } \mathbf{Q}_{\mathbf{aver.h}} \geq 3 \text{ l/S}$$

$$C_P = 3 \qquad \text{If : } \mathbf{Q}_{\mathbf{aver.h}} < 3 \text{ l/S}$$

- **Rainy weather peak flow ($\boldsymbol{Q}_{Rwp}$)**

In order to avoid hydraulic overloading of the storm basin located upstream of the plant during rainfall, the storm basin is sized for a maximum flow corresponding to($\boldsymbol{Q}_{Rwp}$)**.** Which represents the flow of wastewater going to the plant in rainy weather. It is calculated using the following formula:

$$\boldsymbol{Q}_{Rwp} = \mathbf{Q}_{Dwp} + \boldsymbol{\alpha}\, \mathbf{Q}_{Dwp}$$

With :

$\mathbf{Q}_{Dwp}$:Dry weather peak flow.

α : Coefficient of dilution taken in general equal to 2.

Therefor:

$$Q_{Rwp} = Q_{Dwp} + \alpha\, Q_{Dwp} = (1+ \alpha)\, Q_{Dwp}$$

$$Q_{Rwp} = (1+2)\, Q_{Dwp} = 3Q_{Dwp}$$

- **Maximum flow entering the WWTP (Qmax)**

The maximum flow entering the WWTP is generally taken to be equal to 2 × the average hourly flow:

$$\mathbf{Q}_{max} = 2 \times \boldsymbol{Q}_{aver.h}$$

6.4. 2.Calculation of pollutant loads

In the following table, I have summarized the analyses of samples taken from three different discharges.

Table 14: Analysis of samples from the three different discharges of Taoura municipality (**According to WRD (Water Ressources Department)of Souk-Ahras state).**

N°	Dischrg name	COD (mg/l)	BOD (mg/l)	SS (mg/l)
1	Ogla	360	320	686
2	Ain Tamtmat	70	35	26
3	Ain Trab	450	340	283

Interpretation of results: From the analysis of these samples, i found that:

- The ratio: $\frac{COD}{BOD} = 1.27 < 1.5$. This means that oxidizable matter is largely made up of highly biodegradable matter.
- The ratio: $\frac{COD}{BOD}$ indicates that wastewater from Taoura municipality is predominantly domestic, therefor it is biodegradable pollution, which leads us to opt for biological processes. The treatment method that meets this requirement is biological purification using microalgae.
- Values of : BOD and COD are too low for sizing a wastewater treatment plant for the year 2050.For this purpose, i will use the values of the hydraulic department for the sizing of wastewater treatment plants, such as :

➢ **BOD_5 load**

In the absence of analysis of representative samples of raw wastewater discharge, and according to the state of Souk-Ahras water resources department, the pollutant load per day per inhabitant is estimated at 52 g/inhab/day.

The BOD_5 pollutant load admitted to the plant will be equal to:

$$\mathbf{BOD_5\ load} = N \times 52 \times 10^{-3}$$

With :

BOD_5 load : Biological oxygen demand pollutant load**.**

N: Number of inhabitant equivalent by 2050.

- **In concentration (mg/l)**

$$[BOD_5] = \frac{BOD5\ pollutant\ load}{Average\ daily\ flow}$$

- **Purification yield**

  The purification yield is given by the following formula:

$$R=\frac{Ci-Cf}{Ci}\times 100$$

With :

C_i: BOD_5 concentration at plant inlet.

C_f : BOD_5 concentration at plant outlet ($[BOD_5]$=30mg/l).

- **TSS loads**

The total suspended solids content per inhabitant per day for a combined sewer system is 70 g/inhab/day. It is calculated using the following formula:

$$\text{TSS load} = N \times 70 \times 10^{-3}$$

With :

TSS load : Pollutant load.

N: Number of equivalent inhabitants by 2050.

- **In concentration (mg/l)**

$$[TSS]=\frac{Pollutant\ load\ in\ TSS}{Average\ daily\ flow\ rate}$$

- **Purification yield**

  The purification yield is given by the following formula:

$$R=\frac{Ci-Cf}{Ci}\times 100$$

With:

Ci: TSS concentration at plant inlet.

Cf : TSS concentration at plant outlet ([TSS]=35mg/l).

- **Nutrient loads**
  - ✓ **Phosphorus loads**

The phosphorus content in domestic wastewater per inhabitant per day is estimated at 15 g/inhab/d. It is calculated using the following formula:

$$\textbf{P load}= N \times 15 \times 10^{-3}$$

Where :

P load : phosphorus polluttant load.

N : Number of equivalent inhabitants by 2050.

- **In concentration (mg/l)**

$$[P]= \frac{Pollutant\ load\ in\ p}{Average\ daily\ flow\ rate}$$

- **Purification yield**

The pufirication yield is given by the following formula:

$$R= \frac{C_{i-}C_f}{C_i} \times 100$$

With :

Ci: Phosphorus concentration at plant inlet.

Cf : Phosphorus concentration at plant outlet ([P] =10mg/l).

- ✓ **Nitrogen loads**

Nitrogen content in domestic wastewater per inhabitant per day is estimated at 20 g/inhabit/d. It is calculated using the following formula

$$\textbf{A load} = N \times 20 \times 10^{-3}$$

with :

A load: Nitrogen pollutant load.

N: Number of equivalent inhabitants by 2050.

- **In concentration (mg/l)**

$$[A]= \frac{Pollutant\ load\ in\ A}{Average\ daily\ flow\ rate}$$

- **Purification yield**

The purification yield is given by the following formula:

$$\mathbf{R=\frac{C_i-C_f}{C_i}\times 100}$$

With :

Ci : Nitrogen concentration at plant inlet.

Cf : Nitrogen concentration at plant outlet ([A]=30mg/l)

The results of the calculations are summarized in Table 18 (Chapter 3).

6.5. Sizing of wastewater treatment plant structures

6.5.1. Pre-treatment

6.5.1.1.Receiving structure

The intake structure will receive the entire flow conveyed by the pipe and will be equipped with the following accessories:

- Weir for all flows in excess of the maximum flow of 1117,389 m^3/h to be admitted in wet weather.
- By-pass flow measurement device with ultrasonic probe on overflow blade.
- Stainless steel manual screen: of 316 l and 80 mm spacing, for by-passed effluent.

6.5.1.2. Screen sizing

Bar screens play a very important role in protecting electromechanical equipment and reducing the risk of clogging pipes installed in the treatment plant. They are grids that collect the bulky waste carried along by the water flowing through the sewage pipes**. (Mzyene & Ouali, 2020)**.

6.5.1.2.1. Coarse screen

This screen is designed to protect the pumps from any large bodies that may be carried by the collector, and is spaced between 10 and 50 mm apart. The rejects from the screen are removed manually using a rake.

The following KIRSCHMER formula is used to calculate the screen width:

$$\mathbf{W} = \frac{\boldsymbol{S\times sin\,\alpha}}{\boldsymbol{H_{max}\times\delta(1-\beta)}}$$

With :

W : scren width (m).

S: Wetted cross-section of the screen with : S = $\frac{Q_{Rwp}}{v}$ (m^2).

We have **:** $\boldsymbol{Q_{Rwp}}$:Rainy weather peak flow (We have : $\boldsymbol{Q_{Rwp}}$ = 0,31m^3/s).

V: Raw water flow velocity at inlet (weassume that V=1m/s).

α : Angle of inclination of the screen in relative to the horizontal (generally α=60°)

$\boldsymbol{H_{max}}$: Maximum admissible height of water on the screen.With :

$\boldsymbol{H_{max}}$= 0.4m for 20000IE.

$\boldsymbol{H_{max}}$= 0.5m for 50,000 IE.

$\boldsymbol{H_{max}}$= 0.6m for 100000 IE.

In our case, we assume : $\boldsymbol{H_{max}}$ =0.5 m.

δ: Clogging coefficient of the screen (δ = 0.5 for a mechanical grille, and 0.25 for a manual screen, we chose δ = 0.5).

β : Fraction of surface occupied by bars. With:

$$\boldsymbol{\beta = \frac{b}{b+e}}$$

we have :

b: Grid bar thickness (b=20mm).

e : Spacing between bars (e=50mm).

6.5.1.2.2. Fine screen

After lifting (an optional operation, depending on the site), the effluent will reach the end of a screening channel equipped with an automatic fine screen. This screen, with its 15mm spacing between bars, stops larger suspended matter escaping from the coarse screen.

To calculate the width of the screen, we apply the KIRSCHMER formula with:

$$\mathbf{W} = \frac{\boldsymbol{S \times \sin\alpha}}{\boldsymbol{H_{max} \times \delta(1-\beta)}}$$

With :

b = 10 mm	v = 1 m/s	α =60°
e =15 mm	$\boldsymbol{H_{max}}$ = 0,5 m	$\boldsymbol{Q_{Rwp}}$=0,31 m³/s

β =0,4 δ = 0,5 $S = \frac{0,31}{1} = 0,31\ m^2$

6.5.1.2.3. Calculating load losses

According to KIRSCHMER, load losses at the screen are depending on the spacing between the bars, the width of the bars, the shape of the bars, the approach speed and the inclination of the screen. They are calculated using the following formula:

$$\Delta h = \frac{\beta \times b^{4/3}}{e^{4/3}} \times \frac{V}{2\,g} \times \sin \alpha$$

Where :

Δh: Load loss in meter of water (m).

β : Coefficient of the bars shape (β= 1.79 for circular-section bars).

b : Grid bar thickness (m).

e : Spacing between bars (m).

V: Approach velocity or water velocity in front of the screen(m/s).

g: Gravity acceleration (g= 9.81 m/s).

α: Angle of inclination of the screen with the horizontal (α=60°).

- **Calculating load losses for the coarse screen (Δh_a)**

The choice of the shape of the screen bars is based on the shape that generates less load losses. In this case, I opted for the circular shape.

With :

β = 1,79 α =60°
e = 50mm g = 9,81m/s
b = 20mm v = 1m/s

- **Calculating load losses for the fine screen (Δh_b)**

we have :

β = 1,79 α =60°
e = 15mm g = 9,81m/s
b = 10mm v = 1m/s.

6.5.1.2.4. Evaluation of screen refusals ($V_{r.max}$)

The volume of detritus retained by the screen depends on the quality of the water to be treated and the spacing between the bars.

$V_{retained}$ is expressed in liters per inhabitant equivalent per year, and is estimated at :

- 5 to 10 l/inhab/year for a fine screen.

- 2 to 5 l/inhab/year for a coarse screen.

It is calculated using the following formula:

$$V_{r.max} = \frac{N_{IE} \times V_{ret} \times 10^{-3}}{365}$$

With :

N_{IE} : Number of Inhabitant Equivalent for the horizon 2050**.**

V_{ret} : The volume of detritus retained by the screen.

- **For the coarse screen**

For urban wastewater, the quantity of waste recovered by the grates per inhabitant per year is estimated at:

$V_{retained} = \frac{2+5}{2}$ (l/inhab/year).

- **For the fine screen**

$we\ have: V_{retained} = \frac{5+10}{2}$ (l/inhab/year).

The screen sizing calculation results are summarized in the table 19 (Chapter 3).

6.5.1.3. Dessander and oil removal sizing

The dessander is a structure in which dense particles with low velocity can settle. These are mainly sands. It is preferable to recover these particles upstream of the plant, rather than allowing them to accumulate at certain points where they can cause a variety of problems. They also limit the life of metal parts in pumps and other equipment. In the desander, 90% of particles equal to or larger than 200 µm (sand) must be eliminated. **(FNDAE, 2002).**

The purpose of the oil removal is to retain oil by natural flotation or accelerated by injection of fine bubbles. These matter are likely to interfere with the biological phase of treatment.

The basin will be equipped with a scraper bridge from which a sand extraction pump will be suspended. Oils will be scraped into a pit by the surface scrapers. We opt for a circular sand and oil removal.

6.5.1.3.1.Sizing the dessander and oil remover

- **Calculation of the dessander and oil remover surface area**

  A velocity of 49 m/h is assumed.The surface area is calculated using the following formula:

$$S=\frac{Q_{Rwp}}{Vasc}$$

With :

Q_{Rwp} **:** Rainy weather peak flow.

V_{asc}**:** Ascendant velocity.

- **Calculation of the dessander's radius**

  The radius is calculated using the following formula:

$$S= \pi\times r^2$$

Therefor :

$$r =\sqrt{\frac{S}{\pi}}$$

Where :

r : The dessander radius (m).

S : The surface of the dessander (m^2).

- **Calculation of the dessander's volume**

The volume of the dssander is calculated using the following formula:

V= S× H

With :

V : Volume of the dessander (m^3).

S : horizontal surface (m^2).

H : Height of the dessander (we assume that : H=4 m).

- **Calculation of dwell time**

Dwell time is calculated using the following formula:

$$t_s =\frac{V}{Q_{Rwp}}$$

With :

t_d : Dwell time (min).

V : volume of the dessander (m^3).

Q_{Rwp} **:** Rainy weather peak flow (m^3/h).

- **Calcultion of injected air flow**

  The quantity of air to be injected varies from 1 to 1.5 m^3 of air/h/m^3 of water **(Berné & Cordonnier, 1991),** and is calculated using the following formula:

$$Q_{air} = Q_{Rwp} \times V_{air}$$

with :

Q_{air} : Air flow to inject into the dessander (m^3/h).

Q_{Rwp} **:** Rainy weather peak flow (m^3/h).

V_{air} : Injecting air volume ($m^3$of air/h/m^3), estimated at 1,5 m^3 of air / h.

- **Matter extracted from the dessander and oil remover**

  TSS contains 30% of MS (Mineral solids) and 70% of VSS (volatile suspended solids),**(Ben Said, 2013),** which means that :

TSS = 70% VSS + 30% MS

with **:** The pollutant load in **TSS** = 2846,34 (kg/d).

-The total mineral solids (MS_T) :

MS_T(Kg/d) = TSS × 0,30.

- The total volatile suspended solids (VSS_T)

VSS_T(Kg/d)= TSS × 0,70.

-Eliminated mineral solids (MS_E)

The dessander eliminates 70% of MS_T

MS_E (Kg/d)= MS_T × 0,70

- Remaining mineral solids (MS_R)

MS_R (Kg/d)= MS_T – MS_E

- Remaining total suspended solids (TSS_R)

TSS_R(Kg/d) = $MS_R + VSS_T$

The dessander and oil remover calculation results are mentioned in the tables 20.

6.5.2. Secondary treatment (biological treatment)

6.5.2.1. Sizing of raceway ponds

The proposed process is based on the principle of medium-load microalgae treatment in four raceway ponds divided as follows:

- **One raceway pond:** intended for microalgae cultivation, for subsequent use.
- **Three raceway ponds:** for secondary treatment, where the pre-treated wastewater arrives after primary decantation and where the microalgae are introduced.

The raceway pond configuration allows optimum use of space and a linear progression of wastewater through the various treatment stages.

6.5.2.1. 1.Sizing of raceway ponds intended for secondary treatment

The parameters characterizing microalgae treatment are as follows:

- **Strain selection**

The microalgae chosen for this study is *Spirulina platensis* (Figure 22), based on the following criteria:

- Highly efficient in wastewater treatment (phosphorus, nitrogen and copper removal rates of 93.3%, 79% and 94.9% respectively, according to studies).
- A high growth rate, *Spirulina platensis* tends to multiply rapidly and can double its biomass in a few hours under optimal conditions (figure 23).
- A eurythermal specie, *Spirulina platensis* can support a wide range of temperatures, which means it can withstand temperature changes between summer and winter **(De la Noue & De Pauw, 1988).**
- Possibility of using the biomase produced in agriculture, *Spirulina platensis* is used in agriculture for its natural nutrient enrichment, enhancing soil fertility and promoting sustainable eco-friendly farming practices.

The systematic classification of spirulina has been studied by several authors. **Gardner (1917),** suggested the name Arthrospira for forms with visibly partitioned walls, and Spirulina for forms with invisible partitions. Subsequently, **Berguey (1994)** classified them as follows:

Order : Nostocales

Family : Oscillatoriaceae

Genus : Spirulina

Specie : *Spirulina platensis* **(Berguey, 1994).**

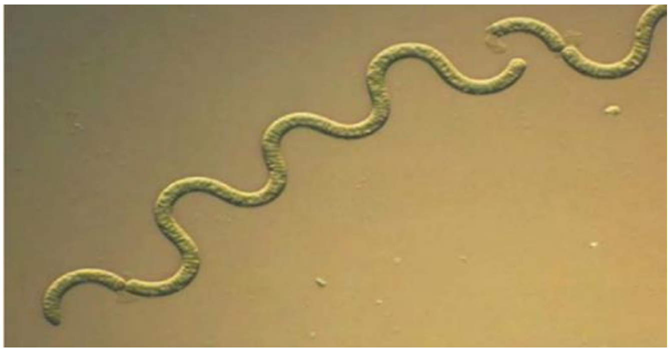


Figure 22: *Spirulina platensis.*
Consulted the : 05/07/2023.
Source : https://www.algaebase.org/

The optimal conditions for growing Spirulina platensis are summarized in the following figure:

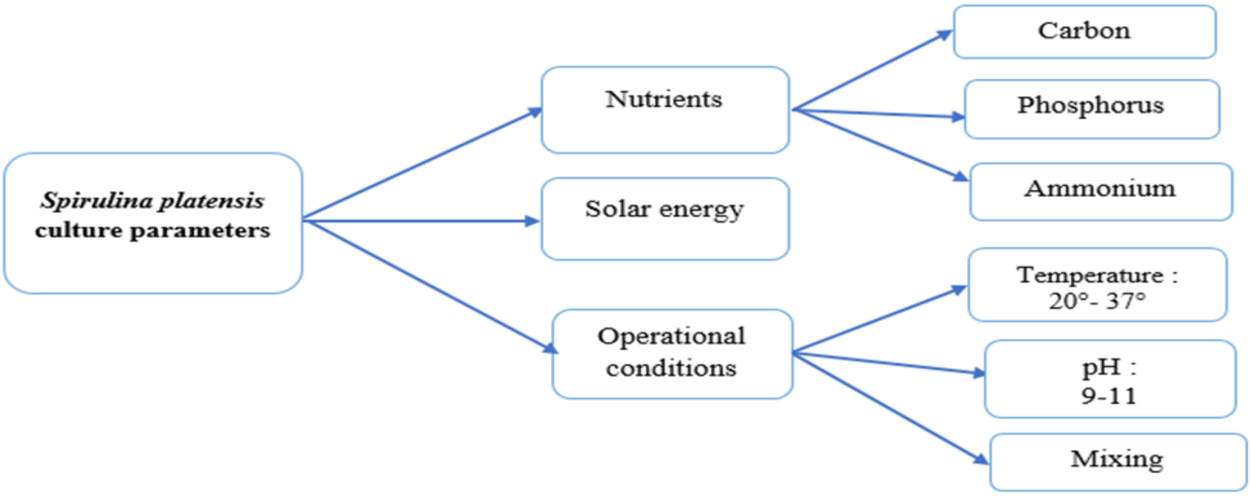


Figure 23: *Spirulina platensis* cultivation parameters (**Razzak *et al.*, 2017).**

- **Mass load (Cm)**

  We have: $0,1 < Mc < 0,5$ Kg BOD_5/Kg.VSS.d

  The mass loading or loading factor expresses the ratio between the mass of pollutant substrate and BOD_5 entering daily and the mass of microalgae contained in the reactors. It is expressed in KG/BOD_5/ KG of dry matter per day.

  The plant calculation will be based on the following Mc value:

  We assume a mass loading: Cm = 0.3 Kg BOD_5/ Kg VSS.d.

- **Volume load (Cv)**

  $0.1 < Vc < 1.5$ Kg BOD_5/ m^3/d.

  The volume load refers to a certain weight of organic matter expressed as BOD_5 (Kg/d) that must be transferred to a pond of volume V (m^3). The volume load is defined as the ratio of pollution per unit of pond volume.

  The plant calculation will be based on the following value:

  $Cv = 0.8$ Kg BOD_5/ m^3/ d In order to size the ponds, we need to make the following

  - **Calculation of the pollutant load at pond outlet (L_F)**

    The pollutant load calculation method used in this study is the BOD_5 concentration calculation method.

    The BOD_5 concentration at the plant outlet must comply with the WHO discharge standards applied in Algeria, which are of the order of 30 mg/l.

    This gives:

    $$L_F = S_S \times Q_{aver.d}$$

    With :

    LF: pollutant load at plant outlet (Kg BOD_5/d).

    S_S: BOD_5 concentration at plant outlet (Kg/m^3).

    $Q_{aver.d}$: verage daily wastewater flow(m^3/d).

  - **Calculation of the eliminated pollutant load (E_L)**

    The following formula is used:

    $$E_L = L_0 - L_F$$

    With:

L_F: Pollutant load at pond outlet (kg BOD_5/d).

L_0: BOD_5 pollutant load at pond inlet (kg/d).

E_L: BOD_5 pollutant load removed (kg/d).

  - **Calculation of the purification yield (ηep)**

    We have:

    $$\eta_{ep} = \frac{L_0 - L_F}{L_0} \times 100 = \frac{E_L}{L_0} \times 100$$

    With :

    η_{ep} : The removal efficiency (%).

L_0 : BOD_5 pollutant load at pond inlet (Kg/d).

E_L : BOD_5 pollutant load eliminated (kg/d).

- **Calculation of the total raceway ponds volume(V_T)**

We have :

$$V_T = \frac{L_0}{C_V}$$

With :

V_T : Total ponds volume (m^3).

Cv: Volume load (kg BOD_5/m^3.d), Cv = 0.8 Kg BOD_5/ m^3/ d.

L_0: BOD_5 pollutant load at ponds inlet (kg /d).

We have three raceway ponds, therefor the total volume wil be devided on three to get the volume of one pond as follows:

$$V_p = \frac{V_T}{3}$$

- **Calculating of the total raceway ponds surface area (S_T)**

We have :

$$S_T = \frac{V_T}{P}$$

With :

S_T : Total Surface area of raceway ponds (m^2).

V_T : Total volume of raceway ponds (m^3).

P : Depth of raceway pond (taken as P= 0,5m).

Therefor, the surface area for a raceway pond is : $S_P = \frac{ST}{3}$

- **Calculation of the length and width of a raceway pond**

We assume that: L = 5 W

With :

L : length of raceway pond (m).

W : width of raceway pond (m).

Therefor :

$$L=\sqrt{5\times S_p}$$

- **Calculation of the total mass of microalgae in raceway ponds (Xa)**

  We have : $\mathbf{X_a}=\frac{L_0}{C_m}$

  With :

  Cm : Volume load (kg BOD_5/m^3.d), Mc= 0.3 Kg BOD_5/ Kg VSS.d.

  L_0 : BOD_5 pollutant load at pond inlet (kg /d).

- **Calculation of the concentration of microalgae in raceway ponds ([X_a])**

  We have :

  $$[X_a]=\frac{X_a}{V_T}$$

- **Calculation of the dwell time**

We have:

$$\mathbf{t_d}=\frac{V_T}{Q}$$

With :

t_d : Dwell time (h).

V_T: Total volime of raceway pond (m^3), (we have :V_T =2541.375 m^3).

Q : Wastewater flow rate.

- **For the Average hourly flow ($Q_{aver.h}$)**

  We have :

  $$t_d=\frac{V_T}{Q_{aver.h}}$$

- **For the dry weather peak flow (Q_{DWP})**

  We have :

  $$\mathbf{T_d}=\frac{V_T}{Q_{DWP}}$$

- **Number of aerators in a raceway pond (Na)**

  Aerators are used in raceway pond for several reasons such as: mixing, temperature control, CO_2 dispersion and maintainig proper oxygen depletion that can harm the microalgae. Therefor We propose the use of one aerator per pond (Na=1), with capacity of E_n =35KW.

Note : After the secondary treatment, and in order to harvest the microalgae biomass, it is necessary to stop the growth: by reducing exposure to light, by covering the raceway basins partially or completely with opaque materials such as shade sails and wait 3 hours before directing the treated water to the disinfection basin, to allow the microalgae to settle naturally to the bottom of the raceway ponds, enabling sedimentation. The proposed harvesting technique is manual harvesting, throught the use of nets to delicately collecte the top layer of microalgae biomass.

6.5.2.1. 2.Sizing of raceway pond intended for microalgae cultivation

Sizing calculation of Raceway pond intended for microalgae cultivation are as follows:

- **Calculating of raceway pond surface area (S)**

  We have : $\mathbf{S = L \times W}$

With :

S : Surface area of raceway pond (m^2).

L : length of raceway pond (m).(we assume that : L= 5 w = 5×26= 130m).

W : width of raceway pond (m).(we assume that : W=26 m).

- **Calculation of the raceway pond volume(V)**

Wa assume that : $\mathbf{V = 10\%\ V_T}$

With :

V : Volume of raceway pond intended for microalgae cultivation (m^3).

V_T: Total volume of raceway ponds intended for secondary treatment (m^3).

We assume that the depth of this raceway pond is equal to : 0,5m.

- **Calculation of the total mass of microalgae in raceway pond (Xa)**

We have : X_a in raceway ponds intented to the secondary treatment is equal to 6777 Kg, therefor we assume that Xa in the cultivation raceway pond is equal to : 7000kg.

- **Calculation of the concentration of microalgae in the raceway pond**

We have :

$$[X_a]=\frac{X_a}{V}$$

- **Number of aerators in a raceway pond (Na)**

We assume the need of two aerators (Na=2) in the raceway pond intended for microalgae cultivation, with capacity of : En =44KW.

The raceway ponds calculation results are mentioned in the tables 21(Chapter 3).

6.5.3. Tertiary treatment (disinfection)

Tertiary treatment is any chemical, physical or biological treatment that supplements primary and secondary treatment in order to eliminate pathogens, bacteria and viruses.

According to the wastewater treatment plants in Algeria, sodium hypochlorite (bleach) is the most widely used disinfectant at this stage of treatment, due to its availability on the market and its low cost. For the Taoura WWTP, I propose disinfection with sodium hypochlorite.

In order to improve water contact with the disinfectant solution, a number of baffles will be built inside the basin to increase water flow. Therefore, i propose 3 baffles, each 5m long and 2m wide.

- **Chlorine injection dose (Dcl)**

The chlorine dose required under normal conditions for treated effluent is

5 to 10 mg/l for a contact time of 30 minutes.

A dose of Dcl=10 mg/l for a contact time of tc=30 min is assumed.

- **Daily chlorine dose (Dj)**

The chlorine dose for disinfection is determined by the following function:

Dj = Qaver.d×Dcl

With:

Dj : chlorine dose for disinfection (Kg/d).

$Q_{aver.d}$: Average daily flow **($Q_{aver.d}$).**

D_{cl} : Unit dose of chlorine.

- **Sizing the disinfection basin**
  - **Calculation of disinfection basin volume (V_d)**

The volume of the disinfection basin is calculated using the following formula:

$$V_d = Q_{Rwp} \times t_C$$

With :

Q_{Rwp} : Rainy weather peak flow.

t_c: Contact time. (tc= 30min).

- **Calculation of the horizontal surface area of the disinfection basin (S_d)**

The horizontal surface area of the basin is calculated using the following formula:

$$S_d = \frac{V_d}{H}$$

With :

H : Height of the basin, we take : H=4m.

- **Calculation of the lenght (L_d) and the width (W_d) of the disinfection basin**

We have the folllowing formula:

$$L_d = \frac{S_d}{l_d}$$

We assume that :

$$L_d = 2\ W_d$$

Therefor :

$$L_d = \sqrt{2 \times S_d}$$

The teriary treatment calculation results are listed in the table 23(Chapter 3).

6.5.4. Storage basin

For the reuse of treated water, we propose a rectangular open-air storage basin with a volume of : $300m^3$.

- **Sizing the storage basin**
  - **Calculation of storage basin surface area (S_S)**

We have :

$$S_S = \frac{V_S}{H}$$

With :

S_S: surface area of storage basin.

H: Height of storage basin (we propose that: H = 1.5 m).

V_S: storage basin volume (We propose that : $V_S = 300m^3$).

- **Calculation of the lenght (L_S) and the width (W_S) of the storage basin**

We propose that the lenght of the storage basin: $L_S = 16m$.

Therefor:

$$W_S = \frac{S_S}{L_S}$$

The storage basin calculation results are listed in the table 24 (Chapter 3).

6.5.4. Microalgal biomass treatment unit

After a wastewater treatment cycle, the microalgae biomass used during the secondary treatment will be harvested and sent to a unit to follow a processing chain in order to extract and concentrate the valuable compouunds for various applications, this unit is called: microalgal biomass treatment unit. We propose a surface area of $130m^2$.

The processing steps at this unit and the machines used are summarized in the table 25(Chapter 3).

Conclusion

Sizing wastewater treatment systems is a critical process that requires careful consideration of various factors such as influent flows rates, pollutant loadings and the used technology.Proper sizing ensures the efficient removal of contaminants, compliance with environmental regulations and cost effectiveness in managing wastewater.

Chapter 3: Results and discussions

Introduction

In this section, we will delve into the calculation results of sizing the structures that constitute the proposed wastewater treatment plant of Taoura municipality.

1. Results of Sizing the treatment plant

1.1. Estimated population

Population trends up to 2050, set arbitrarily in this study, are summarized in table 15.

Table 15: Data on the evolution of population of Taoura untel 2050.

Year	2008	2020	2030	2040	2050
Population	18933	22505	26163	30415	35358

According to the table 14, the population for which the wastewater treatment plant will be sized in this study is that of 2050, where: P = 35358 inhabitants.

1.2. Estimated municipaliti's drinking water requirements

Results of Estimated population's drinking water requirements for various time horizons are given in Table 16.

Table 16: Results of theoretical drinking water requirements for the population of Taoura municipality.

Horizons	**Population (inhabitant)**	**Dotation (l/inhab/d)**	**Total consumption (m^3/d)**
2008	18933	150	2839,95
2020	22505	150	3375,75
2030	26163	150	3924,45
2040	30415	150	4562,25
2050	35358	150	5303,7

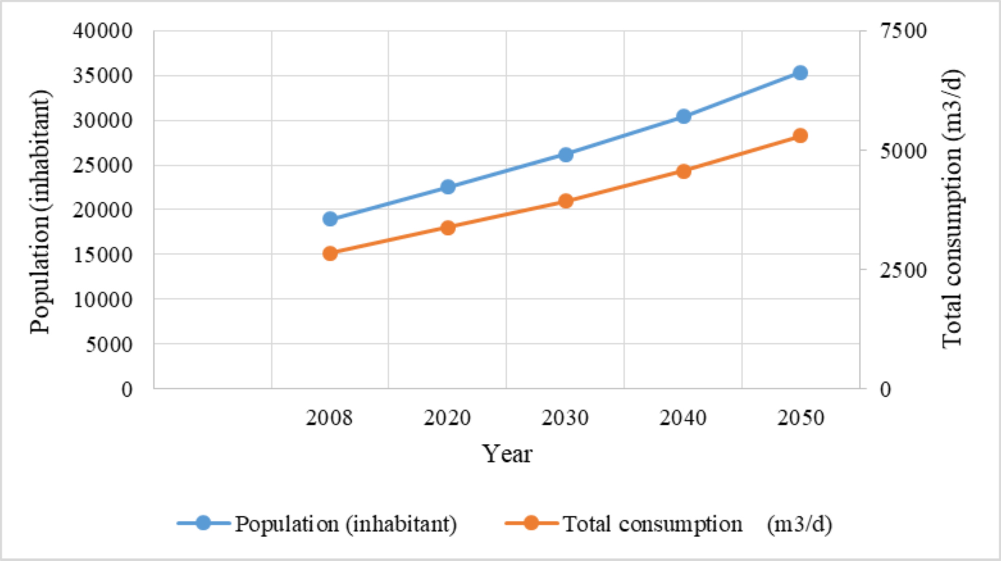


Figure 24: Evolution cruve of population and total conumption according to years.

According to table 16, that shows the results of theoretical drinking water requirements for the population of Taoura municipality.we note that for a dotation of 150 l/inhab/d, the drinking water requirements for the population increases over time, due to the polulation growth until the horizon 2050, from which The total consumption in 2050= 5303,7m^3/d.

1.3. Estimated wastewater flows for the 2050 horizon

1.3.1 Estimated domestic wastewater flows

Results of estimated wastewater flows discharged by the municipality studied at different horizons are summarized in Table 17.

Table 17: Results of evolution of wastewater flows discharged by the municipality of Taoura up to 2050.

Year	2008	2020	2030	2040	2050
Population (Inhabitant)	18933	22505	26163	30415	35358
Average daily flow of domestic wastewater $Q_{ad.d.ww}$ (m^3 /d)	2271,96	2700,6	3139,56	3649,8	4243

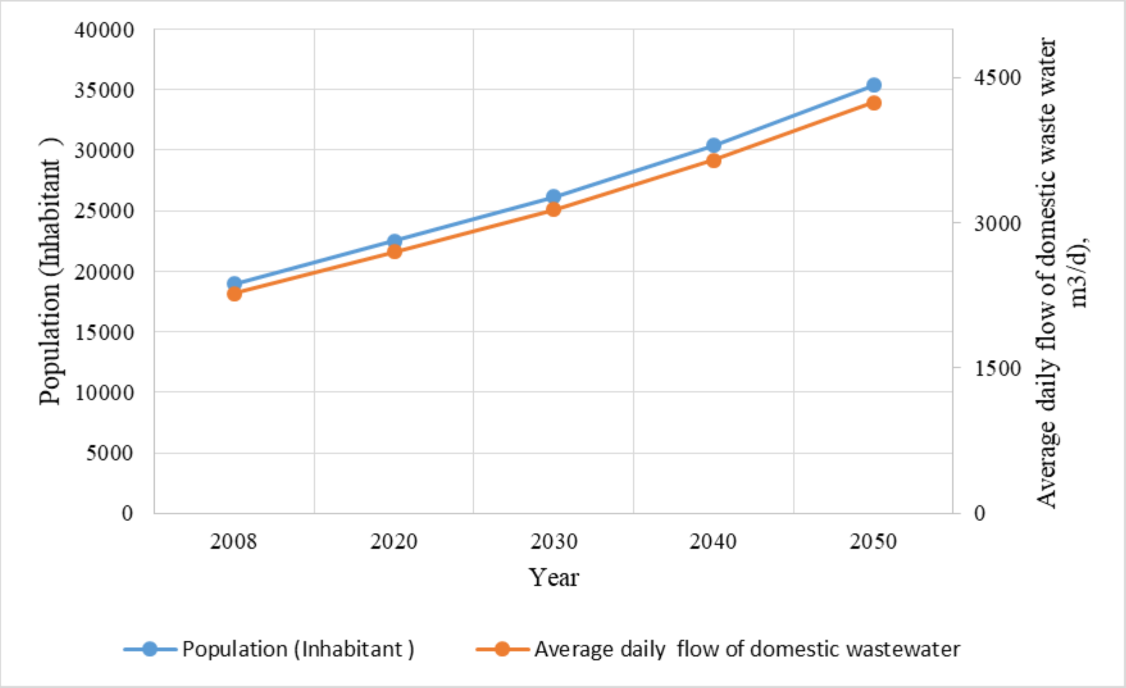


Figure 25: Evolution curve of population and average daily flow of domestic wastewater according to years.

According to the table 16 that shows the results of evolution of wastewater flows discharged by the municipality of Taoura up to 2050, we note that the average daily flow of domestic wastewater of the municipality is increasing with time and increased population, where it arrived to almost twice the number of the average daily flow estimated in 2008, to become 4243 m^3/d in horizon 2050.

1.3.2. Estimated equipment wastewater flows

We have : $\mathbf{Q_{Eq.ww}} = 4243 \times 0{,}15 = 636{,}45 m^3/d$

$\mathbf{Q_{Eq.ww}} = 636{,}45\ m^3/d.$

1.3.3. Estimated total wastewater flows

We have :

$Q_{T.ww} = 636{,}45 + 4243 = 4879{,}45 m^3/d$

$Q_{T.ww} = 4879{,}45 m^3/d.$

1.3.4. Inhabitant equivalent

We have :

$$[IE]_{2050} = \frac{4879{,}45 \times 1000}{0{,}8 \times 150} = 40662\ IE.$$

$[EH]_{2050}$= 40662 I E

The planned capacity of the Taoura wastewater treatment plant is therefore 40662IE.

1.4. Results of hydraulic and pollutant loads

To size the wastewater treatment plant, we need to estimate the hydraulic and pollutant loads for the year 2050, for a capacity of 40662 IE.All the results of hydraulic and pollutant loads are summarized in table 18.

Table 18: Results of basic Taoura WWTP data for 2050.

Parameter	Résultat	
Type of sewar system	Unitary	
Horizon	2050	
Inhabitant Equivalent (IE)	40662	
Hydraulic loads		
total wastewater flows ($Q_{T.ww}$)	m^3/d	4879,45
	m^3/h	203,310
Dry weather peak flow(Q_{Dwp})	m^3/h	372,463
Rainy weather peak flow (Q_{Rwp})	m^3/d	26817,336
	m^3/h	1117,389
Maximum flow entering the WWTP (Qmax)	m^3/d	9758,88
	m^3/h	406,62
Pollutant loads		
BOD_5	g/inhab/d	52
	$kgBOD_5/d$	2033,1
	mg/l	416,665
Purification yield	%	93

TSS	g/inhab/d	70
	Kg/d	2846,34
	mg/l	583,332
Purification yield	%	94
Nitrogen	g/inhab/d	20
	Kg/d	813,24
	mg/l	166,66
Purification yield	%	82
Phosphorus	g/inhab/d	15
	Kg/d	609,93
	mg/l	125
Purification yield	%	92

According to table 18, that shows the results of Taoura basic WWTP data for 2050, we note that for a maximum flow of 9758,88m^3/d entering the WWTP, the pollutant loads of BOD_5 , TSS, nitrogen and phosphorus that shold be removed with the proposed wastewater treatment process must have an effictivness of a purification yield of : 93% ,94%, 82% and 92% respectively.

1.5. Sizing of wastewater treatment plant structures

1.5.1. Pre-treatment

1.5.1.2. Screen sizing

The calculations results of sizing coarse screen and fine screen are summarized in table 19.

Table 19: Results of screen sizing.

Designation	**units**	**quantity**
Screen		
Coarse screen		
Number	U	1 Automatic
Spacing between bars (e)	m	0,050
Grid var thickness (b)	m	0,020
Velocity between the bars (V)	m/s	1
Inclination (α)	°	60
Clogging coefficient (δ)	/	0,5
Maximum water height (H_{max})	m	0,5
Width (W)	m	1,51
load losses for the circular shape (Δh_a)	m	0,023
screen refusals ($V_{r.max}$)	m^3/d	0,45
Fine screen		
Number	U	1 Automatic 1 Manual
Spacing between bars (e)	m	0,015
Grid var thickness (b)	m	0,010
Velocity between the bars (V)	m/s	1
Inclination (α)	°	60
Clogging coefficient(δ)	/	0,5
Maximum water height (H_{max})	m	0,5
width (W)	m	1,79
load losses for the circular shape (Δh_b)	m	0,046
screen refusals ($V_{r.max}$)	m^3/d	0,90

According to table 19, that shows the results of screen sizing**,** we note that the screen which we need during the pre-treatment are : an automatic coarse screen and two fine screen one is automatic and the other is manual.

1.5.1.3. Dessander and oil remover sizing

The dessander and oil remover calculation results are mentioned in the tables 20.

Table 20: Results of dessander and oil remover sizing.

Designation	**Unit**	**Quantity**
Dessander and oil remover		
Type of structure	/	Circular
Totale area surface (S)	m^2	23
Radius (r)	m	3
Volume (V)	m^3	92
Height(H)	m	4
Dwell time in rainy weather ($\boldsymbol{t_d}$)	min	4,94
The quantity of injected air	m^3 of air/h	1676
The total mineral solids (MS_T)	Kg/d	853,902
Eliminated mineral solids (MS_E)	Kg/d	579,731
Remaining mineral solids (MS_R)	Kg/d	256,171
The total volatile suspended solids (VSS_T)	Kg/d	1992,438

Remaining total suspended solids (TSS_R)	Kg/d	2248,609

According to the table 20, that shows the results of dessander and oil remover sizing, the most essential remarks that we note are that : we opted for a circular stucture, with a quantity of injected air to remove oil that equals to 1676 m3of air/h, the eliminated mineral solids MS_E = 579,731 kg/d and the remaining total suspended solids in the structure equals to 2248,609 kg/d.

1.5.2. Secondary treatment (biological treatment)

1.5.2.1. The proposed secondary treatment method

The proposed secondary treatment method in this study is based on the principle of medium-load microalgae treatment in raceway ponds, the results of calculation of sizing raceway ponds are listed in the following table.

Table 21: Results of raceway ponds sizing.

Designation	**Symbole**	**unit**	**Quantity**
Raceway pond intended for microalgae cultivation			
Number of structures	/	U	1
Volume of raceway pond	V	m^3	254,14
Surface area of raceway pond	S	m^2	3380
Depth of raceway pond	P	m	0,5
Lenght of raceway pond	L	m	130
Width of raceway pond	W	m	26
Total mass of microalgae	X_{a1}	Kg	7000
Energy requirement	E_n	KW	44

Raceway pond intended for secondary treatment			
Number of structures	/	U	3
Pollutant load at pond inlet	L_0	Kg/d	2033,1
Pollutant load at pond outlet	L_F	Kg/d	146,383
Eliminated pollutant load	E_L	Kg/d	1886,717
Purification yield	$\boldsymbol{\eta ep}$	%	92,8
Volume of raceway pond	V_p	m^3	847,125
Surface area of raceway pond	S_p	m^2	1694,25
Depth of raceway pond	P	m	0,5
Length of raceway pond	L	m	92,04
Width of raceway pond	W	m	18,40
Dwell time for $(Q_{aver.h})$	T_d	h	12 h30min
Dwell time for (Q_{DWP})	T_d	h	6 h49min
Total mass of microalgae	X_a	Kg	6777
Concentration of microalgae	[Xa]	Kg/m^3	2,66
Total energy requirement	E_n	KW	105

1.5.2.2. Comparison

In order to prove the proposed method, a comparison is made between two biological treatments used during secondary wastewater treatment processes:

- **Biological treatment using microalgae:** An innovative method proposed in this study.
- **Biological treatment using activated sludge**: A conventional method widely used in wastewater treatment plants.

The criteria for comparing the two treatment processes are summarized in the following table :

Table 22: Results of comparison between microalgae and activated sludge processes.

	Comparison criteria	Result	**Refference**
Sizing of wastewater treatment plant with Application of Micoalgae, in Taoura, Souk-Ahras.	Inhabitant equivalent	40662	**(Rehamna, 2023)**
	Surface area	2 to 3 hectares	
	Purification yield	92,8%	
	Total energy requirement	149 kw	
Sizing of a wastewater plant with the Application of activated sludge, in Iflissen, Tizi Ouzou.	Inhabitant equivalent	56355	**(Mzyene &Ouali, 2020)**
	Suface area	4 hectares	
	Purification yield	90,6%	
	Total energy requirement	461,76 kw	
	Inhabitant equivalent	422 500	**(Hammoudi, 2022)**

Sizing of a wastewater plant with the Application of activated sludge, in Bouinan, Blida.	Surface area	6 hectares	
	Purification yield	90%	
	Total energy requirement	1440 kw	

According to table Table 22, that shows the results of comparison between microalgae and activated sludge processes used in this study and two other studies, for a number of Inhabitent Equivalent that is approximately the number of the proposed WWTP we note that :

- Secondary astewater treatment using activated sludge requires a large surface area.
- Secondary wastewater treatment using microalgae, has shown the highest purification yeald (92,8%).
- The lowest Total energy requirement, was recorded in the secondary treatment using microalgae, while the highest energy requirement was recorded in the process with activated sludge, and that is due to pumping.
- the ideal process with the most advantages for wastewater treatment is the microalgae-based treatment process.

1.5.3. Tertiary treatment (disinfection)

The disinfection methode proposed is disinfection with sodium hypochlorite. The calculations results of sizing the disinfection basin are summarized in table 23.

Table 23: Results of disinfection basin sizing.

Designation	**Unit**	**Quantity**
Type of structure	/	Rectangular
Volume of disinfection basin	m^3	558,85
Surface area of the basin	m^2	139,7125
Lenght of the basin	m	16,68
Width of the basin	m	8,34
Height of the basin	m	4
Buffles number	U	4
Buffles lenght	m	5
Baffles width	m	2
Daily chlorine dose	Kg/d	48,794

Acording to table 23, that shows the results of disinfection basin sizing, we note that in order to treat the wastewater obtained from the secondary treatment, we need a daily chlorine dose that equals to 48,794 kg/d.

1.5.4. Storage basin

For the reuse of treated water, we propose a rectangular open-air storage basin. The calculations results of sizing coarse screen and fine screen are summarized in table 24.

Table 24: Results of storage basin sizing.

Designation	**Unit**	**Quantity**
Type of stucture	/	Rectangular
Volume of storage basin	m^3	300
Surface area of storage basin	m^2	200
Lenght of storage basin	m	16
Width of storage basin	m	12,5
Height of storage basin	m	1,5

According to table 24, that shows the **r**esults of storage basin sizing, we note that this basin with a volume of $300m^3$, will be used to store the treated water that arrives from the disinfection basin in order to reuse it later in irrigation.

1.5.5. Microalgal biomass treatment unit

The processing steps at this unit and the machines used are summarized in the following table.

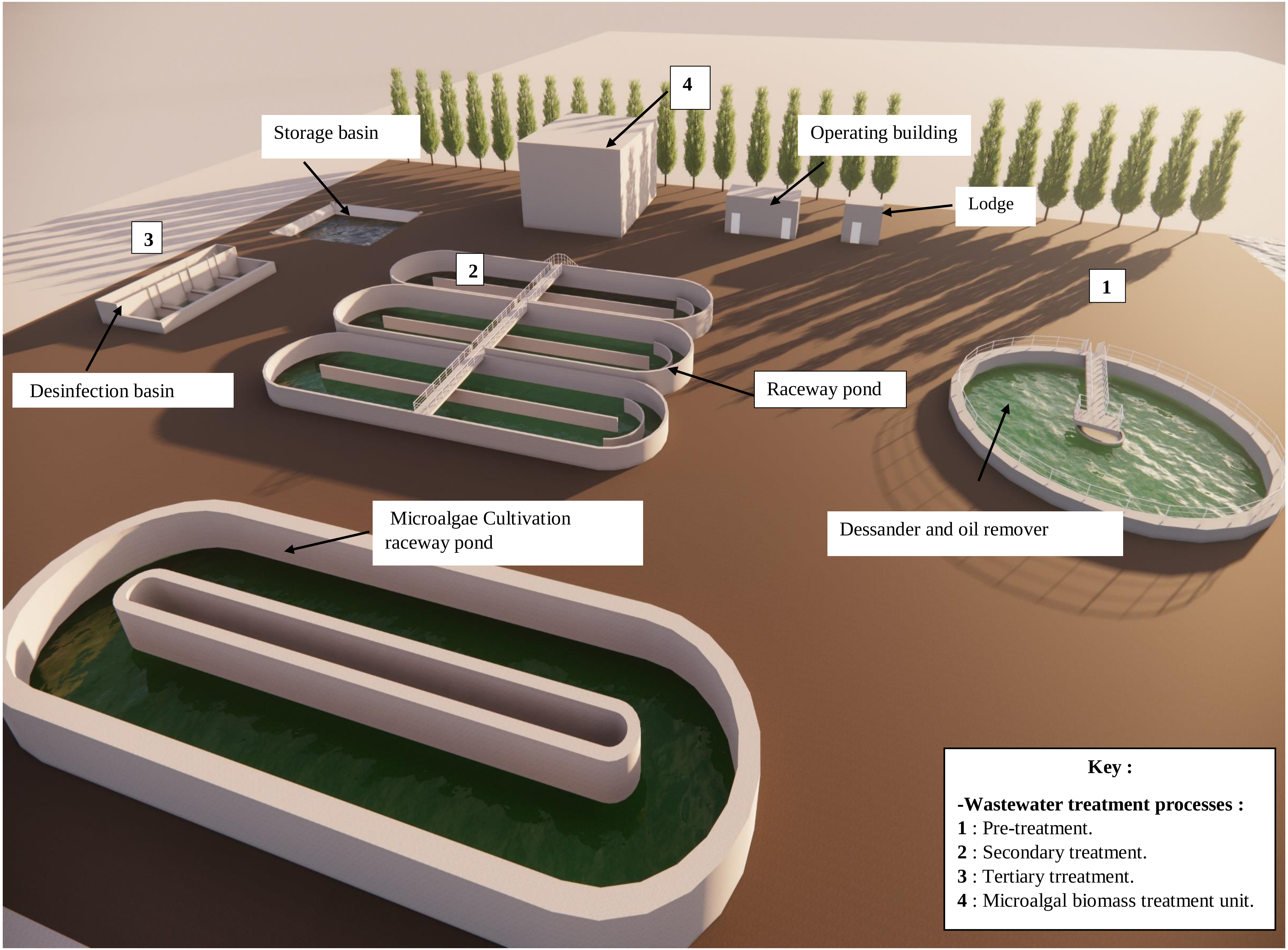
Table 25: Summary of the processes, methods and machines used at the Microalgal biomass treatment unit.

Process	Purpose of use	Methode	Brand of machine
Dewatering	Since *spirulina platensis,* contains a hight water content, dewatering is often necessary to remove excess moisture.	Spray drying	GEA-spray drayer
Cell disruption	To access the valuable compounds within microalgae cells, cell walls need to be disrupted.	Ultrasonication	Qsonica-Ultrasonic homogenizer
Extraction	After cell distruption, the desired compounds (proteins, pigments…) are extracted	Solvent extraction	Buchi-Rotary evaporator
Purification	The extracted mixture is typically purified to isolate and refine the specific compounds of interest.	Chromatography	Waters-Chromatograph
Drying	The purified extracts are often dried to creat a stable product	Spray drying	GEA-spray drayer
Product utilisation	The purified spirulina platensis compounds can be used for varios applications including dietary supplements, cosmetics and food additives.	Converting extracts of microalgae into capsules	Capsugel-Capsule filling machine

According to table 25, that shows a Summary of the processes, methods and machines used at the Microalgal biomass treatment unit, we note that this unit requires the use of several machines to enhace the produced microalgae biomass, starting from the first process (Dewatering), untel the last process (Drying) in order to obtain the final product.

1.6. Three-Dimensional WWTP

The proposed layout of the future Taoura WWTP is presented in three-dimensional form in the following figure :



Key :

-Wastewater treatment processes :

1 : Pre-treatment.
2 : Secondary treatment.
3 : Tertiary trreatment.
4 : Microalgal biomass treatment unit.

Figure 26: Three-dimensional plan of the proposed Taoura WWTP.

Conclusion

Through the calculations results carried out in this chapter, we can judge that the application of microalgae in the sizing of wastewater treatment plant shows significant promise by harnessing the natural capabilities of microalgae to remove pollutants and nutrients from wastewater, we can potentially reduce the overall footprint and cost of wastewater treatment facilities.

General conclusion

At the end of this work, I would like to remind that my study falls within the general framework of sustainable development and environmental protection. We

Microalgae are photosynthetic micro-organisms with a wide morphological diversity and interesting biochemical characteristics, giving them a variety of scientific and industrial applications in various fields: the production of high-value-added molecules used in pharmaceuticals and cosmetics, human and animal nutrition, renewable energy production and wastewater treatment.

In order to demonstrate the role of microalgae in wastewater treatment, We suggest to apply this microorganismes to the design of the future wastewater treatment plant of the municipality of Taoura, as this project aims to design a microalgae treatment plant, given that the water discharged is biodegradable This choice of variants has been made with a view to horizon 2050.

Based on our calculations made in this thesis, we can conclude that the proposed treatment method is a promising and feasible one, and that the land reserved for the wastewater treatment plant has the required characteristics, with sufficient surface area to accommodate the various structures of which it is composed for the requested horizon (2050). However this methode can be inhibited in winter due to changes in several parameters such as the drop in temperature, therefor i suggest the use of greenhouses to be able to control the growth parametrers of microalgae.

The valorization of the microalgae biomass produced and the reuse of purified water are the two other perspectives from which the region's farmers could benefit.

However, despite its advantages, wastewater treatment using microalgae also presents challenges and limitations. Large-scale implementation of this technology requires significant investment in terms of infrastructure, equipment and technical knowledge. Further research and development efforts are needed to overcome technical, economic and regulatory obstacles and enable more widespread adoption of this technology.

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Appendix

Appendix 1: Microalgae cultivation systems.

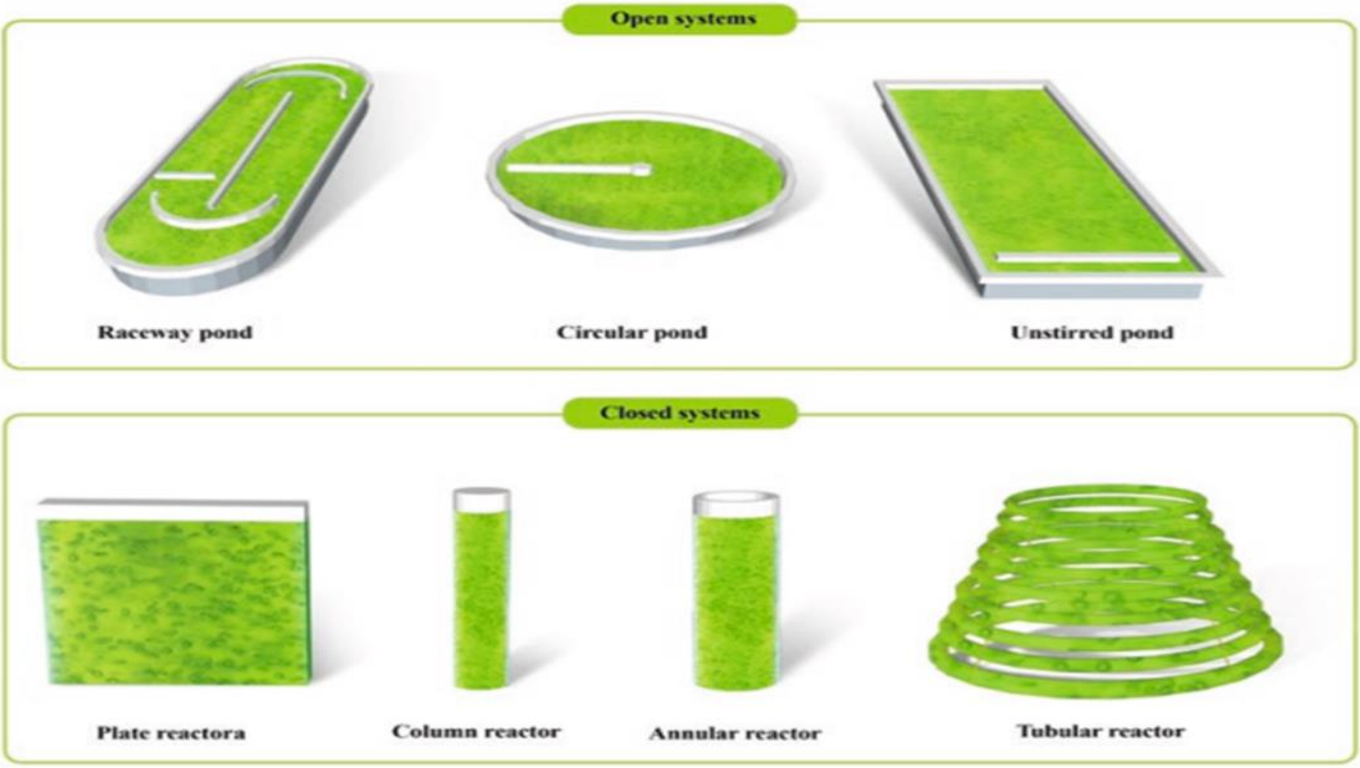

Figure 1: Examples of different types of pond systems for outdoor microalgae cultivation **(Zerrouki &Abdellah, 2019).**

Appendix 2

The discharge standards in Algeria are shown in the following two tables:

Table 1: Maximum limit values for the content of harmful substances in wastewater other than domestic at the time of their discharge into a public sewer network or in a sewage treatment plant. (According to the **Ministry of water ressources official journal of the Democratic Republic of Algeria).**

Parameters	**Maximum limit values**
Total nitrogen	150
Aluminium	5
Arsenic	0,1
Silver	0,1
Beryllium	0,05
Cadmium	0,1

Chlorine	3
Trivalent chromium	2
Chrome hexa valent	0,1
Chromates	2
Copper	1
Cobalt	2
Cyanide	0,1
Diochemical oxygen demand (BOD_5)	500
Chemical oxygen demand (COD)	1000
Etain	0,1
Iron	1
Fluorides	10
Total hydrocarbons	10
Suspended matter	6à0
Magnesium	300
Mercury	0,01
Nickel	2
Nitrites	0,1
Total phosphorus	50
Phenol	1
Lead	0,5
Sulphides	1
Sulphates	400
Zinc and compounds	2

Temprerature ≤ 30 pH : Between : 5,5 and 8,5

Table 2: Limit values of the discharge parameters in a receiving environment. (**According to the Ministry of water ressources official journal of the Democratic Republic of Algeria).**

Parameters	**limit Values**	**Unit**
Temperature	30	°C
pH	6,5 to 8,5	/
SS	35	mg/l
BOD_5	35	mg/l
COD	120	mg/l
Kjeldahl nitrogen	30	mg/l
Phosphates	02	mg/l
Total phosphorus	10	mg/l
Cyanides	0,1	mg/l
Aluminum	03	mg/l
Cadmium	0,2	mg/l
Iron	3	mg/l
Manganese	1	mg/l
Total mercury	0,01	mg/l
Total nickel	0,5	mg/l
Total lead	0,5	mg/l
Total copper	0,5	mg/l
Total Zinc	3	mg/l
Oils and fats	20	mg/l
Total hydrocarbons	10	mg/l
Total chromium	0,5	mg/l
Chlorinated organic compounds	0,5	mg/l
Detergents	02	mg/l
Organic solvents	20	mg/l

Abstract

Microalgae are promising candidates that can be used in secondary wastewater treatment thanks to their ability to reduce the amount of nitrogen and phosphate as well as other toxic compounds, including heavy metals, so they will provide a bio -processing Coupled with the production of a potentially recoverable biomass, which can be used for several purposes.

The aim of this thesis is to demonstrate the importance and feasibility of using microalgae to treat wastewater by building a wastewater treatment plant in the locality of Taoura (State of Souk-Ahras), in order to improve the region's ecological conditions, wastewater quality, preserve the natural environment and protect public health.

In this dissertation, we have dimensioned microalgae wastewater treatment plant for the 2050 horizon, with a capacity of 40662 Inhabitant Equivalent.

Key words: Microalgae, Bioprocessing, Biomass.

Résumé

Les microalgues sont des candidats prometteurs qui peuvent être utilisés dans le traitement secondaire des eaux usées grâce à leur capacité à réduire la quantité d'azote et de phosphate ainsi que d'autres composés toxiques, y compris les métaux lourds, de sorte qu'ils fourniront un bio-traitement couplé à la production d'une biomasse potentiellement récupérable, qui peut être utilisée à plusieurs fins.

L'objectif de cette thèse est de démontrer l'importance et la faisabilité de l'utilisation des microalgues pour traiter les eaux usées en construisant une station d'épuration dans la localité de Taoura (La ville de Souk-Ahras), afin d'améliorer les conditions écologiques de la région, la qualité des eaux usées, de préserver l'environnement naturel et de protéger la santé publique.

Dans ce mémoire, nous avons dimensionné une station d'épuration à microalgues à l'horizon 2050, d'une capacité de 40662 Equivalents Habitants.

Mots clés : Micro-algues, Bio-traitement, Biomasse.

ملخص

تعتبر الطحالب الدقيقة مرشحة واعدة يمكن استخدامها في المعالجة الثانوية لمياه الصرف الصحي نظرًا لقدرتها على تقليل كمية النيتروجين والفوسفات بالإضافة إلى المركبات السامة الأخرى، بما في ذلك المعادن الثقيلة، بحيث توفر المعالجة الحيوية مقترنة بإنتاج الكتلة الحيوية التي يحتمل أن تكون قابلة للاسترداد. والتي يمكن استخدامها لعدة أغراض. .

تهدف هذه المذكرة إلى بيان أهمية وجدوى استخدام الطحالب الدقيقة لمعالجة مياه الصرف الصحي من خلال بناء محطة معالجة مياه الصرف الصحي في بلدية تاورة (ولاية سوق اهراس)، وذلك من أجل تحسين الظروف البيئية للمنطقة، ونوعية المياه العادمة، والحفاظ على البيئة الطبيعية. وحماية الصحة العامة.

من خلال مذكرة التخرج هذه، قمنا بتصميم محطة لمعالجة الطحالب الدقيقة بحلول عام 2050، بسعة 40662 مكافئ ساكن.

الكلمات المفتاحية: الطحالب، المعالجة الحيوية، الكتلة الحيوية.