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Assessing the Suitability of purified wastewater from the WWTP in Southern Algeria (Saïd Otba - Ouargla) for agricultural reuse

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Dedication

I am grateful to those who provided support and motivated throughout my journey in this endeavor. I dedicate this work to my beloved father, allah God have mercy on him, he consistently supported me during my academic pursuit, constantly encouraging me to reach new heights, unfortunately, fate intervened and he departed before witnessing my achievements and success. May Allah grant him mercy?

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AAS	**A**tomic **A**bsorption **S**pectrometer
AS	**A**lgerian **S**tandard
BOD_5	**B**iochemical **O**xygen **D**emand
COD	**C**hemical **O**xygen **D**emand
EC	**E**lectrical **C**onductivity
MMS	**M**ineral **M**atters
NMO	**N**ational **M**eteorological **O**ffice
NSO	**N**ational **S**anitation **O**ffice
O_{2diss}	**D**issolved **O**xygen
OM	**O**rganic **M**atter
PCA	**P**rincipal **C**omponent **A**nalysis
SS	**S**uspended **S**olids
SVM	**S**uspended **V**olatile **M**atter
TN	**T**otal **N**itrogen
TP	**T**otal **P**hosphorus
UWW	**U**rban **W**aste**W**ater
WHO	**W**orld **H**ealth **O**rganization
WQI	**W**ater **Q**uality **I**ndex
WWTP	**W**aste**W**ater **T**reatment **P**lant

Contents

GENERAL INTRODUCTION

General introduction:

Water is a precious commodity that is subject to various types of pollution and degradation: ecosystems and people's health are directly impacted. The pollution present in the water is of various origins: industrial, domestic or agricultural **[1].**

Figures published by the World Health Organization **(WHO)** in **2004** reveal that every **1.8** million people, **90%** of whom are children under five, mostly living in developing countries, die of diarrheal diseases, globally, **88%** of diarrheal diseases are attributable to poor quality drinking water and inadequate wastewater treatment. Water has become a global strategic issue whose management must imperatively be integrated into a political perspective of sustainable development. Some indeed affirm that it will be, in the third millennium, an issue of wars like oil has been and still is today **[2].**

The Saharan regions of Algeria are subject to significant demographic expansion leading to a continuous increase in the quantities of wastewater produced. Pollution or contamination of water can be defined as the degradation of the latter by modifying its physical, chemical and biological properties, by spills, discharges, direct or indirect deposits of foreign bodies or undesirable materials such as micro-organisms, products toxic, industrial waste **[3].**

For this, wastewater, whether industrial or household, should not be directly reused or discharged into the natural environment, they should be directly reused or discharged into the natural environment, they should be directed to treatment plants in order to obtain good results, in accordance with the standards for discharges or those for irrigation, it is necessary to choose an efficient purification technique that is economical and respects the environment **[3].**

Our study is a contribution to the evaluation of the suitability of treated wastewater from the **WWTP** of the city of Ouargla for irrigation. The objective of this work is to examine according to salinization, mineralization and physico-chemical quality of treated wastewater whether it can be reused for irrigation of agricultural land, for what type and method of irrigation.

This memorandum is divided into four chapters, namely:

- ***Chapter Ⅰ:*** Generalities about wastewater.
- ***Chapter Ⅱ:*** Wastewater Treatment Methods.
- ***Chapter Ⅲ:*** Materials and methods.
- ***Chapter IV***: Results and discussions.

In this study, we will present our observations and interpretations of field measurements, in an attempt to answer several questions, the main ones being:

- What is the current plant of the physico-chemical quality of treated wastewater from the WWTP of the city of Ouargla?
- Is it possible to reuse this water for the irrigation of agricultural land?

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Chapter I : Generalities on Wastewater

Chapter's summary

In this chapter, everything related to contaminated water, especially wastewater, was reviewed.

I. 1. Wastewater:

I. 1. 1. Wastewater definition:

Wastewater, also called urban waste water **(UWW),** is liquid waste produced by man during his domestic, agricultural and industrial activities. They can increase the pollution of the natural environment because they are generally loaded with various detritus, dissolved mineral matter and organic products in suspension. Wastewater is water loaded with pollutants, soluble or not, originating mainly from human activity. Wastewater is generally a mixture of pollutants corresponding to these categories, dispersed or dissolved in water used for domestic or industrial needs [1].

I.1.2. Nature and origin of wastewater:

I.1. 2.1. Domestic wastewater:

They come from home, and are generally transported by the sewerage network to the treatment plant. These water are characterized their high levels of organic matter, mineral salts (nitrogen, phosphorus), detergents and faecal germs **[1].**

Domestic wastewater can come from three possible sources:

- ***Kitchen water:*** They contain mineral matter in suspension from the washing of vegetables, food substances based on organic matter (carbohydrates, lipids, proteins, etc.), and detergent products used for washing dishes and having as their fat solubilization effect.
- ***Water from the bathrooms:*** They are loaded with products used for personal hygiene, generally hydrocarbon fats.
- ***Sewage*****:** They come from sanitary facilities, and are very rich in hydrocarbon matter, nitrogen, and phosphorus. This water represents a suitable substrate for biological treatment processes, but may contain pathogenic elements (bacteria, viruses and various parasites) **[1].**

I.1.2.2. Industrial wastewater:

Coming from factories, they are characterized by a great diversity, depending on the use of water. All the products or by-products of industrial activity are found concentrated in water (pollution) [1]:

- Pollution due to suspended mineral matter (coal washing, quarry, sieving of sand and gravel, industries producing phosphate fertilizers…….).
- Pollution due to materials in mineral solution (stripping plant, galvanizing….).
- Pollution due to organic matter and fats (food industries, renderings, paper pulp, etc.).
- Pollution due to various hydrocarbons and chemical discharges (oil refineries, pharmaceutical products, etc.).
- Pollution due to toxic radioactive discharges (untreated radioactive waste, radioactive effluents from nuclear industries….).
- Pollution due to hot water (cooling circuits of thermal power stations).

I.1.2.3. Storm water:

These are the runoff water that closes after a precipitation. They can be particularly polluted, especially at the beginning of the rain, by two mechanisms:

-The washing of floors and waterproofed surfaces.

-The suspension of collector deposits, they are of the same nature as domestic wastewater, with heavy metals and toxins (lead, zinc, hydrocarbons) mainly from automobile traffic [2].

I.1.2.4. Urban wastewater:

Urban wastewater is first formed by a mixture of domestic wastewater and industrial wastewater. To this is added a third component formed by rainwater and effluents from collective facilities (hospitals, shops, barracks, etc.) [3].

I.1.2.5. Agricultural wastewater:

The agricultural sector remains the largest consumer of water resources. Pollution due to agricultural activities is of several types:

-Input of nitrate and phosphate surface waters used as fertilizers.

-Intake of chlorinated or phosphorus pesticides, weed killers, insecticide.

-Supply of sulphate, copper and arsenical compounds intended for the protection of vines in wine-growing regions [4].

I.1.3. Composition of wastewater:

The composition of wastewater is extremely variable depending on its origin (industrial, domestic, agricultural, etc.) so it is variable and depends essentially on human activity. They can contain many substances, in solid or dissolved form, as well as many micro-organisms. Depending on their physical, chemical and biological characteristics and the health hazard they represent, urban wastewater also contains solid matter, dissolved substances and micro-organisms: bacteria, protozoa, viruses and helminths [5].

Table (I.1): Typical major components of domestic wastewater [6].

Consists	Concentration (mg/l)		
	Fort	**Average**	**Weak**
Solids Totals (ST)	1200	700	350
Solids Dissolved (SD)	850	500	250
Solids Suspension (SS)	350	200	100
Nitrogen	85	40	20
Phosphorus	20	10	6
Alkaline (in CaCO3)	200	100	50
Grease	150	100	50
DBO_5	300	200	100

I.2. Water pollution:

I.2.1. Definition:

Water pollution occurs when material is dumped into water that degrades its quality. Pollution in water includes all superfluous materials that cannot be destroyed by water naturally. In other words, any matter added to water that is beyond its ability to destroy it is considered pollution. Pollution can in some circumstances be caused by nature itself, such as when water runs through soils that have a high level of acidity. On the other hand, most of the time it is human actions that pollute the water **[7].**

I.2.2. Main type of water pollution:

I.2.2.1. Physical pollution:

It is pollution due to physical agents (any solid element carried by water), it can be divided into two classes: thermal and radioactive.

a. Thermal pollution:

Caused by the excessive increase in the temperature of the water as a result of discharges of water from the cooling circuits of industrial establishments, especially power stations **[8].**

b. Radioactive pollution:

It is that caused by a possible artificial radioactivity of the discharges which find their source in the use of nuclear energy in all its forms (uranium mining facilities and power stations, radioactive waste processing) **[9].**

I.2.2.2. Chemical pollution:

Chemical water pollution results from the release of certain toxic mineral substances into waterways, for example: nitrates, phosphates, ammonia and other salts, as well as metal ions. These substances have a toxic effect on organic materials and make them more dangerous.

Chemical pollutants are currently classified into five categories **[10]:**

-So- called undesirable chemical substances.

-Pesticides.

-Related products.

-Detergents.

-Dyes and other toxic elements.

It results from chemical discharges, mainly of industrial, domestic and agricultural origin. Chemical water pollution is grouped into two categories:

A-Organic pollution:

These are the effluents loaded with fermentable organic matter (Biodegradable), supplied by the food and agri-food industries (dairies, beaters, sugar, factories, etc.), and by domestic effluents. The first consequence of this pollution is the consumption of dissolved oxygen in these waters. Organic pollution is mainly detergents, pesticides and hydrocarbons **[11]:**

-Detergents: These are synthetic surfactant compounds whose presence in detergents water is due to urban and industrial effluent discharges.

-Pesticides: Pesticides are a major problem for the environment. These are products generally used in agriculture; the harmful consequences due to pesticides are linked to the following characteristics:

- Chemical stability leading to an accumulation in the food chains.
- Disruption of the natural balance

-Hydrocarbons: They come from the oil and transport industries; they are substances that are not very soluble in water and difficult to biodegrade **(I.1),** their lower density than water causes them to float. On the surface, they form a film which disrupts gas exchange with the atmosphere **[12].**

Fig (I.1): Oil pollution **[13]**

B-Mineral pollution:

Mineral pollution of waters can cause disturbances in plant growth or physiological disorders in animals. Mineral pollutants are mainly heavy metals and mineral nutrients **[14].**

***-Heavy metals*:** Elements with a density greater than or equal to **5 g.cm.** Heavy in living organisms and can contaminate the entire food chain. These are essentially Mercury **(Hg)**, Cadmium **(Cd)**, Lead **(Pb),** Silver **(Ag)**, Copper **(Cu)**, Chromium **(Cr)**, Nickel **(Ni)** and Zinc **(Zn)**. These elements, although they may have a natural origin (subsoil rocks, ores), come mainly from water contamination by discharges from various industrial activities **[15].**

-Nutrient mineral elements: Coming mainly from agriculture and domestic effluents, they are at the origin of the phenomenon of eutrophication, that is to say the excessive proliferation of algae and plankton in the environments aquatic **[11].**

I.2.2.3. Microbiological pollution:

It manifests itself when there are certain types of microorganisms capable of proliferating in water **[16].** A large number of micro-organisms can proliferate in water, which serves as a natural habitat or as a simple means of transport for these micro-organisms. The main pathogenic organisms that multiply in water are: Bacteria, viruses, parasites and fungi **[17].**

Table (I. 2): Microbiological parameters in wastewater **[18]**

Micro-organisms	Gram	Respiration	Genus
Coliforms	–	Optional anaerobic	*Escherichia, Citrobacter, Enterobacter, Klebsiella, Yersinia, Serratia*
Faecal *Streptococci*	+	Aero-anaerobic	*Streptococcus, Enterococcus Lactococcus*
Sulphite-reducing Bacteria	+	Strict anaerobic	*Clostridium*
Staphylococci	+	Aero- anaerobic optional	*Staphylococcus*
Shigella	–	Optional anaerobic	*Shigella*
Salmonella	–	Optional anaerobic	*Salmonella*

I. 2.3. Wastewater characteristics:

Wastewater has physical, chemical and biological characteristics:

I. 2. 3. 1. Physical parameters:

I. 2. 3. 1. 1. Temperature:

Temperature is both an ecological and physiological factor. Thus, it acts on conductivity, solubility of salts, determination of pH and the origin of water and possible mixtures. At the same time, it acts on the metabolism and growth of micro-organisms living in water **[19].**

I.2.3.1.2. Suspended Solids (SS):

They represent any element in suspension in water (neither in the soluble state nor in the colloidal state) whose size allows its retention on a filter of given porosity. The **SS** are linked to the turbidity of the water (measurement of the cloudiness of the water) and mark the degree of pollution of an urban or even industrial effluent **[20].**

It is estimated that **30%** of **SS** is organic **70%** is mineral. Thus, suspended volatile matter **(SVM)** represents the organic fraction of **SS** and is obtained by calcining **SS** at **525ºC.** For **2** hours. The difference in weight between the **SS** at **105ºC** and the **SS** at **525ºC** give the loss on ignition and correspond to the **SVM** content in **(mg/l).** However, mineral matter **(MMS)** represents the result of total evaporation of water, the dry extract consists of both suspended solids **SS** and soluble matter such as chlorides, phosphates, etc **[21].**

I.2.3.1.3. Electrical Conductivity:

This measurement gives a precise indication of the total concentration of dissolved salts **[22].**

I.2.3.1.4. Turbidity:

Fine suspended solids, micro-organisms and colloidal matter of organic or mineral origin cause the reduction of water transparency by obstructing the penetration of light **[23].** Turbidity therefore represents the opacity of a turbid medium **[24].**

I.2.3.1.5. Odor:

Fresh sewage has a bland smell which is not unpleasant. On the other hand, in a state of fermentation, it gives off a nauseating odor **[24].**

I.2.3.1.6. Flow:

Flow measurement makes it possible to quantify the pollution discharged through an "equivalent inhabitant" which expresses the average volume of wastewater discharged per inhabitant and per day **[24].**

I.2.3.1.7. Color:

The color of the water can be caused by the presence of natural (Iron and Magnesium) but also can be due to the presence of plankton, grass and organic compounds (polyphenols). Domestic wastewater is grayish in color, sometimes black. On the other hand, industrial wastewater can be colorless, as it can several colors due to the discharge of industrial dyes **[24].**

I.2.3.2. Chemical parameters:

I.2.3.2.1. Hydrogen potential (pH):

pH represents the acidity or alkalinity of a solution. The **pH** of domestic or urban water is generally between **6.8** and **7.8**, beyond which is an indication of industrial pollution **[25].**

I.2.3.2.2. Biochemical Oxygen Demand (BOD_5):

The biochemical oxygen demand is the quantity of oxygen expressed in mg/l for micro-organisms to oxidize for five **(5)** days under the conditions of the test incubation at **20ºC.** Biodegradable materials present in wastewater. To measure it, the quantity of oxygen consumed after **5** days is taken as a reference; it is the **BOD_5**. It boils down to the following chemical reaction:

$$\text{Substrate + micro-organism} + O_2 \Rightarrow CO_2 + H_2O + \text{energy + biomasses}$$

Organic matter (**OM)** is given by the empirical equation as a function of the **BOD_5** and the **COD** **[26]** such as:

$$MO = (2\,BOD_5 + COD)/3$$

I.2.3.2.3. Chemical Oxygen Demand (COD):

The chemical oxygen demand is the quantity of oxygen necessary for the degradation of any matter contained in the waste water that it is biodegradable and non-biodegradable present waste water **[27.28].** It is expressed by the quantity of oxygen provided by potassium dichromate necessary for the oxidation of organic substances **[29]**.

I.2.3.2.4. Relationship between (COD) and (BOD_5):

The **COD**/$\mathbf{BOD_5}$ ratio give an estimate of the biodegradability of wastewater. The concept of biodegradability represents the ability of a substance or its ability to be decomposed by micro-organisms (bacteria, fungi, etc.).

Table (I.3): Classification of wastewater according to **COD** values **[30].**

	Value	The origin of the effluent
COD	**1.5** to **2** times $\mathbf{BOD_5}$	For urban wastewater
COD	**1** to **10** times $\mathbf{BOD_5}$	For all wastewater
COD	>**2.5** times $\mathbf{BOD_5}$	For all industrial wastewater

I.2.3.2.5. Dissolved Oxygen:

This is very important parameter which is determined in situ with an oximetry. Dissolved oxygen gives an indirect measure of the degree of pollution of water **[29].** It depends on the origin of the water. Domestic wastewater can contain **2** to **8 mg/l** **[31].**

I.2.3.2.6. Biodegradability:

Biodegradability reflects the ability of an effluent to be decomposed or oxidized by micro-organisms involved in biological water purification processes. It is expressed by a coefficient **K**, with $\mathbf{K = COD / BOD_5}$ **:**

- ✓ If **K** <**1.5**, this means that the oxidizable materials are largely made up highly biodegradable materials.
- ✓ If **1.5**< **K**< **2.5**, this means that the oxidizable materials are moderately biodegradable.
- ✓ If **2.5**<**K**< **3**, oxidizable materials are not very biodegradable.
- ✓ If **k** >**3**, oxidizable material are non-biodegradable.

A very high **K** coefficient reflects the presence in the water of elements that inhibit bacterial growth, such as metal salts, detergents, phenols, hydrocarbon, etc. The value of the coefficient **K** determines the choice of the treatment process to be adopted, if the effluent is biodegradable a biological treatment is applied, otherwise a physico-chemical treatment is applied **[32].**

I.2.3.2.7. Ammonium (NH_4^+):

Ammonium ions represent one of the basic stages in the nitrogen cycle, and the presence of ammonium in large quantities in surface water is evidence of pollution resulting from wastewater thrown into the watercourse **[33].**

I.2.3.2.8. Nitrates Electrolytes (NO_3^-):

Medical research has proven the harmful effects of nitrates on public health, especially infants, in addition to the increasing concentration of nitrates in surface and groundwater as a result of the large expansion in the use of chemical fertilizers. Determining water pollution with nitrates is a difficult process as a result of the continuous transformations of nitrogen within the nitrogen cycle. Nitrates represent the final stage of oxidation of nitrogenous organic compounds, and therefore their presence in polluted water is evidence of the progression of the self-purification process. The sources of nitrates in water are many and varied; including the natural source as a result of the dissolution of nitrate compounds in the watercourse, but its percentage is very weak and does not exceed **1 mg /l**. Nitrogenous fertilizers in agriculture may reach **60%** **[33].**

I.2.3.2.9. Nitrite ions (NO_2^-):

The nitrite ions represent a transitional stage between nitrate ions and ammonium ions within the process of oxidation and return to them. Therefore, nitrite ions in the aqueous medium are either the result of the return of nitrate ions, or the oxidation of ammonium ions, and there is no direct natural source of nitrite ions **[33].**

I.2.3.2.10. Total Organic Carbon (TOC):

It represents only the carbon present in organic compounds. **TOC** value determines which compounds are difficult or biochemically degradable. It is measured by an infrared CO_2 analyzer after high temperature catalytic combustion of the sample **[34].**

I.2.3.2.11. Nitrogen:

Nitrogen is present in domestic wastewater in an organic form (component major protein) or ammoniacal **(NH_3 and NH_4)** [35].

I.2.3.2.12. Phosphorus:

Phosphorus is present in wastewater in an organic form (of industrial or biological origin from faeces) or mineral (ortho and poly phosphates from washing powder, phosphate fertilizer). The daily intake of phosphorus is about **4g** per capita per day. The quantification of phosphorus in raw wastewater makes it possible to know whether biological treatment is possible [21].

I.2.3.2.13. Chlorides and sodium:

Chlorides and sodium can be of natural origin (sea water: **27g/l NaCL,** and saline soils), human (**10** to **15g/l Na CL** in urine /day) or industrial (potash, oil industry, electroplating, agri-food). They can be problematic when sewer systems drain brackish groundwater [34].

I.2.3.3. Biological parameters:

The micro-organisms found in the wastewater are at the origin of the biological treatment. They include, in increasing order of size: viruses, bacteria, protozoa and helminthes. Among the most frequently encountered pathogenic elements are:

I.2.3.3.1. Viruses:

Viruses are intracellular parasites that can only multiply in a host cell. Their concentration in urban wastewater is estimated at **103** to **104** particles per liter. Enteric viruses are those that multiply in the intestinal tract. Among the most important human enteric viruses are enteroviruses, rotaviruses, adenoviruses and hepatitis A virus, which have a lifespan of approximately 3 months [26].

I.2.3.3.2. Protozoa:

Protozoa are unicellular organisms with a nucleus, more complex and larger than bacteria. Most pathogenic protozoa are parasitic organisms. Some protozoa adopt during their life cycle a form of resistance, called a cyst. This form can generally resist the treatment processes of wastewater **[36]**. Among the most important protozoa from a health point of view, mention should be made of Entameoba histolytica, responsible for amoebic dysentery and giardia lamblia **[36]**.

I.2.3.3.3. Bacteria:

Bacteria are single-celled organisms without a nucleus. Their size is between **0.1** and **10 µm**. The average amount of bacteria in faeces is about $\mathbf{10^{12}}$ bacteria/g **[37].** Urban wastewater contains approximately $\mathbf{10^{6}}$ to $\mathbf{10^{7}}$

Bacteria/100 ml including $\mathbf{10^{5}}$proteus and enterobacteria, $\mathbf{10^{3}}$ to $\mathbf{10^{4}}$ streptococci and $\mathbf{10^{2}}$ to $\mathbf{10^{3}}$ clostridium **[37].**

I.2.3.3.4. Helminths:

Helminths are multicellular worms. Lake protozoa, they are mostly parasitic organisms. The concentration of helminth eggs in the wastewater is around **10** to $\mathbf{10^{3}}$ **eggs/l**. It is worth mentioning, in particular, Ascaris Lumbricades, Oxyuris vermicularis, Trichuris trichuria, Taenia saginata **[37].**

Table (I.4): pathogen found in wastewater **[17].**

Organisms	Pathogen	Associated disease
Bacteria	*Salmonella typhi*	Typhoid fever
	Shigella spp	Shigellosis (bacillary dysentery)
	Vibrio cholera	Cholera
	Campilobacter jejuni	Gastroenteritis
	Pathogenic *Escherichia coli*	Gastroenteritis
	Enterobacter aerogenes	Gastroenteritis
Viruses	Polioviruses	Poliomyelitis
	Picornaviruses (animal viruses)	Paralysis, common cold, myocarditis
	Hepatitis A virus	Infectious hepatitis
	Hepatitis E virus	Hepatitis
	Rotaviruses	Gastroenteritis
	Noroviruses	Gastroenteritis
Protozoa	*Entamoeba histolytica*	Amoebiasis (Amoebic dysentery)
	Giardia intestinalis	Giardiasis (diarrhea)
	Cryptosporidium parvum	Cryptosporidiasis (diarrhea)
Helminths	*Ascaris lumbricoides* (N)	Ascariasis (roundworm infection)
	Taenia spp. (C)	Taeniasis
	Trichuris trichiura (N)	Trichuriasis
	Schistosoma spp. (T)	Schistosomiasis (bilharziasis)

N: Nematodes; C: Cestodes; T: Trematodes.

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Chapter II :

Wastewater treatment processes

Chapter summary:

In this chapter, we have dealt with the issue of wastewater treatment and methods of treatment.

Introduction:

Wastewater treatment includes a group of natural and chemical processes

Which waste water is removed solids and organic matter and micro-organisms or Reduced to an acceptable level, this may include the removal of some. The high concentration nutrients such as phosphorus and nitrogen in this water can be divided into operation according to the degree of processing into preliminary, primary, secondary and advanced operations, and the purification process comes to the judiciary on the micro-organisms at the end of processing steps **[1].**

In this chapter, I will discuss the methods and stages wastewater treatment.

II.1. Wastewater treatment steps:

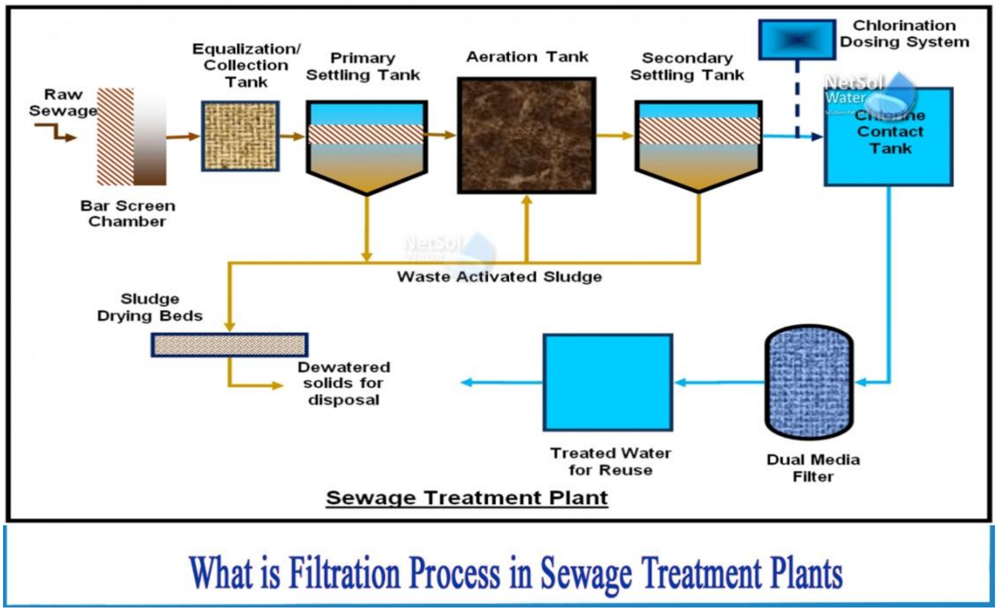

Fig (II. 1): Wastewater treatment steps **[2].**

The stages of water treatment are divided into:

II.1.1. Pretreatment:

The purpose of pre-processing is to separate the coarsest materials and the elements likely to interfere with subsequent processing steps. It includes screening to retain bulky waste, desilting to obtain better settling, degreasing and de-oiling to prevent clogging of the station by fatty substances **[3].**

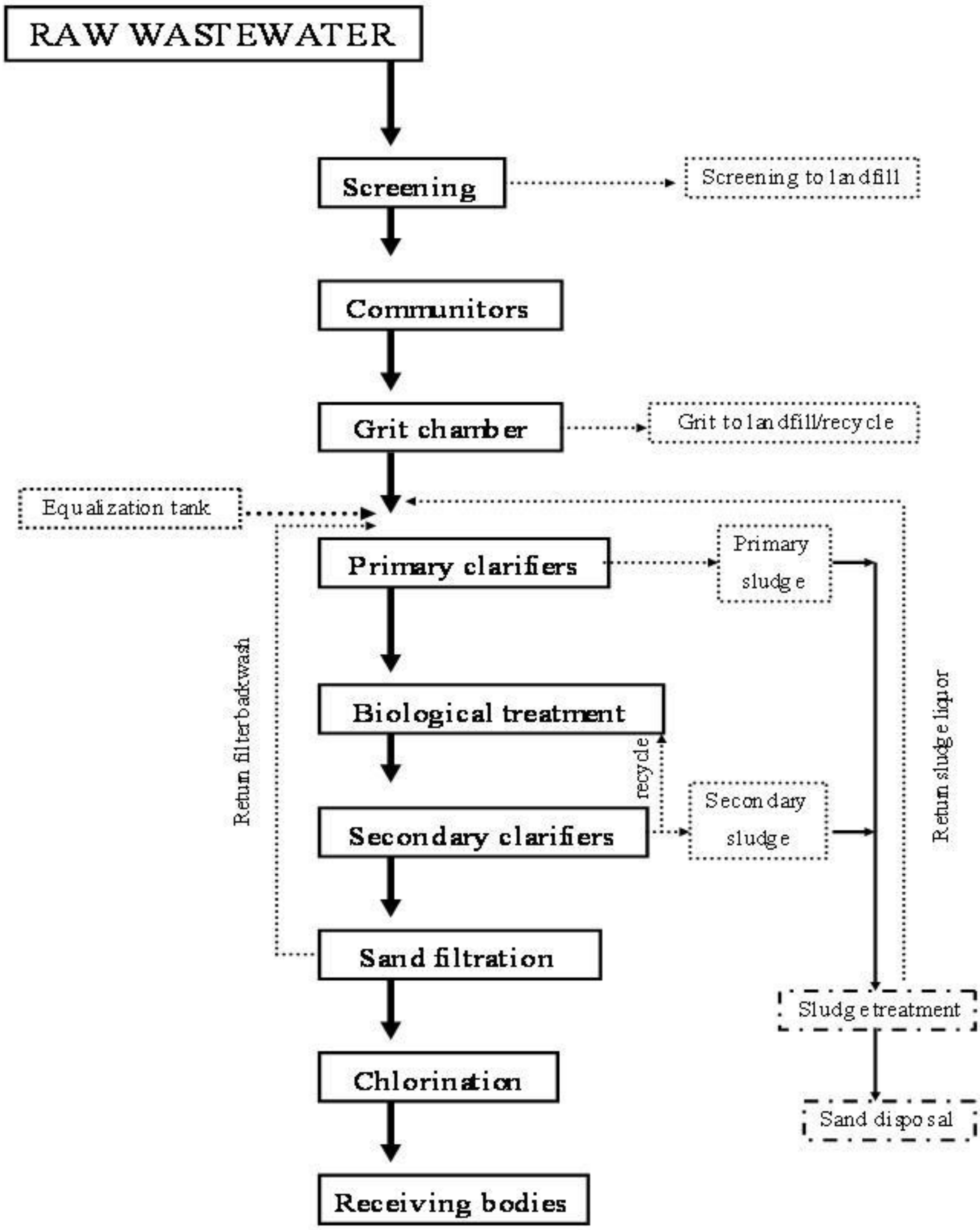

Fig (II. 2): Diagram of a preliminary treatment of a **WWTP** **[2].**

II.1.1.1. Screening:

This operation consists of passing the effluent between the bars of a grid, from which water the fragments larger than the spacing of the grid, the screening makes it possible to protect downstream structures against the arrival of large objects likely to cause blockages in the various units of the installation. It also makes the following treatments because they are not hindered by these coarse materials. Screening is classified into **03** categories according to the spacing between bars of the grid **[5]:**

- Pre-screening, for a spacing **e = 30-100 mm**
- The average screening for a gap of **e =10 to 30 mm**
- Fine screening for a gap of less than **10 mm** **[4]**

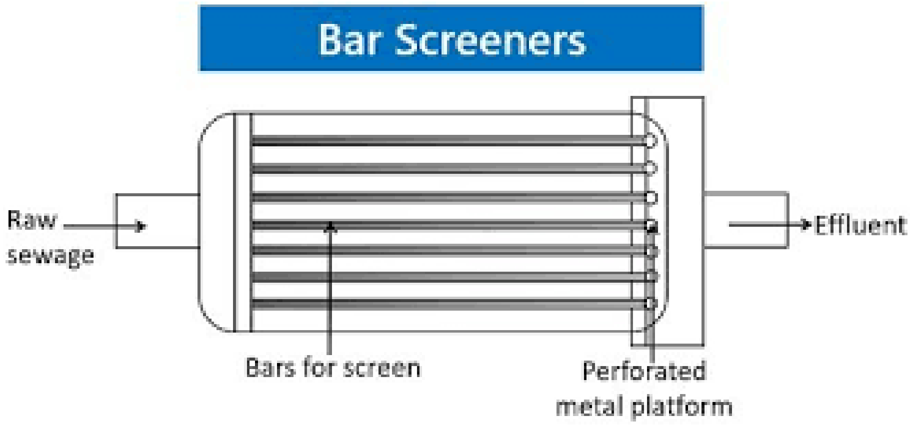

Fig (II.3): Diagram of a bar screen **[5].**

II.1.1.2. Desanding:

Desanding consists of removing sand and more or less fine mineral particles from the effluent, in order to protect the pipes and pumps against corrosion and even avoid the clogging of the pipes by deposits in the treatment yard, the technique the classic grit trap consists of circulating the water in a stilling chamber at a speed of approximately **0.3m /s** which allows the deposit of a large part of the sand **[6].** According to the principle of operation, there are two types of grit basin: Longitudinal grit traps and circular grit traps **[7].**

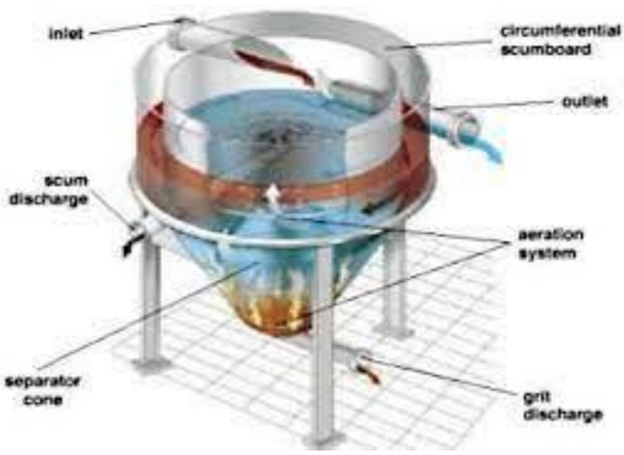

Fig (II. 4): Photo of a grit trap **[8].**

II.1.1.3. De-oiling and degreasing:

The purpose of degreasing is to eliminate the presence of grease in the wastewater, which can interfere with the effectiveness of the biological treatment that takes place afterwards. Degreasing is carried out by flotation. The injection of air at the bottom of the work allows the rise to the surface of fatty substances. The fats are scraped off the surface and then stored before being eliminated **[9].**

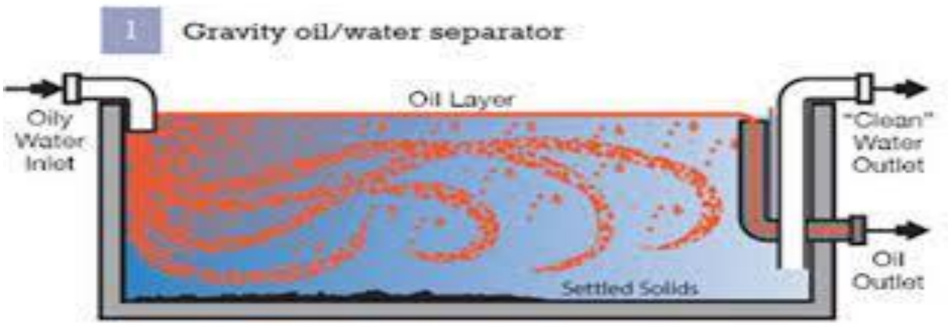

Fig (II. 5): Photo of an oil separator used in wastewater treatment **[8].**

II.1 .2. Primary treatment:

It is most often a decantation which makes it possible to lighten the biological treatments or subsequent chemicals, removing some of the suspended solids. The effectiveness of the treatment depends on the residence time and the rate of rise (which opposes settling). Primary settling eliminates, for an upward speed of **1.2m/h**, **40** to **60%** of suspended solids **(SS)**, and either **10** to **30%** of viruses, **50** to **90%** of helminthes and less than **50%** of protozoan cysts **[10].**

By using physical or physico-chemical processes aimed at the through settling of suspended solids in the water. We distinguish:

❖ *Physical settling (natural):*

Suspended matter, which often has a high organic matter content (**70** to **90%**) and a density slightly greater than that of water, will settle naturally in a primary settling tank in **1** to **2** hours. The water thus clarified will flow by overflow and the suspended solids which have settled at the bottom of the basin (primary sludge) will be extracted and sent to the sludge treatment works **[11]**.

❖ *Physicochemical settling:*

Settling performance can thus be improved by adding chemicals (alumna sulphate, ferric chloride, etc.) which neutralize the charged particles, thereby
Increasing the probability of collision between the particles (coagulation flocculation), as well as that the formation of flocks subsequently easily decantable. This step removes **90%** of the colloidal matter **[12].**

II.1.3. Secondary treatment (Biological treatment):

Biological treatment of wastewater is the process that allows the degradation of pollutants through the action of micro-organisms **[13].**

The different biological wastewater treatment processes are:

II.1.3.1. Intensive biological processes:

a) Biological discs:

Biological discs or bio discs are discs strung parallel on a rotating horizontal axis. These discs plunge into a trough, where the water to be purified after having undergone decantation circulates. During a part of their rotation they take care of substrate then they emerge in the air the rest of the time (to absorb oxygen). The discs are covered with a biofilm on both sides. They have a diameter of **1** to **3 m**, are spaced **20 mm** apart and rotate at a speed of **1** to **2 rpm.** Excess sludge detaches from the disk and is recovered in a secondary clarifier before discharge into the natural environment **(Figure I. 6)** **[13].**

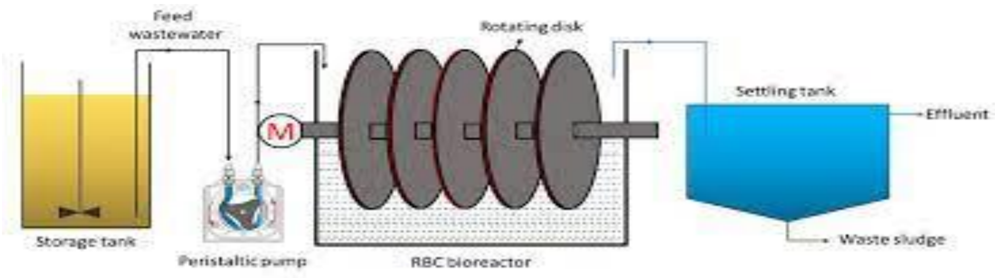

Fig (II. 6): Biological discs.

b) Biological filters (Bacterial beds):

The principle of operation of a bacterial bed consist in making the waste stream, previously decanted, flow over a mass of porous or cavernous materials which support the purifying micro-organisms (bacteria). Ventilation is practiced either by natural draft or by forced ventilation. Provide the oxygen needed to keep aerobic bacteria functioning properly **fig** (**II. 7**) **[14].**

Fig (II. 7): bacterial beds.

c) Activated sludge:

Under ideal aeration conditions, the micro-organisms in wastewater develop and agglomerate in flocs. At rest, the latter separate very well from the liquid phase by decantation. The principle of the activated sludge process therefore consists in causing the development of a bacterial floc in a basin supplied with wastewater to be treated (aeration basin) in order to avoid the settling of the flocs in this basin, vigorous mixing is necessary. The proliferation of micro-organisms also requires sufficient oxygenation **Fig (II. 8) [15].**

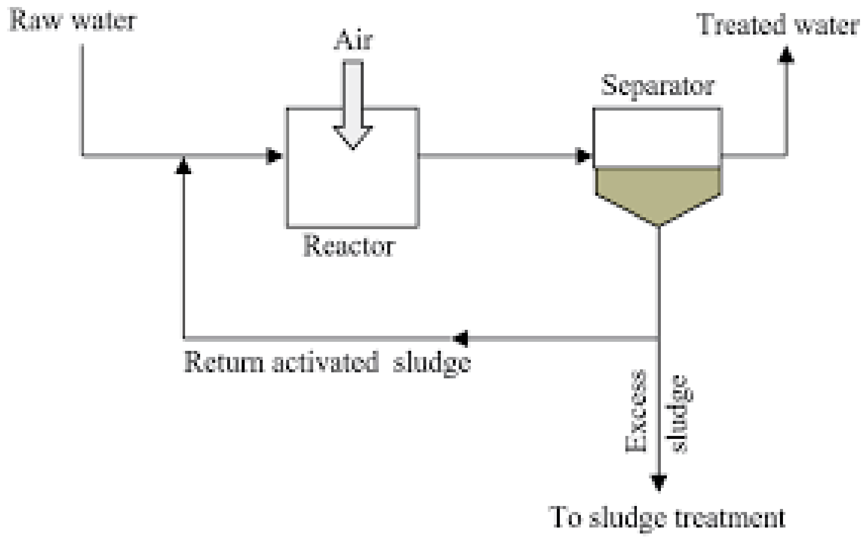

Fig (II. 8): Activated sludge.

II.1.3.2. Extensive biological processes:

They are based on the phenomena of natural self-purification and they require low energy but, on the other hand, require large surfaces and long stays of wastewater. From an economic point of view, they are less expensive. These are lagooning, spreading, etc **[16].**

II.1.3.2.1. Lagooning:

Lagooning is a biological purification system based on the balanced presence of aerobic bacteria in algae. The oxygen necessary for bacterial respiration is produced solely by the photosynthetic mechanisms of plants in the presence of light radiation **[16].**

a. Natural lagoon

Purification is ensured thanks to a long residence time in several sealed basins arranged in series. The number of pools most commonly encountered is three **(03).** The basic mechanism on which natural lagooning is based is photosynthesis. The top water slice of basins is exposed to light; this allows the existence of algae which produce the oxygen necessary for the development of aerobic bacteria. These bacteria are responsible for the degradable of organic matter. The carbon dioxide formed by the bacteria as well as the mineral salts in the wastewater allow the algae to multiply, at the bottom of the basin where the light does not penetrate; are anaerobic bacteria that degrade sediments resulting from the settling of organic matter **Fig (II. 9)** **[17].**

Fig (II. 9): Natural lagoon.

b. Aerated lagoon:

It is one or more basins **2** to **4** meters deep, in which the supply oxygen is provided by an artificial system (surface aerators, air diffusers) **[17].** This mode of purification makes it possible to eliminate **80%** to **90%** of the **BOD**, **20%** To **30%** of the nitrogen and contributes to a very significant reduction of germs. However, it has the disadvantage of using large areas and not offering constant yields throughout the year **(Figure I. 10)** **[18].**

Fig (II. 10): Aerated lagoon

II.1.3.2.2. Phytotreatment ponds:

Plant treatment ponds or what is known as artificial wet areas. The ponds are designed similar to what they are in nature. The ponds are filled with a layer of gravel, followed by a layer of fine sand. These two layers are considered a support for the cultivated plants. After the polluted water is subjected to primary treatment, it passes into the plant ponds vertically, horizontally, or both **[19].**

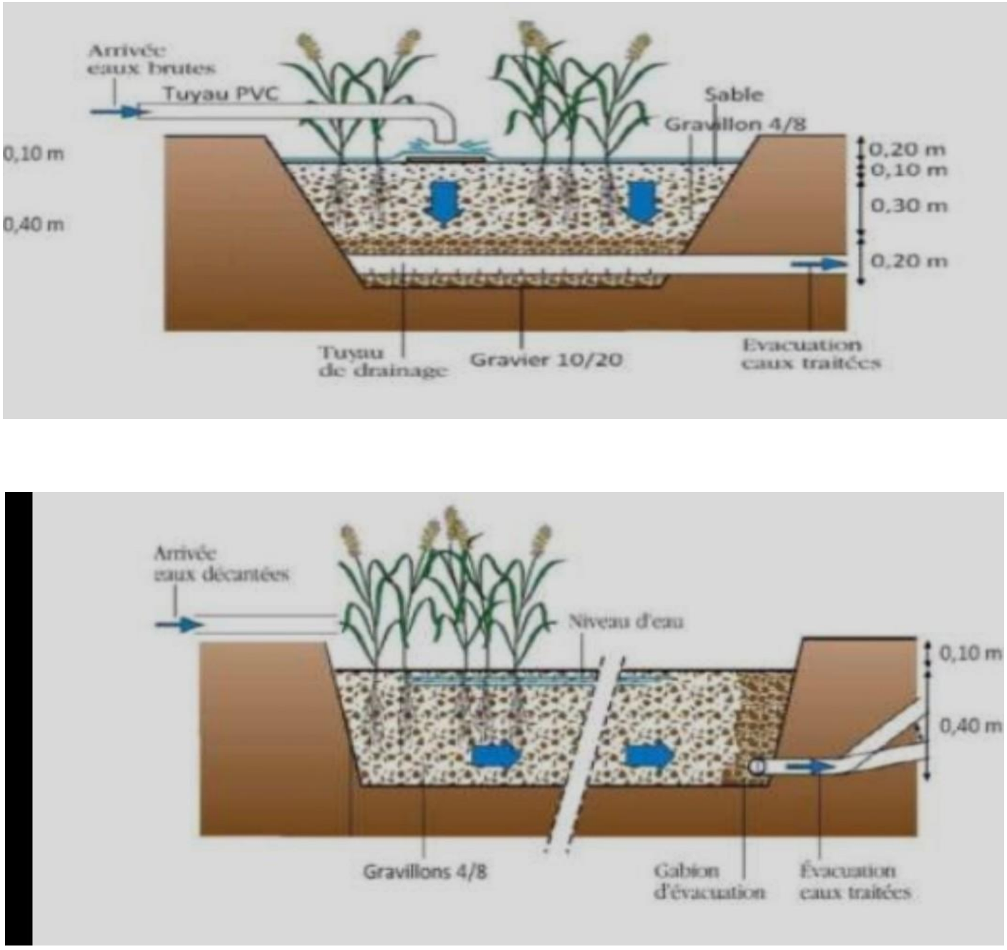

Fig (II. 11): Scheme of Phytotreatment ponds, both horizontal and vertical **[19].**

II. 1. 4. Secondary settling:

The clarifier is a circular basin, equipped with a scraper point. The mixed liquor, coming from the biological basins via the second distribution chamber, is separated into purified water and biological sludge by settling. The settled sludge is siphoned off by a vacuum pump, part of which will be conveyed to the first chamber of the distributer ensuring the recirculation of the sludge containing the purifying bacterial. In order to maintain the necessary biomass concentration in this basin, the other part will be transmitted to the float **(Figure II. 12)** **[20].**

Fig (II. 12): Secondary settling.

II. 1. 5. Tertiary treatment:

Some treated water discharges are subject to specific regulations concerning the elimination of nitrogen, phosphorus or pathogenic germs, which require the implementation of tertiary treatments **[20].** It includes all the physical and chemical operations that complete the primary and secondary treatments.

a- Nitrogen removal:

Wastewater treatment plants only eliminate about **20%** of the nitrogen
Present in the wastewater, through nitrification-denitrification treatments **[21].** Nitrogen removal usually occurs through two-part biological process milestones **[22]:**

- ***Nitrification:*** is one of the steps in the treatment of wastewater

Which aims to transformation of ammonium $(\mathbf{NH_4^+})$ into nitrate $(\mathbf{NO_3^-})$.This transformation is carried out by bacteria, in an aerobic environment.

- ***Denitrification:*** is an anaerobic process by which nitrates

are reduced to nitrogen and nitrogen oxides. The micro-organisms use nitrates as an oxidizing source instead of oxygen and in the presence of a source of organic carbon which must be brought into the medium.

b-The elimination of phosphorus:

The elimination of phosphorus or "Dephosphatation", can be carried out by physic-chemical or biological means. With regard to the physico-chemical treatment, the addition of reagents, such as iron or aluminum salts, makes it possible to obtain a precipitation of insoluble phosphates and their elimination by decantation. These techniques, the most used currently, eliminate between **80%** and **90%** of the phosphorus, but generate a significant production of sludge **[23].**

c-Elimination and treatment of odors:

Wastewater, loaded with particulate and dissolved organic matter, can Induce directly or indirectly, through its purification by-products (grease, sludge), the formation of unpleasant odors following a fermentation process. Odors from **WWTPs** are due to gases, aerosols or vapors emitted by certain products contained in the wastewater or in the compounds formed during the various treatment phases.

The most important sources of odors are:

- ✓ Pretreatments.
- ✓ Sludge and its treatment.

To avoid these nuisances, sensitive structures will be covered and equipped with a ventilation system and a biological odor treatment unit. There are generally two types of biological odor treatment: bio-filters and bio-scrubbers. In the former, the biomass is supported by a specific floor and the air passes through the massif (often peat). The latter make a second filter using a suspension. The biomass is free, and the purification occurs in a reactor **[14].**

II. 2. Sludge:

Introduction:

The sludge is mainly made up of solid particles not retained by the pre-treatment upstream of the treatment plant, underrated organic matter, suspended mineral matter and micro-organisms (mainly degrading bacteria). They come in the form of a "thick soup" which then undergoes treatments aimed in particular at reducing their water content **[24].**

II.2.1. Types of WWTP sludge:

The sludge from the treatment plant is classified into four major groups **[16].**

II.2.1.1. Primary sludge:

They come from the primary treatment and are produced by simple decantation, at the head of the treatment plant. This sludge is fresh, i.e. unstabilized (high organic matter content) and highly fermentable **[25].**

II.2.1.2. Secondary sludge:

This sludge is biologically stabilized resulting from biological treatment through the purifying properties of the micro-organisms therefore the mineral matter and the refractory organic matter are accumulated while the biodegradable organic matter serves as a substrate for the purifying micro-organisms. These micro-organisms, mainly bacteria, use biodegradable pollution for their maintenance and for their growth. The products formed are cells, carbon dioxide and water **[25, 26].**

II.2.1.3. Mixed sludge:

The mixing of primary and secondary sludge leads to the production of mixed sludge. Their composition is dependent on the amount of primary and secondary sludge produced. Highly fermentable, this sludge then undergoes stabilization treatment **[25].**

II.2.1.4. Physico-chemical sludge:

This sludge comes from a treatment using mineral flocculants (iron salt or aluminum). Physico-chemical treatment is mainly used on industrial sludge or to compensate for the under sizing of certain stations treatment plants (stations located in tourist areas, for example) **[26].**

II.3. Recovery of treated water and sludge from the WWTP:

II.3.1. Valorization of treated water:

The reuse of wastewater is widespread through the world with several types of recovery **[27].** Five categories can be distinguished:

1- ***Reuse for irrigation:*** fodder crops or market gardening, cereals, meadows…. etc.
2- ***Industrial reuse:*** cooling circuit, cleaning, paper mills, textile industries……etc.
3- ***Reuse in urban areas:*** firefighting, street washing, recycling of wastewater from a building, watering of parks, golf courses, cemeteries…. etc.
4- ***Drinking water production;***
5- ***Groundwater recharges*** **[28].**

In Algeria, the majority of treated wastewater is discharged either far from irrigation schemes and dams or at sea, which makes its reuse in unprofitable irrigation, only **240 million m^3** are potentially usable for irrigation due to the location of the discharge points **[29].**

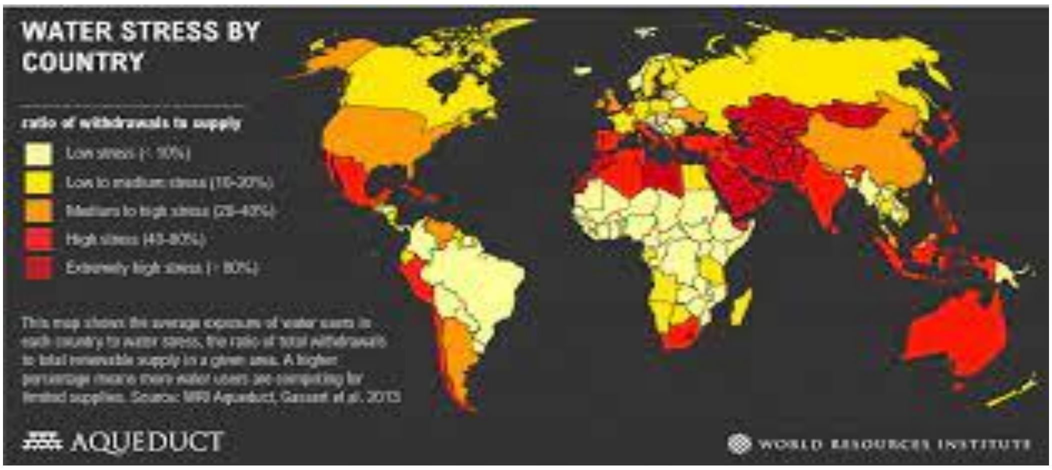

Figure (II. 13): Aspects of **WW** reuse in different regions of the world **[30].**

II.4: Sludge recovery:

The agricultural recovery of residual sludge can be considered as the most suitable mode of recycling to rebalance the biogeochemical cycles, for the protection of the environment and of great economic interest. It aims to conserve natural resources and avoid any waste of organic matter due to incineration or burial in landfills. Residual sludge can thus replace or reduce the excessive use of expensive fertilizers **[30].**

II. 5. Wastewater in the agricultural sector:

II. 5. 1. The importance of treated wastewater:

Wastewater and other poor quality water are important in the context of comprehensive water resources management by freeing up freshwater resources for local supply and other priority uses, reuse contributes to water and energy conservation and improved quality of life. Wastewater can have positive agricultural results. When it is properly planned and controlled along with increasing agricultural yields. However, wastewater reuse can have adverse effects on the environment and public health **[31].**

II. 5. 2. Condition for using treated wastewater in irrigation:

- Treated wastewater to be used for irrigation must comply with standard specifications.
- An analysis of the physical and chemical properties and heavy metals of the soil must be conducted on farms that benefit from treated wastewater in the laboratories of the Ministry of Agriculture or one of its accredited laboratories to monitor and evaluate the effects of using this water on the soil.

- It is prohibited to connect or connect treated wastewater pipes to news network pipes inside farms.
- Use a distinctive color or strips to separate treated wastewater pipes from other pipes.
- Every irrigation system that uses treated wastewater must have warning signs installed in clear places reading "**Warning: Treated wastewater for irrigation only**" **[31].**

Table (II. 1): Some Arab countries use the largest amounts of treated wastewater **[31].**

Country	Quantity of wastewater	Percentage of withdrawn water	Percentage of total water
Egypt	200	16.7	0.36
Kuwait	52	4.3	9.67
Saudi Arabia	217	18.1	1.28
Syria	370	30.8	257
United Emirates	108	9	5.12

Table (II. 2): List of crops that can be irrigation with purified wastewater (Extract from Official Journal No. **41** of Executive Decree No. **07-149**, published in January **2012**).

Crop group that can be irrigation with treated wastewater	List of crops
Fruit trees (*)	Date trees, vine, apple, peach, pear, apricot, meddler, cherry, plum, nectarine, pomegranate, fig, rhubarb, peanuts, walnuts, olive.
Citrus	Grapefruit, lemon, orange, mandarin, tangerine, lime, clementine.
Fodder crops (**)	Bersim, corn, forage sorghum, vetch and alfalfa.
Industrial cultures	Industrial tomato, stalk bean, stalk pea, sugar beet, cotton, tobacco, flax.
Cereal crops	Wheat, barley, triticale and oats.

Crops seeds production	Potato, beans and peas.
Fodder shrubs	Acacia and triplex.
Floral plants to dry or for industrial use	Rose bush, iris, jasmine, marjoram and rosemary.

(*) Irrigation with purified wastewater is permitted provided that irrigation is stopped at least two **(2)** weeks before harvest. Fruits that have fallen to the ground are not picked up and must be destroyed.

(**) Direct grazing in plots irrigated by treated wastewater is strictly prohibited in order to prevent any contamination of livestock and therefore consumers.

Table (II. 3): List of crops that can be irrigation with purified wastewater **[32].**

Designation	Capacity (Pop./Eq)	Nominal flow (m^3/d)	Purified monthly volume (m^3)	Monthly volume reused (m^3)	Agricultural Estate (ha)	Crop type
Boumerdès activated sludge treatment plant	75000	15000	484480	62282.4	Flici: 49	Olive tree nursery, Orange Tree and Vines Nursery
				62282.4	Rahmoun:76	
Ouargla aerated lagoon station	260102	56997	991950	99195	16.5	4000 date palms and 100 olive trees
Kouinine aerated lagoon station (El-Oued)	239134	44335	567600	33600	15	Trees (Eucalyptus and Kazarina)
Tlemcen activated sludge treatment plant	150000	30000	510300	484785	Hennaya Plain 912.22	Arboriculture
Guelma activated sludge treatment plant	200000	32000	550560	550560	Guelma, Boumahra and Bouchegouf 6980	Market gardening and orchards
Bordj Bou Arreridj activated sludge treatment plant	150000	30000	324720	324720	Dhaissa 150	Cereals
Souk Ahras activated sludge treatment plant	150000	30000	182460	182460	200	Arboriculture
Ghriss aerated lagoon station	48000	5800	34950	34950	420	Olive trees

Bouhanifia aerated lagoon station	32500	3900	WWTP stopped		475	
Hacine aerated lagoon station	20000	3200	24630	24630	390	

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Chapter III: Materials and methods

Chapter's summary

In this chapter, we discussed the definition of the station and the materials and methods used in this work

III. 1. Presentation of region and WWTP of Ouargla:

III. 1. 1. Geographical location:

The wilaya of Ouargla is located in the Southern-East of the area of **163,323km²**. The wilaya is made up of **21** municipalities grouped into daïras. The province of Ouargla is located between the wilaya of Toughourt and the wilaya of Ghardaïa, it plays a role of balance very important economy, given its hydrocarbon potential, the city of Ouargla belong to the eponymous province, it is located between **31° 57'**of the north altitude and **5°-19"**of west altitude, between **103** and **150 m** above the level of the Mediterranean Sea. The wilaya of Ouargla is one of the main Oases of the Algerian Sahara, it is located approximately **800** km from the capital Algiers, is limited by:

- Toughourt, El M'Ghair, Ouled Djellal: In the North.
- Illizi and In Salah: In the South.
- Ghardaïa, El Meniaa, La-ghouat: To the West.
- Tunisia and El Oued: To the East.

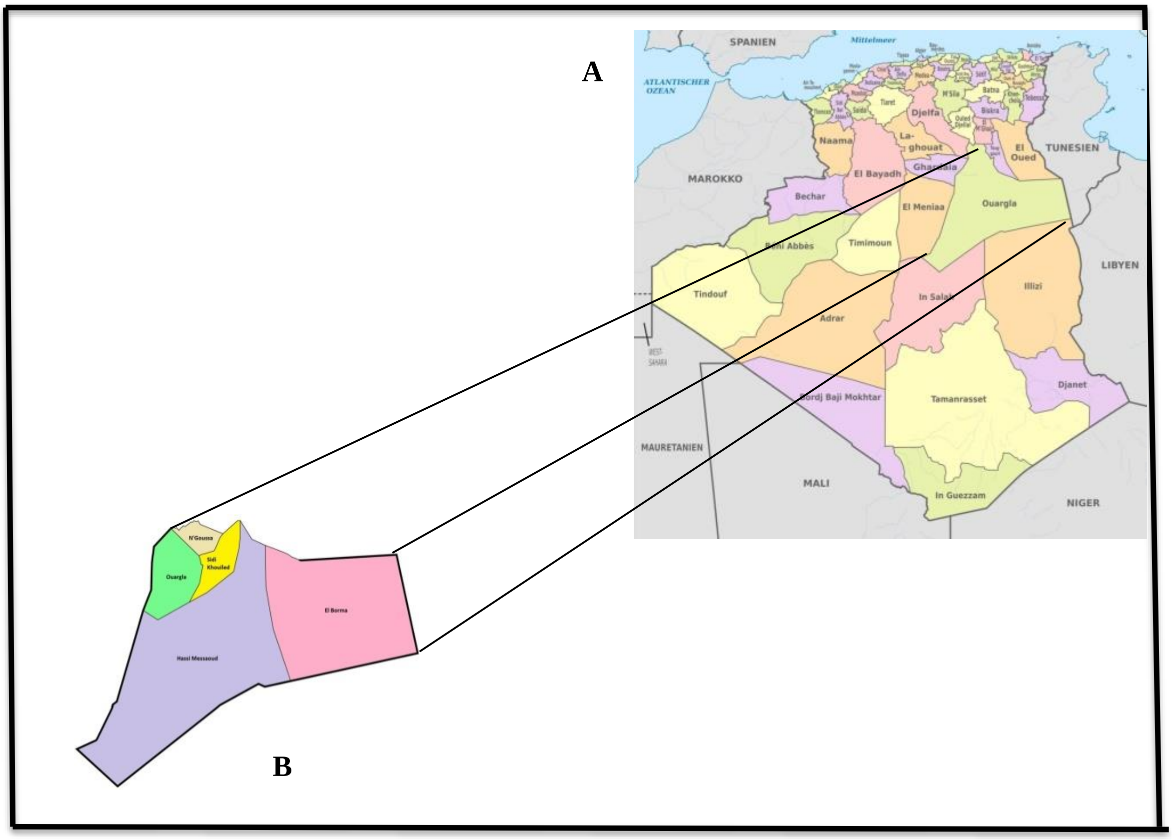

Fig (III. 1): Geographical map of Ouargla.

III.1.2. Presentation of the WWTP of Ouargla (Saïd-Otba):

The wastewater treatment plant is located in the **Saïd – Otba** district north of the city of Ouargla. This station, with a capacity of around **382391** populations equivalent until **2023** and put into service in **2009**, it was carried out by the German company dwydag on behalf of the **NSO** the construction of this station was part of the major Sanitation and control project against the remotisation of the water table, launched in the basin of Ouargla **(Figure III. 2) [1].**

III.1.2.1. Technical characteristics:

- ✓ Purification process: Aerated lagoon.
- ✓ Purification capacity: Sebkhet sefioune.
- ✓ Nature of treatment: Domestic.
- ✓ Residence time: **12** days.

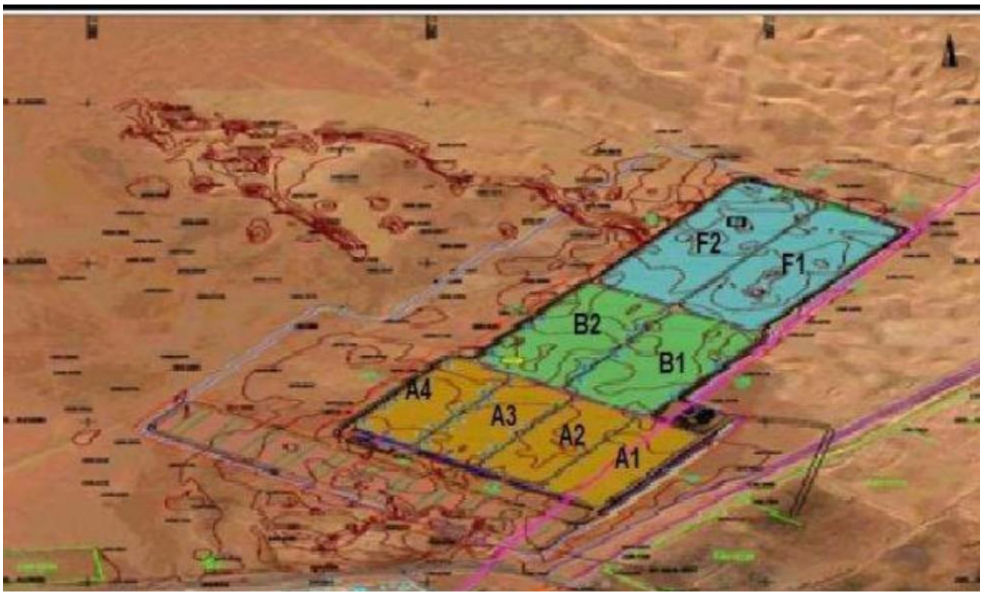

Fig (III. 2): Location of the Ouargla water filtration plant area.

This region is characterized by a very hot climate (desert climate) with little rainfall, high temperatures, and high evaporation. This is what the following table shows:

Table (III. 1): Average climate data for the period **2019** for the Ouargla region.

Month	Temperature (℃)	Humidity (%)	Rain (mm)	Wind (km/h)
Jan	10.8	40.8	00	10.3
Fab	12	37.8	00	13.8
Mar	16.9	33.5	4.07	14.4
April	23.2	25.9	13.97	14.9
May	26.7	25	3.81	16.1
June	35.3	13.9	00	17.5
July	37.4	13.8	00	13
August	36.9	17.8	00	13.3
September	31.8	27.5	1.53	12.8
October	24.2	35.8	2.03	10.4
November	16.2	37.3	00	11
December	13.8	46.7	00	10.3

(N.M.O. OUARGLA, 2019)

III. 1. 2. 1. 1. Temperature:

This region is characterized by a very cold winter, where the temperature reaches **10.8 °C** in January, while in summer the temperature reaches **37.4 °C** recorded in July.

III.1.2.1.2. Humidity:

The air in Ouargla is very dry. The area is characterized by humidity, with a maximum humidity of **7.46 %** in December and a minimum of **13.8 %** in July due to intense evaporation and hot winds in this month.

III.1.2.1.3. Rain:

We notice from the table that the highest rainfall occurred in April reaching **13.64 mm;** the lowest value was in September at **1.53 mm**.

III.1.2.1.4. Wind:

Winds are frequent in the region, blowing throughout the year in different directions depending on the season.

III. 2. Steps of measuring water level and sampling:

a. Measure the volume of water raw and treated:

In order to measure the amount of water raw, this device is placed on a channel that diverts the water to the actual level and is placed after the sand drain in a longitudinal manner. To measure the volume of water leaving the station, it is placed in the basin in which the treated water collects and is also placed longitudinally.

b. Take samples:

Take samples from the watercourse is an important and essential process for achieving correct analytical results, so any change in the physical or chemical properties of the water is avoided when the sample is taken. It is preferable to use glass or plastic bottles, tightly closed. The bottle is cleaned before use with a concentrated solution of potassium permanganate, then with sulfuric acid, then washed with plain water three times, then with distilled water **[1].**

III. 3. Treatment by aerated lagoon method:

III. 3 .1. Definition of aerated lake treatment:

It is one of the methods used in treating wastewater, which relies as a basic principle on the slow flow and flow of water. Treatment in these lakes is done in a natural way that depends on an integrated joint activity carried out by algae and bacteria in the presence of sunlight and some elements present in the wastewater. In which the biodegradable charge of the effluent is destroyed by bacteria and at least part of this treatment is carried out aerobically thanks to the contribution of dissolved oxygen in the water by aeration, there is no circulation of bacteria **[2].**

III. 3. 2. Types of lagoons :

a. Aerated lagoon:

In the aeration step, the water to be treated is in the presence of microorganisms consuming nutrients formed by the pollution to be eliminated, these microorganisms are mainly bacteria and fungi (similar to those found in activated sludge plants), and requires artificial aeration that ensures the oxygenation of wastewater, and this is to ensure the biochemical oxidation of organic matter. The breakdown of all organic, protein, fat or carbohydrate substances is the result of the evolution of microorganisms.

The aerobic purification process is a process of three basic steps (adsorption, absorption, oxidation) and the products of this oxidation are CO_2, H_2O.

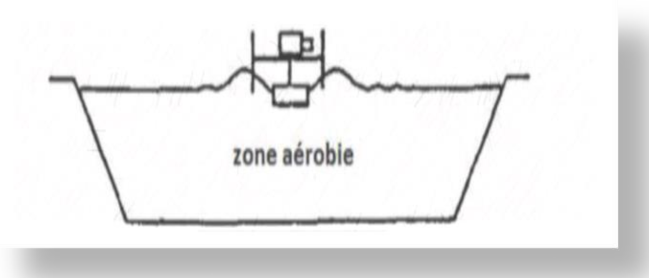

Fig (III. 3) : Aerated lagoon

b. *Optional lagoon (Anaerobic lagoon) :*

In this type of pond, oxygen is maintained in the upper part only, in addition to that most of the suspended inert materials and non- oxidizing biological materials settle at the bottom of the pond to be decomposed anaerobically. The sink can be modified to include a separate settling chamber that has the ability to provide clear wastewater.

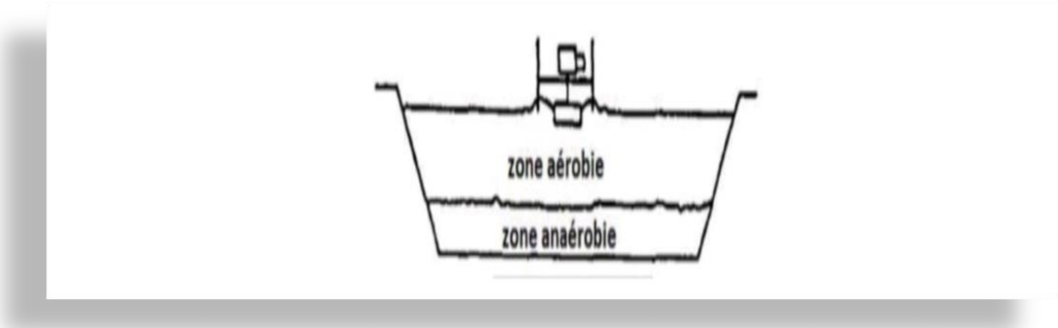

Fig (III. 4): Optional lagoon

III. 4. Steps of wastewater treatment in the WWTP:

The purification of the effluents generated by the agglomeration of Ouargla consists of treating all the wastewater in the aerated lagoon type treatment plant. The treatment chain consists of:

a. Degassing of raw wastewater:

This step consists of degassing the wastewater arriving at the treatment plant in a basin called the basin **(Figure III.5).**

Fig (III. 5): Wastewater inlet to the station (degassing basin).

b. *Pretreatment:*

Preprocessing includes the following elements:

b.1. Screening:

The wastewater passes through two automatic screens and a manual screen arranged in parallel to retain the largest materials **(Figure III. 6).**

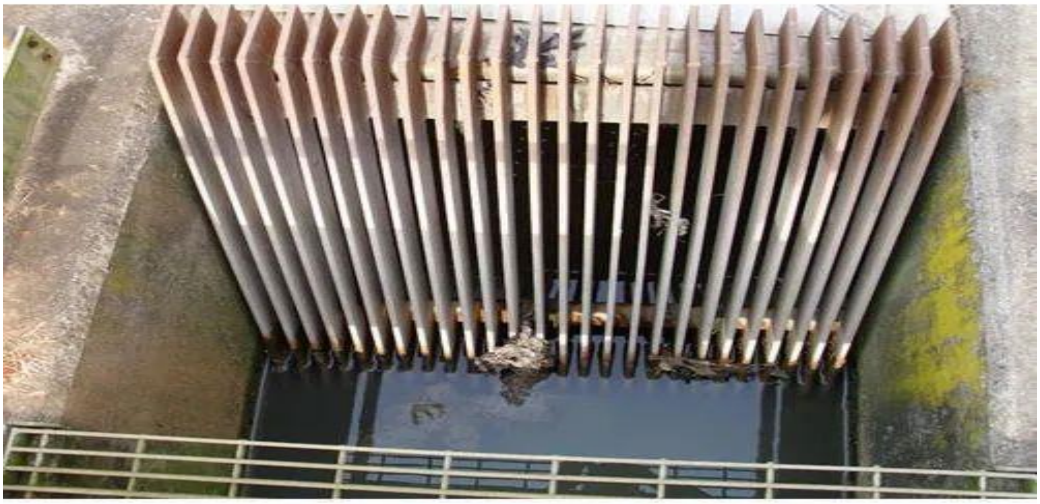

Fig (III. 6): Screen in the Ouargla station.

b .2. Desanding:

Desanding allows by decantation to remove the sands contained in the wastewater, it is carried out in **3** rectangular channels arranged in parallel and in which a decantation of the sands is produced. The sands are decanted and concentrated at the bottom of the work then scraped using an automatic scraper programmed towards a sand pit; a pump ensures the extraction of the sands towards a sand classifier. This classifier is a separator in which the sand particles sediment and are extracted from the bottom by an Archimedean screw, while the water is recovered in the upper part after crossing a siphoïd partition. The extracted sands are then stored in a skip. The station currently does not have a de-oiling system **(Figure III. 7)** **[3].**

Fig (III. 7): Desanding in the Ouargla station.

b.3. Distribution structure:

Arranged at the head of the station downstream of the pre-treatment works, it distributes the wastewater to the lagoons of the first floor (**A1**, **A2**, **A3**, and **A4**). This distribution is ensured by six identical weirs, 1.50m wide, equipped with cofferdams to be able to put any lagoon if necessary.

Fig (III. 8): Distributor to the aeration basin.

c. Biological treatment by aerated lagoon:

Following these pre-treatments, the treated water undergoes treatment by the system of aerated lagoon. This stage consists of two aeration stages and a finishing stage.

Table (III. 2): Gathers the characteristics of the lagoons.

Characteristic	First floor	Second floor	Third floor
Basin surface (Ha)	2.4	4.1	4.9
Basin number	4	2	2
Basin volume	85200	113600	47024
Water height	3.5	2.8	1.5
Residence time(day)	5	3	2

c.1. Aeration lagoons:

Ensure the degradation of organic matter thanks to a supply of oxygen provided by the surface aerators which operate at the rate of **13 h/d**.

This artificial ventilation promotes the development of micro-organisms which degrade organic matter by assimilating nutrients **(Figure III. 7) [3].**

c.2.The finishing lagoon:

Ensure the separation of the purified water and sludge phases and an improvement in purification yields **[4].**

Fig (III. 9): Aeration lagoon in the Ouargla station.

The water treated at the **WWTP** and the drainage water is transported [separately towards Sebkhet Sefioune (it is **42** km away from Säid Otba) for later reuse in irrigation] **(Figure III. 8).**

Fig (III. 10): Channels for transporting wastewater **(left)** and water drainage **(right)** in the Ouargla station **[5].**

III.5. Analyzing the results:

Introduction:

At the National Office for Disinfection in Ouargla. They conducted espionage activities containing various examinations would be entrance and exit:

PH, dissolved oxygen ($\mathbf{O_2}$), temperature (**T**), electrical conductivity (**EC**), salinity, chemical demand for oxygen (**COD**), biochemical demand for oxygen **($\mathbf{BOD_5}$)**, suspended solid (**SS**), nitrite ($\mathbf{NO_2^-}$), nitrate ($\mathbf{NO_3^-}$), orthophosphorus ($\mathbf{PO_4^{3-}}$), total nitrogen (**TN**), total phosphorus (**TP**), ammonium ($\mathbf{NH_4^+}$).

III.5.1. Analyzing the results:

Determining the quality of urban water discharged in Sebkhet Sefioune (Ouargla) and with the aim of clarifying the role of protecting the natural environment, while monitoring the physico-chemical properties and comparing the results obtained in the wastewater treatment plant in the city Ouargla with (**AS**) and (**WHO**).

III.5.2. Purification yield:

We determined the purification efficiency of the measured media by the '

$$R\% = ((X_i - X_f)/X_i) \times 100$$

R: Purification yield (%).

X_i: Concentration of the media presents in the wastewater entering the basin (**mg/l**).

X_f: Concentration of the media presents in the wastewater coming out of the basin (**mg/l**).

III.6. Measured physico-chemical parameters:

Introduction:

In order to determine the quality of the water entering and leaving the station, a series of measurements were conduction for a set of water pollution parameters. Sample were taken from the station's inlet and outlet, and then analyzed in the parameters identified included **pH**, temperature**(T)**, Electrical conductivity **(EC)**, total, suspended solid **(SS)** ……etc.

These analyses also allowed us to monitor the proper functioning of the process at this station.

III.6.1 Materials and analysis methods:

III.6.1.1. pH:

Hydrogen potential is measured using a **pH meter** of type **(EUTECH INSTRUMENT 510)**

- ***Working method***:
  - Adjust and turn on the device.
  - Rinse the electrode with distilled water and wipe it.
  - Take **100 ml** of the sample and place it in a beaker.
  - Place a magnetic stirrer in the beaker with gentle stirring.
  - Insert in the device electrode into the beaker and let it stabilize.
  - Read the result on the device.

III.6.1.2. Electrical Conductivity (EC):

The conductivity is measured using a **WTW** Terminal device.

- ***Working method***:
  - ✓ Adjust and turn on the device.
  - ✓ Rinse the electrode with distilled water.
  - ✓ Take **100 ml** of the sample and place it in a beaker.
  - ✓ Place a magnetic stirrer in the beaker with gentle stirring.
  - ✓ Insert the device electrode into the beaker.
  - ✓ Read the result on the device **(mS/cm).**

III.6.1.3. Dissolved oxygen (O_2) and the temperature (T):

Dissolved oxygen and temperature are measured using the same device of type **Oximeter HACH HQ 30 d.**

- ***Working method:***
  - Adjust and turn on the device.
  - Rinse the electrode with distilled water and wipe it with filter paper.
  - Take **100 ml** of the sample and place it in a beaker.
  - Place a magnetic stirrer in the beaker.
  - Read the value from the device once it stabilizes.

III.6.1.4. Suspended solids (SS):

- ***The materials and methods used are:***

  Filter paper - Beaker - Analytical-Distilled water -Vacuum filtration device -Dryer at **105 ºC** –Desiccator.

- ***Working method:***

There are two methods for measuring suspended solids: filtration method and centrifugation method.

- ***Filtration method:***
  - Wet the filter paper with distilled water and place it in the dryer at **105 ºC**.
  - Weigh the filter paper when dry, its weight is **M_0**.
  - Connect the filtration device under vacuum.
  - Place 100 ml of the water to be filtered in a beaker and filter it through the vacuum device.
  - Then place the filter paper in the dryer at **105 ºC** for two hours.
  - Place the filter paper in a desiccator for **15** minutes.
  - Then weigh the filter paper using an analytical balance and record its weight as **M_1**.

The result is calculated using the following equation:

$$SS\ (mg/l) = (M_1 - M_0) / V$$

SS: Concentration of Suspended Solids (**mg/l**).

M_0: Weight of empty filter paper (**mg**).

M_1: Weight of filter paper after use (**mg**).

V: Volume of water used (**l**).

Centrifugation method:

- Take **100 ml** of the sample and place it in a container with a capacity of **100 ml**.
- Then subject it to centrifugation for **20** minutes until sediment is obtained.
- Remove the suspended water, wash the sediment with distilled water, then subject it again to centrifugation for **20** minutes.
- Weigh a clean crucible and record its weight as **M_0**.
- Pour the sediment into the crucible, then place it in the incubator at **105 ºC.**
- Remove the crucible from the incubator and let it cool away from moisture inside the desiccator.
- Weigh the crucible with the dry sediment and record its weight as **M_1**.

The concentration of **SS** is calculated using the following equation:

$$SS\ (mg/l) = (M_1 - M_0) / V \times 1000$$

SS: Suspended solids concentration **(mg/l)**.

M0: Weight of the beaker before use **(mg).**

M1: Weight of the beaker with the sediment after use **(mg).**

V: Volume of water used for oxygen **(l)**.

III.6.1.5. Biochemical oxygen demand (BOD_5):

The quantity **BOD_5** was determined using the magnetic stirrer device in a specific **manometric** method.

- ***Methods and material used:***
  - Magnetic stirrer device.
  - Pressure measuring device **BOD_5 (MF 120)** mercury manometric.
  - Insulated glass bottles with a capacity of **500 ml**, equipped with inner and outer lids.
  - Incubator, forceps, beaker, standard burette, **NaOH (Sodium hydroxide)**.

❖ ***Working method:***

Adjust the device according to the sample taken.

Table (III. 3): The coefficient of change in **BOD5** value as a function of the volume of the used sample.

Range (mg/l)	**0 - 40**	**0 - 80**	**0 - 200**	**0 - 400**	**0 - 800**	**0 - 2000**
V (ml)	**432**	**365**	**250**	**164**	**97**	**43.5**
Factor	**1**	**2**	**5**	**10**	**20**	**50**

- ***Internal water:***

The necessary sample was measured using a graduated flask for internal water analysis 164 ml then poured into a light – tight incubation bottle (to prevent the occurrence of photochemical reaction).

- The magnetic rod is placed inside the bottle.
- Three drops of inhibitor solution **1- alkyl-2-thiourea** **($C_4H_8N_2S$)** are added inside the bottle to inhibit nitrogenous materials from oxidizing in the presence of oxygen.
- A plastic holder is placed inside the bottle and two tablets of a substance are placed inside it using forceps.
- The bottles are loosely closed.
- The bottles are placed in a refrigerator on the stirrer device at a temperature of **20 °C** and left for **30** minutes for equilibrium then tightly closed.
- Readings are taken daily for **5** days and in the end the result obtained is multiplied by the coefficient.

- ***External water:***

The required sample quantity is measured using a graduated flask for external water analysis **432 ml** then poured into a light – tight incubation bottle (to prevent the occurrence of photochemical reactions).

- The magnetic rod is placed inside the bottle.
- Nine drops of inhibitor **($C_4H_8N_2S$)** are added.
- A plastic holder is placed inside the bottle and two tablets of **NaOH** are placed inside it using forceps.

- The bottle is loosely closed.
- The bottles are placed in a refrigerator on the stirrer device at a temperature of **20 ºC** and left for **30** minutes for equilibrium then tightly closed.
- Readings are taken daily for **5** days and in the end the result obtained is multiplied by the coefficient.

III.6.1.6. Chemical oxygen demand (COD):

- ***Methods and material used:***
  - The device utilizes Spectrophotometer **HACH DR 3900**- Thermo reactor- vacuum system- beaker- Distilled water. In **COD** measurement a capsule containing the commercial detector **(LCK 114)** was used.
  - In **COD** measurement a capsule containing the commercial detector **(LCK 114)** was used.
- ***Working method:***
  - ✓ The tube is well shaken to mix the deposited materials.
  - ✓ **2 ml** of the sample are taken using a pipette and poured onto the inner wall of the capsule which contains the reagent so that the capsule is titled.
  - ✓ The tube is tightly closed and shaken well.
  - ✓ The tube is heated for two hours at a temperature of **148 ºC** inside the thermo reactor.
  - ✓ The tube is shaken from the thermo reactor and left to cool on a stand for **15** minutes.
  - ✓ After 15 minutes the tube is shaken inside the Spectrophotometer **HACH DR 3900**.
  - ✓ The **COD** value is read from the spectrophotometer **(mg/l).**

III.6.1.7. Orthophosphorus (PO_4^{3-}):

- ***Methods and material used:***
  - The device utilizes Spectrophotometer **HACH DR 3900**.
  - In **PO_4^{3-}** measurement a capsule containing the commercial detector **(LCK 350).**

- ***Working method:***
  - **0.4 ml** of the sample is taken.
  - Taken by 0.5 mm absorbent of **B** Detector.
  - The **DoSiCap** grey screw is placed on the tube.
  - Stir the tube several times in order to blend the deposited material.
  - After **10** minutes of heart several times clean the tube from the outside.
  - The tube is placed in the spectrophotometer reading device.
  - The value is read from spectrophotometer **(mg/l).**

III.6.1.8. Nitrite (NO_2^-):

- ***Methods and material used:***
  - Device spectrophotometer **HACH DR 3900**.
  - In Nitrite measurement you use a capsule containing commercial detector **(LCK 338).**
- ***Working method:***
  - Place **2 ml** of sample in the tube.
  - Close the tube and shake the mixture.
  - Leave it for **10** minutes and then put it the device.
  - The value is read from the spectrophotometer **(mg/l)**.

III.6.1.9. Nitrate (NO_3^-):

- ***Methods and material used:***
  - Device spectrophotometer **HACH DR 3900**.
  - In Nitrate measurement you use a capsule containing commercial detector **(LCK 339)**.
- ***Working method:***
  - Place **2 ml** of sample in the tube.
  - Close the tube and shake the mixture.
  - Leave it for **10** minutes and then put it in the device.
  - The value is read from the spectrophotometer **(mg/l)**.

III.6.1.10. Total Nitrogen (TN) :

- ***Methods and material used :***
  - Device spectrophotometer **HACH DR 3900**.

- In Total Nitrogen measurement you use a capsule containing commercial detector **(LCK 338).**

- ***Working method:***
  - Place **1 mm** of sample water in the nitrate tube.
  - Place **0.2 mm** from the **A** catalyst.
  - The mixture is well, and then leaves it for **15** minutes.
  - Read the value of spectrophotometer **(mg/l).**

. *III.6.1.11. Total phosphorus (TP):*

- ***Methods and material used:***
  - Device spectrophotometer **HACH DR 3900**.
  - In total Azote measurement you use a capsule containing commercial detector **(LCK 338)**.
- ***Working method:***
  - **0.2 ml** of sample is placed inside a tube.
  - Add **2.3 ml** of catalyst.
  - Place the tube in the heater at **120 ºC** for **30** minute.
  - The tube comes out and leaves to cool for **15** minute.
  - Shake the tube two or three times.
  - The gas test tube is taken with oils and added to it **0.5 ml** of the previously lectured sample.
  - Add **0.2 ml** of the **D** catalyst and then shake.
  - Leave the mixture to rest for **15** minutes and then clean the outside of the tube.
  - The tube is placed in the spectrophotometer reading device.
  - The value is read from Spectrophotometer **(mg/l)**.

III.6.1.12. Ammonium (NH_4^+):

- ***Methods and material used:***
  - ✓ Device spectrophotometer **HACH DR 3900**.
  - ✓ In Ammonium measurement you use a capsule containing commercial detector **(LCK 303).**
- ***Working method:***
  - ✓ Replace the tube cap.

- Add **0.2 ml** of the sample.
- Mix for **3** minute.
- Allow the mixture to stand for **15** minutes and then clean the outer part of the tube.
- Place the tube in a spectrophotometer for reading **(mg/l).**

III.6.1.13. Determination of heavy metals in polluted water:

The tubular test method was used for all heavy metal analyses of wastewater from Saïd Otba station (Ouargla). Using the Crapsey Laboratory spectrophotometer using the **SAA** device.

- ***Lead (Pb) (mg/l):*** In an alkaline solution, lead ions react with **(Pyridyl-2-aso)-4-resorcinol** to form a red complex, which we quantified through photometry.
- ***Cadmium (Cd) (mg/l):*** In an alkaline solution, cadmium ions react with a derivative of the cation to form a red complex which is quantified by a photometer.
- ***Chromium (Cr) (mg/l):*** In a weakly phosphoric solution, chromium ions react with diphenylcarbazone to form chromium and diphenylcarbazone, which form a reddish-purple complex that is quantified by photometry.
- ***Copper (Cu) (mg/l):*** Copper with cuprizone in an ammoniacal medium, copper ions form a blue complex that we quantify using photometry.
- ***Nickel (Ni) (mg/l):*** After oxidation of Nickel ions by iode, then transformation by dimethyi-glyoxime in an ammoniacal solution into a red-brown complex, we measured this element by photometry using the method applied for this analysis which is analogous to US standard method (**3500 –NiE)**.

III.6. Water Quality Index (WQI):

Initially developed by **HORTON (1965)** in the United States, the **W**ater **Q**uality **I**ndex **(WQI)** selects **10** commonly used water quality variables such as Dissolved Oxygen **(DO), pH**, Alkalinity, and Chloride. It has been widely applied and accepted in European, African, and Asian countries. Additionally, a similar approach to **HORTON'S** index was developed by **BROWN et al**. in **1970**, which assigned weights to individual parameters.

A Water Quality Index **(WQI)** provides a single value expressing the overall water quality based on multiple water quality parameters. Its objective is to transform complex water quality data into simple, understandable, and usable information for the general public.

III. 6. 1. Weighted Arithmetic Water Quality Index:

The weighted arithmetic water quality index method classifies water quality based on purity using commonly measured water quality variables. This method has been widely used by several researchers **[7-13].**

The wastewater quality index method reflects the composite influence of different water quality parameters on irrigation.

The index is calculated using the equations provided:

$$W_i = K_i / S_i \qquad \text{(III. 1)}$$

***W_i*:** is the weight of each parameter based on its relative importance in drinking water quality.

***K_i*:** is a proportionality constant and can also be calculated using the following equation:

$$K_i = 1 / \sum_{i=1}^{n} (1/Si) \qquad \text{(III.2)}$$

n: number of parameters.

Si: maximum value of the standard norm for each parameter in mg/l except for **pH**, temperature **(T°C)**, and electrical conductivity. Then, a quality assessment scale **(Q_i)** is calculated for each parameter by diving the concentration by the norm of that parameter and multiplying the result by **100** as in the following formula:

$$Q_i = (C_i / S_i).\ 100 \qquad \text{(III.3)}$$

Qi: Quality assessment scale for each parameter.

Ci: Concentration of each parameter in **mg/l.**

Finally, the overall water quality index is calculated by the following equation:

$$WQI = \sum_{i=1}^{n} Qi \, . Wi \,/ \sum_{i=1}^{n} Wi \qquad \text{(III.4)}$$

Table (III.4): Assessment of water quality according to the arithmetic weighted water quality index **(WQI)** **[14].**

WQI classification	Water type	Possible use
0 - 25	Excellent quality	Drinking water, irrigation and industry
26 - 50	Good quality	Drinking water, irrigation and industry
51 - 75	Bad quality	Irrigation and industry
76 - 100	Really bad quality	Irrigation
> 100	Non-drinkable water	Proper treatment required before use

III.7. Statistical analysis:

All data from our study on wastewater from the **Saïd Otba** (**Ouargla**) plant were processed using Excel software. In addition, the result of the physico-chemical, and heavy metals analyses was subjected to **P**rincipal **C**omponent **A**nalysis (**PCA**), which was conducted using the **XLSTAT** software version (**5.6.7**). This statistical method allows for the transformation of the initial quantitative variables, which are interrelated in one way or another into new uncorrelated quantitative variables called principal components **[6]. PCA** was performed on the physico- chemical parameters in a data matrix, where **14** variables were measured (**T, EC, pH, $O_{2dissolved}$, NO_2^-, NO_3^-, PO_4^{3-}, SS, COD, BOD_5, NH_4^+, TN, TP**). As for the heavy metals, five metals were measured namely [Nickel (**Ni**), Lead (**Pb**), Copper (**Cu**), Chromium (**Cr**), Cadmium (**Cd**)].

«XLSTAT is statistical analysis software that is an extension of Excel. This program has over 200 features for general or field studies. Using Excel as an interface makes XLSTAT an easy-to- use and highly efficient package for statistical and multivariate data analysis. The program includes many analyses, including linear, logistic, and non-linear regression analysis, multivariate data analysis, Principal Component Analysis (PCA), discriminant analysis, multidimensional scaling, cluster analysis, simulation, and many other analyses » **[15].**

Multiple regression analysis was used to determine if there were statistically significant relationships between pollution outcomes (dependent variables) and concentrations of raw flow parameters and treated liquid waste using climatic and hydraulic parameters that were important in predicting the dependent variables **(BOD_5, COD, SS).** The multiple linear regression model estimates the behavior of the dependent variable as a function of several independent variables, assuming a linear relationship between the dependent variable and the other parameters. The result of this analysis is a linear equation:

$$(Yi = ax_1 + bx_2 + \dots\dots\dots\dots\dots\dots + d)$$

The linear regression equation takes the form:

$$(Yi = a^*X_i + b^*X_{i+1} + \dots\dots\dots\dots\dots + d)$$

X_i	=	Independent variable
Y_i	=	Dependent variable
a, b	=	Correlation coefficients
i	=	Index i=1,2,……….., n
N	=	Number of sample

The correlation coefficient denoted by **r** is given by the equation:

$$\mathbf{r} = \frac{\sum_i[(X_i-\overline{X})\times(Y_i-\overline{Y})]}{\sqrt{\sum_i(X_i-\overline{X})}\times\sqrt{\sum_i(Y_i-\overline{Y})}}$$ or simplified form $$\mathbf{r} = \frac{n\sum_i X_iY_i - \sum_i X_i \times \sum_i Y_i}{\sqrt{n\sum_i X_i^2-(\sum_i X_i)^2}\times\sqrt{n\sum_i Y_i^2-(\sum_i Y_i)^2}}$$

$\overline{X}$	=	Moyennes X
$\overline{Y}$	=	Moyennes Y

The closer the value of **r** is to **±1** the stronger the linear relationship. Conversely the closer the value of **r** is to **0** the weaker the linear relationship. The coefficient of determination (**R**) gives the percentage of variation in the dependent variable (**Y**) explained by the independent variable (**X**).

For each variable entered into the model, it was chosen by statistical calculation (**ε= 0.05**) to avoid eliminating important factors. This procedure calculates the coefficient of determination (**R^2**) and the standard deviations for all models.

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Chapter IV: *Results And discussion*

Chapter's summary

In this chapter, we discussed and analyzed the obtained results.

Introduction:

In this chapter, we presented the results obtained from laboratory analyzes and discussed each factor separately through the completed plans in order to determine the efficiency of the station. Results were obtained for raw and treated wastewater from the Ouargla wastewater station using the aerated lake method during the year **2019** (January…. December).

IV. 1. Biodegradation coefficient K= (DCO/BOD$_5$):

The **DCO/BDO$_5$** report determines the biodegradability of organic matter from wastewater discharge. Therefore, a ratio equal to or greater than **3** indicates weak biological decomposition, which can be attributed to the resistance of the organic matter in the solution, hypo oxidation of the aqueous medium.

Hence the need to use more effective methods with regard to this rejection. This report also makes it possible to conclude whether wastewater discharged directly into the future environment has the characteristics of domestic wastewater [1,2].

Table (IV. 1): Biodegradation plants for Ouargla station.

Months	COD(mg/l)	BOD$_5$	K= COD/BOD$_5$
January	450	143.33	3.14
February	561	200	2.81
March	531	200	2.66
April	304	100	3.04
May	314.33	126.67	2.61
June	353.20	205	1.72
July	387.50	140	2.77
August	359	160	2.24
September	324	153.33	2.11
October	262.93	195	1.35
November	460	90	5.11
December	307.33	95	3.24

Through the table **(IV.1)** for the biological degradation coefficient, it’s evident that household wastewater is generally biodegradable. However, in November, the biodegradation coefficient increased to **5.11** due to a rise in the percentage of organic matter resulting from events in the area, indicating that sewage discharge mainly originates from urban areas, with minimal industrial discharge affecting these values.

IV. 2. Physico-chemical characteristics of the station's waste (raw) and (treated) water:

Table (IV. 2): Physico-chemical characteristics of wastewater entering the Ouargla station.

Parameters	Maximum value	Average value	Minimum value
T (℃)	33.10	26.18	19.36
O_2 dissolved (mg/l)	1.90	0.89	0.26
pH	7.70	6.77	7.26
EC (mS/cm)	49.79	28.31	11.94
Salinity (mS/cm)	34013.64	15434.62	23.86
SS (mg/l)	281.00	153.95	82.00
COD (mg/l)	561.00	384.53	262.93
BOD_5(mg/l)	205.00	150.69	90.00
NO_2^-(mg/l)	0.90	0.21	0.02
NO_3^-(mg/l)	1.27	0.53	0.18
PO_4^{3-}(mg/l)	5.04	3.29	0.33
TN (mg/l)	125.50	60.00	34.90
NH_4^+(mg/l)	39.28	30.68	21.40
TP	5.62	4.36	2.66

According to **Table (IV. 2)** the average values of parameters for used water, including temperature **T, pH**, suspended solids **SS**, **COD, BOD_5** coefficients, comply with the standards for domestic sewage water as per the **(AS) (2012) (see appendix).**

Table (IV. 3): Physico-chemical characteristics of treated water leaving the Ouargla station.

Parameters	Maximum value	Average value	Minimum value
T	31.70	23.61	15.52
O_2disso	6.01	3.42	0.83
pH	8.02	7.64	7.26
EC (mS/cm)	45.28	29.17	13.07
Salinity (mg/l)	30818.01	15527.50	237
SS (mg/l)	165.00	96.50	28.00
COD (mg/l)	190.15	104.24	93.55
BOD_5(mg/l)	66.67	42.50	18.33
NO_2^-(mg/l)	0.50	0.27	0.04
NO_3^-(mg/l)	1.98	1.00	0.02
PO_4^{3-}(mg/l)	3.73	2.21	0.70
Total. N(mg/l)	122.85	77.72	32.60
$N-NH_4^+$(mg/l)	43.60	34.26	24.92
Total. P (mg/l)	4.62	3.61	2.60

IV. 3. Physico-chemical analyses of wastewater:

All physical and chemical analyses have been conducted for sewage water at the inlet and outlet of the treatment station. The parameters analyzed include: ***pH, T, EC,*** $O_{2\,dissolved}$, $N-NO_2^-$, $N-NO_3^-$, PO_4^-, ***SS, COD,*** BOD_5, $N-NH_4^+$, ***TN, TP, Salinity.***

Table (IV. 4): Analyzed parameters (STEP Said Otba).

	Parameters	Unit	Designation	Reference method
01	Suspended Solid	mg/l	SS	Gravimetric Elecronic precision Balance (kern. ABT) – filtration Device filtration on 0.45µm membrane and drying in an oven at 105 and weighing.
02	Biological Oxygen Demand	mg d’O_2/l	BOD_5	BOD self-checking measurement Oxi Top is 12 and Thermostat TS 606 /4-i.
03	Chemical Oxygen Demand	mg d’O_2/l	COD	And measured by a spectrophotometer (DR 2800). By the potassium dichromate method $K_2Cr_2O_2$.
04	Dissolved Oxygen (DO)	mg d’O_2/l	DO	We used the potentiometric method. (potable oximeter, Oxi 340i /Set WTW).
05	Ammonium	mg/l	$N-NH_4^+$	By the method (spectrophotometry).
06	Nitrite	mg/l	$N-NO_2^-$	Spectrophotomerty DR.2800.
07	Nitrate	mg/l	$N-NH_3^-$	Hach Lange.
08	Temperature		T	Thermometric: Hanna type Electronic thermometer.
09	Potential hydrogen	pH unit	pH	PH meter type WTW 340 I /Set Portable and electrode Sen Tix 41-3.
10	EC	µs/cm	cond	Pocket conductivity meter type WTW 3401.

IV. 4. Discuss the results:

Introduction:

In this part we will evaluate the quality of the purified water leaving the station purification plant of Ouargla. In order to determine the quality of wastewater from the Ouargla treatment plant, analyses were conducted for various pollution standards.

IV. 4. 1. Temperature:

Table (IV. 5): Monthly variations in the temperature of raw and treated water from the **WWTP** (Ouargla, **2019**).

Month / Parameter		JAN	FEB	MAR	APRIL	MAY	JUNE	JULY	AUG	SEPT	OCT	NOV	DEC
T°C (in)	In	2O.75	19.36	22.22	24.5	28.6	30.35	33.1	31.82	30.08	28.54	23.27	21.63
T°C (out)	Out	17.79	15.68	18.57	21.55	25.38	28.76	31.7	28.84	25.96	23.62	18.19	15.52
STANDARD(AS)		30	30	30	30	30	30	30	30	30	30	30	30
STANDARD (WHO)		30	30	30	30	30	30	30	30	30	30	30	30

Temperature is a parameter that fluctuates depending on the seasons. The wastewater treatment plant in Ouargla is experiencing a rise in temperature, especially in the summer.

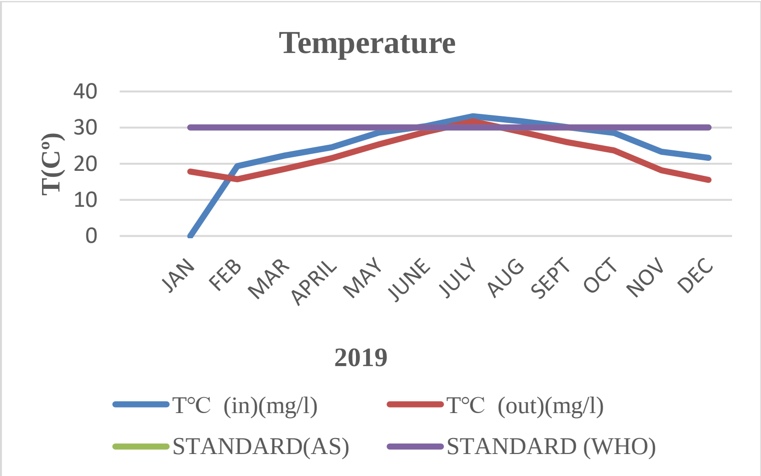


Fig (IV. 1): Monthly variations in the temperature of raw and treated water from the **WWTP** (Ouargla, **2019**).

Changes in the temperature of the wastewater treatment plant have important effects because they affect the development of colonies of micro-organisms **[4].** At the station entrance the average water temperature is **26.18 ℃** and at the station outlet the average water temperature is **22.63 ℃** and this value is less than the threshold **30 ℃ (WHO) (1971)** and (**AS) (2012).**

The decrease in temperature in the treated ponds is explained by the decrease in the number of bacteria and the lack of biochemical reactions. Temperature is related to the time the sample was taken and local conditions (climate, duration and sunlight). As for used ponds, the decrease in temperature is explained by contact of treated water with air. These differences do not affect the selection of microorganisms responsible for purification **[4].**

IV. 4. 2. pH:

The **pH** of water represents its acidity or alkalinity. Water with a **pH** around **7** is called neutral, a **pH** below **7** is called acidic water and a **pH** above **7** is called basic. Except in the case of specific industrial discharges, it is rare for the **pH** to be outside the potable range. It is one of the most important for evaluating water quality. It must be closely monitored during all treatment operations **[3]**.

The results showed **pH** values between **7.26** and **7.7** for raw water and between **7.26** and **8.02** for pure water, with an average output of **7.65**, which according to Algerian standards is considered discharge to nature and then for agricultural use **(6.5 to 8.5).**

Most the values of **pH** during the study were recorded towards the base values, and the reason for this is the presence of carbonates and bicarbonates in abundance in natural waters. We explain the increase in the value of **pH** in the case of treated water through the intense activity in lakes, there is a large consumption of oxygen and thus the release of a large amount of carbon dioxide **[4]**.

Table (IV.6): Monthly variations in the **pH** of raw and treated water from the Ouargla **WWTP (2019).**

Month / Parameter		JAN	FEB	MAR	APRIL	MAY	JUNE	JULE	AUG	SEPT	OCT	NOV	DEC
pH	in	7.31	7.26	7.29	7.43	7.7	7.3	7.3	7.31	7.45	7.52	7.51	7.28
pH	out	7.26	7.32	7.39	7.48	7.97	8.02	7.78	7.99	7.66	7.64	7.85	7.48

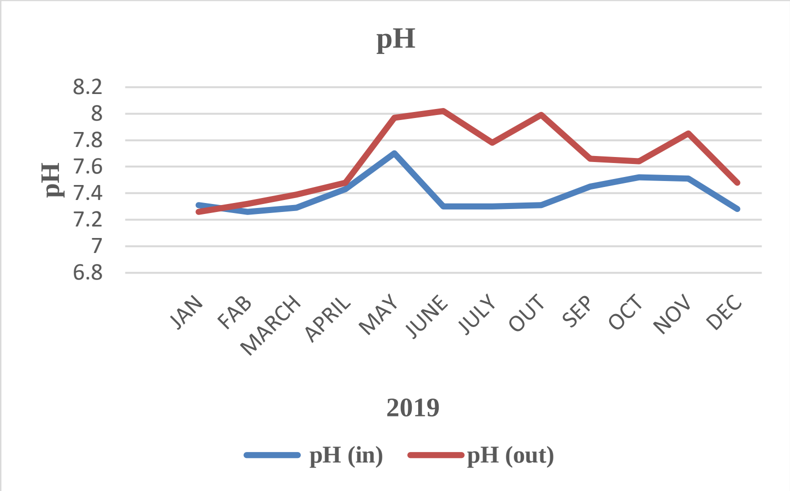


Fig (IV. 2): Monthly variations in the **pH** of raw and treated water from the Ouargla **WWTP (2019).**

IV. 4. 3. O_2 dissolved:

Through the figure, we observe that the average dissolved oxygen values are higher in the treated water in various basins compared to the wastewater. According to the results obtained in the figure, in the case of the wastewater at the Ouargla station, the average dissolved oxygen values are **0,89 mg/l**, fluctuating between a maximum value of **1,9 mg/l** in December and a minimum value of **0,26 mg/l** in August. These values are within the standards for domestic wastewater according to **(AS) (2012) (see appendix).**

Regarding the treated water, the average dissolved oxygen is **1.9 mg/l**, fluctuating between a maximum value of **6.02 mg/l** in November and **0.83 mg/l** in April. These values comply with Algerian national standards but fall outside **(WHO) (1971).**

The decrease in oxygen levels in wastewater at the inlet to the treatment plant can be attributed to the presence of organic and inorganic matter, solvents, fats, and detergents entering the system. These substances may deplete oxygen during their breakdown by microorganisms, leading to a reduction in oxygen levels.

On the other hand, the increase in oxygen levels in treated water at the outlet can be explained by good aeration of the water in the aeration basin, which allows for the development of aerobic microorganisms and stimulates them to oxidize organic matter. This leads to improved biological treatment of sewage. Additionally, the depth of the aeration basin plays a significant role in determining the oxygen content in both influent and treated water **[4]**.

Table(IV. 7): Monthly variations in the O_2 **dissolved** of raw and treated water from the Ouargla **WWTP (2019).**

Month / Parameter		JAN	FEB	MAR	APRIL	MAY	JUNE	JULY	AUG	SEPT	OCT	NOV	DEC
O2 Dissolved (mg/l)	in	0.75	O.88	1.88	0.96	0.7	0.36	0.47	0.26	0.9	0.59	1.01	1.9
O2 Dissolved (mg/l)	out	1.79	1.35	1.31	0.83	1.99	1.83	1.02	1	1.90	1.39	6.02	2.83
STANDARD (WHO)		5	5	5	5	5	5	5	5	5	5	5	5

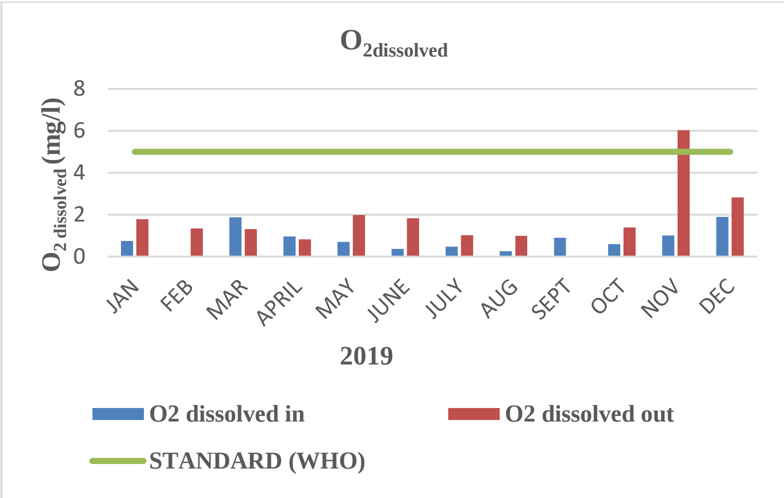


Fig (IV. 3): Monthly variations in the O_2 dissolved of raw and treated water from the Ouargla **WWTP (2019).**

IV. 4. 4. Electrical Conductivity EC:

Through the **fig (IV. 4)**, we notice that the average conductivity decreases in the treated water in various basins compared to the used water except for June, July, December at the station. According to the results obtained in the **fig (IV. 4)** the average conductivity in the used water is **28.40 (mS/cm)**, fluctuating between the maximum value of **49.78 (mS/cm)** recorded in April and the minimum value of **11.93 (mS/cm)** recorded in December.

In the case of treated water, the average conductivity is **26.99 (mS/cm)**, fluctuating between a maximum value of **45.28 (mS/cm)** in April and a minimum value of **13.07 (mS/cm)** in December. These results are outside the **(AS) (2012)** and **(WHO) (1971).**

The reason for the higher conductivity values in used water compared to treated water is that the water entering the plant represents household wastewater, often laden with significant amounts of salts. This change in the concentration of dissolved salts (chlorides, sulfates, calcium, sodium, magnesium) in the water reaching the station is attributed to this [5].

Controlling water conductivity primarily occurs through water evaporation in basins. Given the arid climate, temperatures in the summer are very high, leading to significant evaporation, particularly during the summer and spring seasons.

Table (IV. 8): Monthly variations of the **E**lectrical **C**onductivity of raw and treated water from the Ouargla **WWTP (2019).**

Month / Parameter		JAN	FEB	MAR	APRIL	MAY	JUNE	JULY	AUG	SEPT	OCT	NOV	DEC
EC (mS/cm)	in	23.63	37.17	38.83	49.78	15.64	40.86	27.20	20.95	15.01	16.89	41.80	11.93
EC (mS/cm)	out	22.30	28.63	36.95	45.28	15.28	43.28	37.20	16.21	15.2	15.28	34.88	13.07
STANDARD (AS)		3	3	3	3	3	3	3	3	3	3	3	3
STANDARD (WHO)		3	3	3	3	3	3	3	3	3	3	3	3

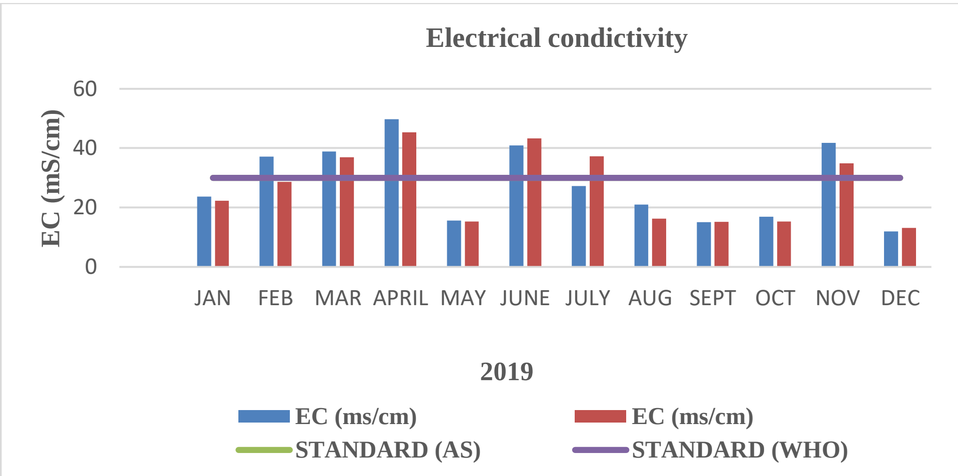


Fig (IV. 4): Monthly variations of the **E**lectrical **C**onductivity of raw and treated water from the Ouargla **WWTP (2019).**

IV. 4. 5. Salinity:

Through the **fig (IV. 5),** we observe that the average salinity level decreases in treated water across various basins compared to untreated water, except for certain months such as (January, June, December). The results obtained in the figure **(IV. 5**) indicate that the average salinity is **15631.55 mg/l**, fluctuating between the maximum value of **3401.64 mg/l** recorded in April and the minimum value of **2386 mg/l** recorded in November.

In the case of the treated water at the station in Ouargla, the average salinity is **13976,38 mg/l**, with the maximum value of **30818,8 mg/l** recorded in April and the minimum value of **237 mg/**l in July. The increase in salinity at the station is explained by the mixing of internal salinity with drainage water before the start of treatment. The reason for the high salinity in the used water is attributed to the lack of differentiation between domestic and industrial water, it is possible that the values found originate from the salinity of drinking water in the study area. Comparing these values with the standard discharge network indicates that the raw sewage studied is saline and of poor quality.

Table (IV. 9): Monthly variations of the **S**alinity of raw and treated water from the Ouargla **WWTP.**

Month / Parameter		JAN	FEB	MAR	APRIL	MAY	JUNE	JULY	AUG	SEPT	OCT	NOV	DEC
SALINITY (mg/l)	in	10236.5	25765	24828.5	34013.6	9211	24155	16900	13031.8	9414.2	10136.3	2386	7500
SALINITY (mg/l)	out	13309	25685	23166.6	30818.1	8985.7	27980	237	9622.7	8960	8968.1	2174	7810

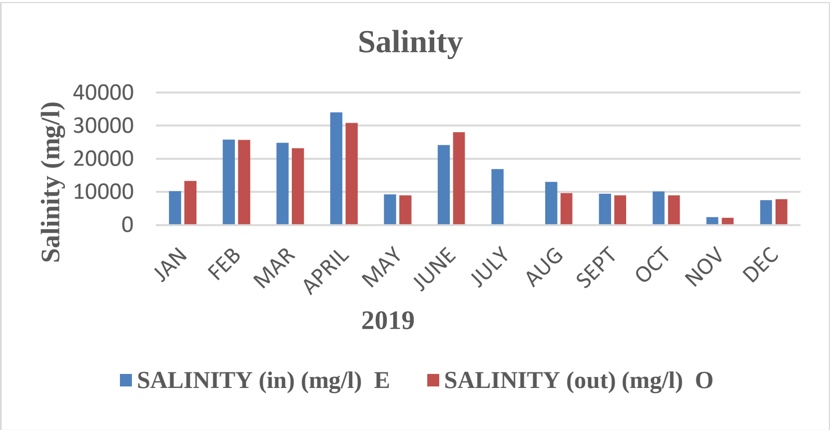


Fig (IV. 5): Monthly variations of the **S**alinity of raw and treated water from the Ouargla **WWTP.**

IV. 4. .6. Suspended Solids (SS):

According to the results obtained in **fig (IV. 6)**, the average SS in wastewater is **153.95** mg/l at the station, fluctuating between the maximum value of **281 mg/l** in February and the minimum value of **82 mg/l** recorded in November. These values are within the standards of domestic wastewater according to **(AS) (2009).**

But it is known that it is difficult to obtain lower values through the lake process, especially if the outlet basins are the site of intense photosynthesis. The increase and decrease in the content in terms of SS due to the activity of algae cannot be explained by the presence of the phenomenon of massive algae reproduction in the different stages of biological processing **[5]**.

In the case of the station's treated water, the average **SS** is estimated at **83.625 mg/l**, fluctuating between the maximum value of **165 mg/l** recorded in February and the minimum value of **28 mg/l** in November. These values are outside the **(AS) (2012)** and outside the (**WHO) (1971).** These results show that it is not suitable for agricultural irrigation. On the other hand, we note that the annual yield reached a maximum of **76.8%** in January and a minimum of **15.24%** in June, with an average of **46.02%.** These results confirm the ineffectiveness of the refinery.

This decrease may be due to the deposition of agglomerated particles along the open water channel. Suspended Solids **SS** constitute a large portion of carbon. Thus their use contributes to improved performance on **BOD_5** and **COD.**

Table (IV. 10): Monthly variations in **SS** of raw and treated water from the **WWTP (2019).**

Month / Parameter		JAN	FEB	MAR	APRIL	MAY	JUNE	JULY	AUG	SEPT	OCT	NOV	DEC
SS (mg/l)	in	263.00	281.00	154.00	216.00	157.00	154.00	161.00	112.50	109.00	91.00	82.00	67.00
SS (mg/l)	out	61.00	165.00	67.50	133.50	78.67	130.50	94.00	65.67	69.00	67.67	28.00	43.06
Standard (WHO)		30	30	30	30	30	30	30	30	30	30	30	30
Standard (AS)		35	35	35	35	35	35	35	35	35	35	35	35

Table (IV. 11): Monthly yields of the average **SS** at **WWTP** of Ouargla.

Month	JAN	FEB	MAR	APRIL	MAY	JUNE	JULY	AUG	SEPT	OCT	NOV	DEC
Yield (SS) %	76.80	41.20	56.10	38.10	49.80	15.24	41.60	41.60	36.60	25.63	65.85	43.06

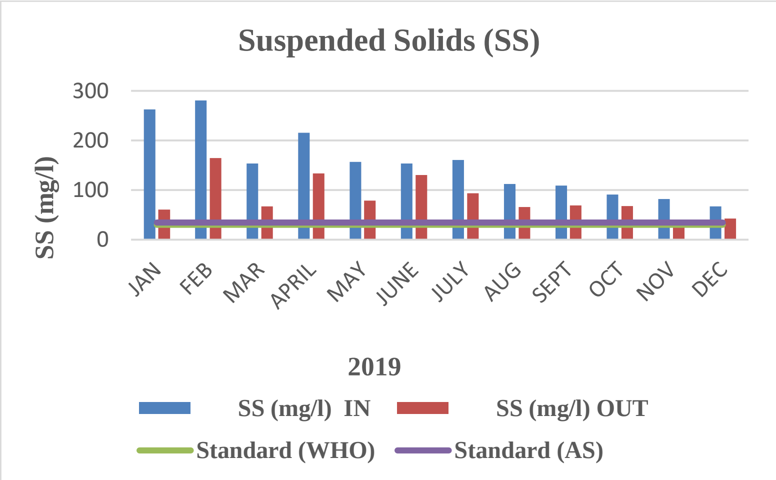
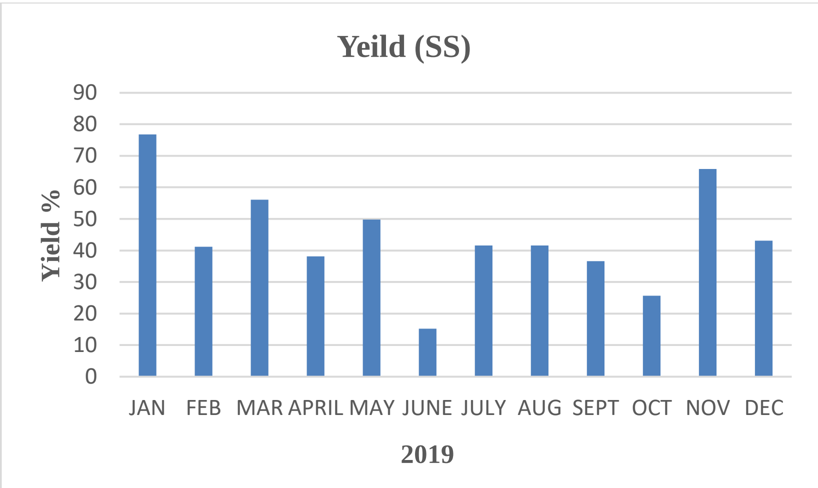


Fig (IV. 6): a- Monthly variations in **SS** of raw and treated water from the **WWTP (2019).**



b- Monthly yields of the average **SS** at **WWTP** of Ouargla.

IV.4.7. Chemical Oxygen Demand (COD):

Through the time evolution of **COD** in fig **(IV. 6)**, we not that the average values of chemical oxygen demand in treated water are lower than those in wastewater. According to the results obtained in figure **(IV. 6)**, the average **COD** in wastewater is **384.53 mg/l,** fluctuating between the maximum value of 561 mg/l recorded in February and the minimum value of **262.93 mg/l** recorded in October. These values are within the standards of domestic wastewater according to the official Gazette **(2009).** As for treated water, the average **COD** was **113.63 mg/l** at the station, fluctuating between the maximum value of **190.15 mg/l** recorded in July and the minimum value of **93.55 mg/l** recoded in April. These values are outside the (**AS) (2012)** and the **(WHO) (1971).** This decrease is facilitated by the destruction of part of the organic materials is due to the chemical oxidation of molecules (continuous oxidation in water) easily as a result of biological oxidation, and some require stronger oxidation, i.e. (chemical oxygen demand). The chemical oxygen demand gives an indication of the amount of oxygen required to oxidize organic and inorganic waters that can be oxidized by chemical processes **[4]**.

Table (IV. 12): Monthly variations in the **COD** of raw and treated water from the **WWTP (Ouargla 2019).**

Month / Parameter		JAN	FEB	MAR	APRIL	MAY	JUNE	JULY	AUG	SEPT	OCT	NOV	DEC
COD (mg/l)	in	450.00	561.00	531.00	304.00	314.30	353.20	387.50	359.00	324.00	262.93	460.00	307.33
COD (mg/l)	out	106.00	120.10	97.50	93.50	137.80	109.40	190.15	102.87	109.07	100.73	102.00	94.40
Standard (AS)		90	90	90	90	90	90	90	90	90	90	90	90
Standard (WHO)		25	25	25	25	25	25	25	25	25	25	25	25

Table (IV. 13): - Monthly yields of the average **COD** at **WWTP** Ouargla.

Month	JAN	FEB	MAR	APRIL	MAY	JUNE	JULY	AUG	SEPT	OCT	NOV	DEC
Yield (COD) %	76.40	78.50	81.60	69.20	56.15	69.02	50.92	71.43	68.25	61.60	77.80	69.20

other hand, we note that the highest yield is **81.6%** in March and the lowest yield is **50.92%** in July**,** with an average of **66.26%.** This slowdown in reducing **COD** pollution can be explained by the fact that the fractions that are difficult to biodegrade and dissolve are large during purification **[5]**.

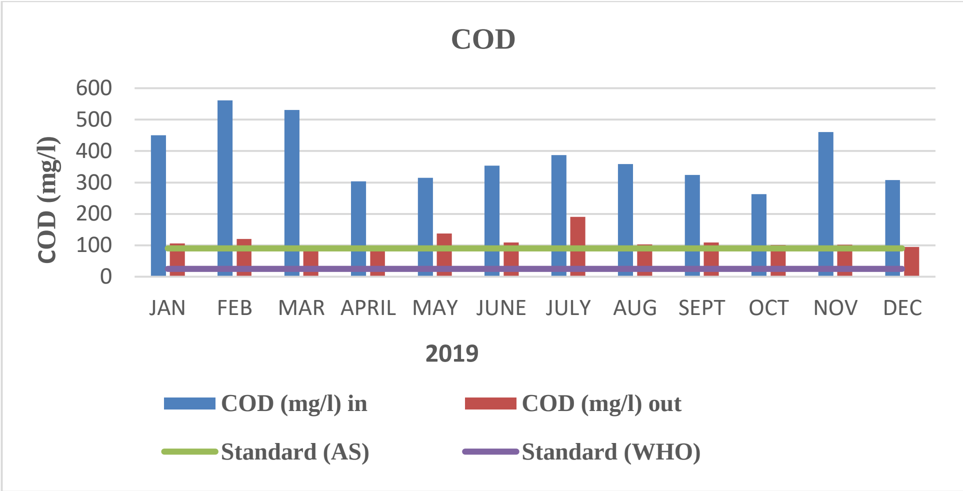
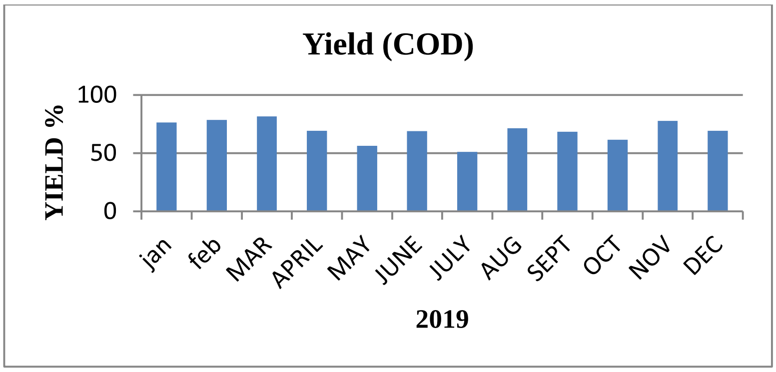


Fig (IV. 7): a- Monthly variations in the **COD** of raw and treated water from the **WWTP (Ouargla 2019).**



b- Monthly yields of the average **COD** at **WWTP** Ouargla.

IV. 4. 8. Biochemical Oxygen Demand (BOD5):

Through the temporal evolution of the **BOD_5** in **fig (IV. 4),** we notice that the average values of biochemical oxygen demand in treated water are lower than that in the inlet wastewater. Based on the results obtained in **fig (IV. 4)**, the average **BOD_5** in the inlet wastewater is **150.69 mg/l** at the station, which fluctuates between the maximum value of **205 mg/l** recorded in June and the minimum value of **90 mg/l** recorded this month of November. These values are within the standards of domestic wastewater according to **(AS) (2009).**

As for treated water, the average is **BOD_5** is **40.31 mg/l** at the station, fluctuating between the maximum value of **66.67 mg/l** recorded in January and the minimum value of **18.33 mg/l** recorded in November. These values are outside the **(AS) (2012)** and the **(WHO) (1971).** The increase in the Biochemical Demand for Oxygen **BOD_5** is explained, especially during the drought period, because the station receives raw sewage water rich in organically degradable substances and in nutrients coming from urban population centers. This is due to a significant increase in organic pollution of surface water in a limited area. The **BOD_5** in the dry period can also be explained by creating conditions for the decomposition of organic matter by micro-organisms whose activity increases with increasing temperature **[4]**.

We note that the average rate of reduction **(yield)** is estimated at **72.02 %,** which is fluctuating, and this confirms that the lake system does not guarantee the complete disposal of organic matter, but rather the conversion of a large part of it from infected organic matter to particulate organic matter in the form of biomass of algae, zooplankton and bacteria and observed this phenomenon more in the summer **[4]**.

Table (IV. 14): Monthly variations of **BOD_5** of raw and treated water from the **WWTP** (Ouargla).

Month / Parameter		JAN	FEB	MAR	APRIL	MAY	JUNE	JULY	AUG	SEPT	OCT	NOV	DEC
BOD5 (mg/l)	In	143.30	200.00	200.00	100.00	126.67	205.00	140.00	160.00	153.30	195.00	90.00	95.00
BOD5 (mg/l)	Out	66.67	30.00	48.00	40.00	35.00	45.00	40.00	58.67	44.00	28.00	18.33	30.00
Standard (AS)		35	35	35	35	35	35	35	35	35	35	35	35
Standard (WHO)		30	30	30	30	30	30	30	30	30	30	30	30

Table (IV. 15): Monthly yields of the average **BOD_5** at **WWTP** of Ouargla

Month	JAN	FEB	MAR	APRIL	MAY	JUNE	JULY	AUG	SEPT	OCT	NOV	DEC
Yield (BOD5)	53.47	85.00	76.00	60.00	72.36	78.04	71.40	63.33	71.20	85.64	79.60	68.40

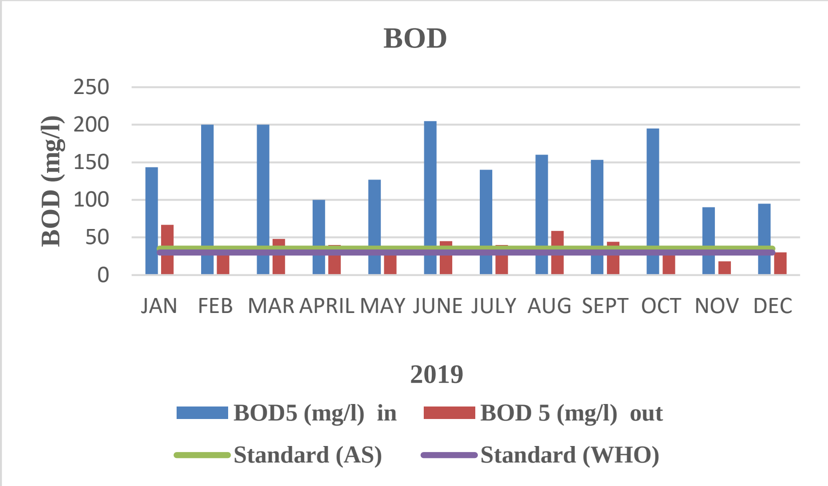
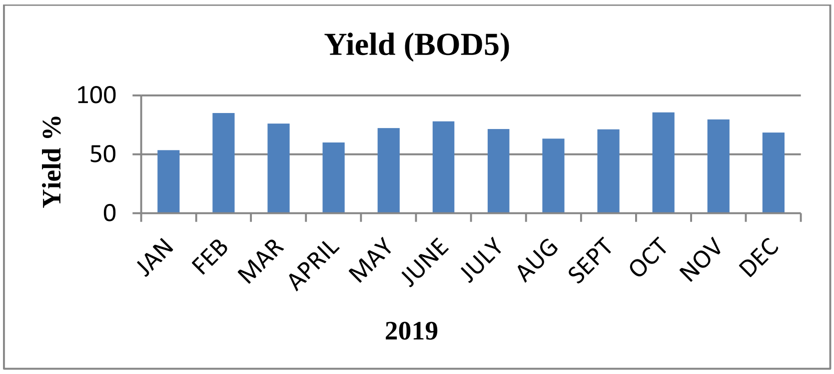


Fig (IV. 8): a- Monthly variations of $\mathbf{BOD_5}$ of raw and treated water from the **WWTP** (Ouargla).



b- Monthly yields of the average $\mathbf{BOD_5}$ at **WWTP** of Ouargla.

IV. 4. 9. Nitrite (NO_2^-):

Through the time evolution of nitrite $\mathbf{NO_2^-}$ in **fig (IV. 9)**, we notice the average concentration of nitrite in station's wastewater is greater than the treated water with the exception of (Avril, June, and December). Through the results obtained in **fig (IV. 9)** average nitrite concentration in wastewater **0.21 mg**/l in Ouargla station, where it fluctuates between the maximum value **0.9 mg/l** recorded in October and the minimum value **0.02 mg/l** recorded in April. As for treated water, the average nitrite **0.14 mg/l** in the Ouargla station, where it fluctuates between the maximum value **0.5 mg/l** recorded in December and the minimum value **0.04 mg/l** recorded in November. These values are within (**AS**)and (**WH0**).

There is an increase in treated water in (Avril, July, and December) as there is not enough oxygen to convert all the nitrite into nitrate (nitrification). Nitrite come either from incomplete oxidation of ammonia, where nitrification is not complete, or from the return of nitrate, and whenever there is a lack of oxygen, organic pollution increases [4].

Table (IV. 16): Monthly variations of NO_2^- of raw and treated water from the **WWTP** of Ouargla.

Month / Parameter		JAN	FAB	MARCH	APRIL	MAY	JUNE	JULY	AUT	SEP	OCT	NOV	DEC
NO2- (mg/l)	in	0.25	0.25	0.12	0.02	0.11	0.09	0.15	0.06	0.13	O.9	0.23	O.16
NO2-(mg/l)	out	0.08	0.06	0.06	0.11	0.05	0.07	0.19	0.05	0.09	0.42	0.04	0.5
Standard (AS)		0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1
Standard (WHO)		0.3	0.3	0.3	0.3	0.3	0.3	0.3	0.3	0.3	0.3	0.3	0.3

Table (IV. 17): Monthly yield of the average NO_2^- at **WWTP** of Ouargla

Month	JAN	FEB	MAR	APRIL	MAY	JUNE	JULY	AUG	SEPT	OCT	NOV	DEC
Yield (N-NO_2) %	80	76	50	-450	54.5	22.2	-26.6	16.6	30.76	53.33	82.6	-212.5

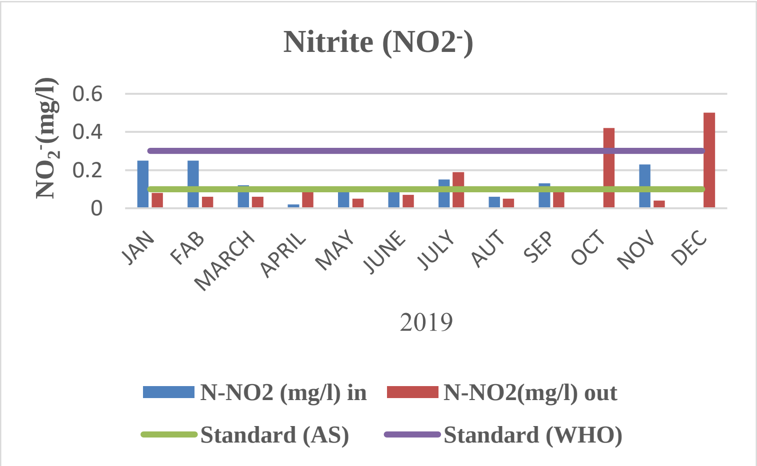
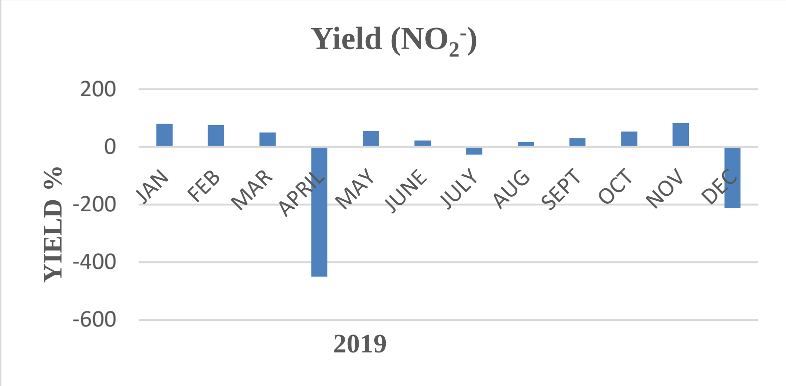


Fig (IV. 9): **a-** Monthly variation of **NO_2^-** of raw and treated water from the **WWTP** (Ouargla).



b-Monthly yield of the average $\mathbf{NO_2^-}$ at **WWTP** of Ouargla.

IV. 4. 10. Nitrate NO_3^-:

Through the **fig (IV. 10),** we notice that the average nitrate concentration in the water used by the station is greater than that in treated water except for (March, June, December). According to the results obtained in the **fig (IV. 10),** the average nitrate in the water used is **0.53 mg/l** fluctuating between a maximum value of **1.27 mg/l** recorded in June and a minimum value of **0.18 mg/l** recorded in May.

As for treated water, the average nitrate is **0.40 mg/l** fluctuating between a maximum value of **1.98 mg/l** recorded in June and a minimum value of **0.02 mg/l** recorded in February. These values are lower than (**AS)** and **(WHO).**

The decrease in treated water is explained by the conversion of ammonium to nitrate, primarily due to denitrification, which decreased primarily due to nitrification enhanced by non-aerated condition, partially due to increased evaporation due to higher temperatures [7].

Table (IV. 18): - Monthly variations of $\mathbf{NO_3^-}$ raw and treated water from the **WWTP** of Ouargla

Month / Parameter		JAN	FEB	MAR	APRIL	MAY	JUNE	JULY	AUG	SEPT	OCT	NOV	DEC
NO_3^- (mg/l)	in	0.90	0.77	0.19	0.46	0.18	1.27	0.70	0.21	0.50	0.20	0.66	0.25
NO_3^- (mg/l)	out	0.27	0.02	0.52	0.06	0.15	1.98	0.32	0.12	0.42	0.04	0.37	0.47
Standard(AS)		30	30	30	30	30	30	30	30	30	30	30	30
Standard(WHO)		25	25	25	25	25	25	25	25	25	25	25	25

Table (IV. 19): Monthly yield of the average $\mathbf{NO_3^-}$ at **WWTP** of Ouargla

MONTH	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC
YIELD (NO_3^-) %	70	97,4	-173,6	86,9	16,66	-55,9	54,28	42,8	55,7	80	43,9	-88

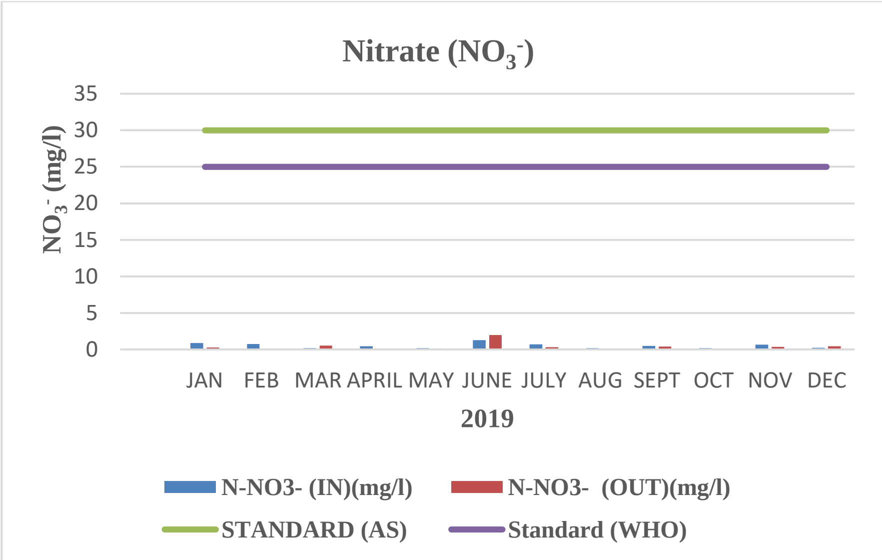
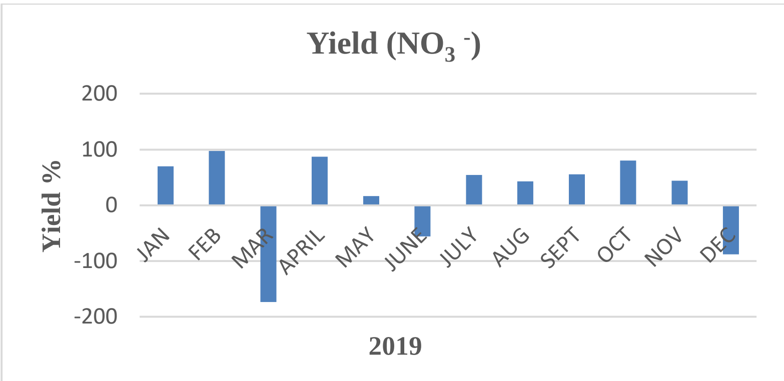


Fig (IV. 10): **a**- Monthly variations of $\mathbf{NO_3^-}$ raw and treated water from the **WWTP** of Ouargla



b- Monthly yield of the average $\mathbf{NO_3^-}$ at **WWTP** of Ouargla.

IV.4.11. Orthophosphorus (PO_4^{3-}):

Through the temporal evolution of orthophosphate levels, we observe that the average concentration in treated water is lower than in used water. The average efficiency at the station is estimated at **26.06 %.** In the used water, the average orthophosphate concentration is **3.30 mg/l**, fluctuating between a maximum of **5.04 mg/l** recorded in April and a minimum of **0.33 mg/l** in September. As for treated water, the average orthophosphate concentration is **2.44 mg/l**, fluctuating between a maximum of **3.73 mg/l** in April and a minimum of **0.70 mg/l** in November. These values exceed both the **AS** of **(2012)** and the **WHO** of **(1971).**

The increase in the average content of raw water compared to treated water is explained by the activity of microorganisms involved in the conversion of organic phosphorus into polyphosphates and orthophosphates. The average concentration is lower in winter compared to summer due to temperature and the accelerated biological degradation of polyphosphates by microorganisms.

Table (IV. 20): Monthly variations of **PO_4^{-2}**at raw and treated water from the **WWTP** of Ouargla

Month / Parameter		JAN	FEB	MAR	APRIL	MAY	JUNE	JULY	AUG	SEPT	OCT	NOV	DEC
PO_4^{3-}(mg/l)	**in**	**3.92**	**4.06**	**3.00**	**5.04**	**3.28**	**3.62**	**3.54**	**2.20**	**0.33**	**1.62**	**4.48**	**4.46**
PO_4^{3-}(mg/l)	**out**	**2.92**	**2.33**	**3.13**	**3.73**	**2.16**	**3.63**	**1.11**	**2.14**	**2.76**	**1.41**	**0.70**	**3.30**
STANDAD (WHO)		**1**	**1**	**1**	**1**	**1**	**1**	**1**	**1**	**1**	**1**	**1**	**1**

Table (IV. 21): Monthly yields of the average of **PO_4^{3-} WWTP** of Ouargla

MONTH	JAN	FEB	MAR	APRIL	MAY	JUNE	JULY	AUG	SEPT	OCT	NOV	DEC
YIELD PO_4^{-3} (%)	**25,5**	**42,61**	**-4.33**	**25,99**	**34,1**	**-0.27**	**68,6**	**2,72**	**-736.36**	**12,9**	**84,37**	**26**

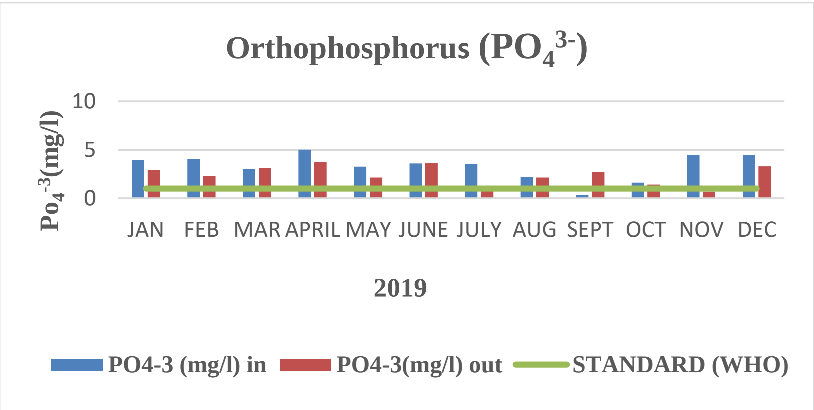
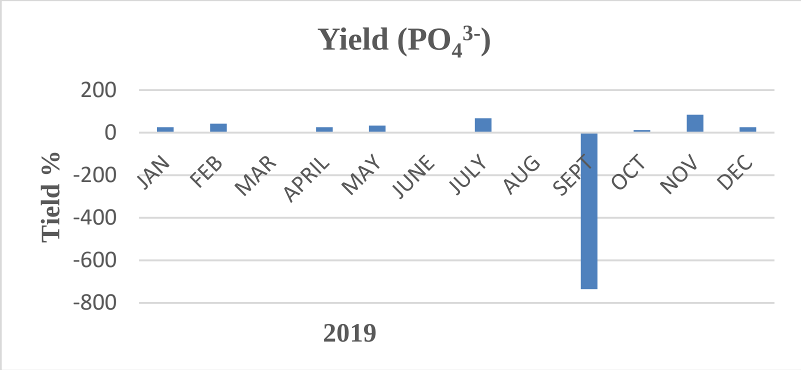


Fig (IV. 11): **a-** Monthly variations of **PO_4^{-3}**at raw and treated water from **WWTP** of Ouargla.



b- Monthly yields of the average of **PO_4^{3-}WWTP** of Ouargla

IV. 4. 12. Total Phosphorus TP:

Through the figure **(IV. 11),** we observe that the concentration of **TP** in treated water is lower than in raw water, with an estimated average efficiency at the plant of **22.70 %**. Based on the results obtained in the figure **(IV. 11)**, the average total phosphorus in raw water is **4.36 mg/l**, fluctuating between a maximum value of **5.62 mg/l** recorded in April and a minimum value of **2.66 mg/l** recorded in August. As for treated water, the average total phosphorus is **3.37 mg/l**, ranging between a maximum value of **4.62 mg/l** recorded in November and a minimum value **2.60 mg/l** recorded in October these values are less than **(AS)** and higher than **(WHO).**

The increase in temperature affects phosphorus removal biologically by enhancing phosphorus reuptake, as phosphorus release mechanisms may slow down at lower temperature. Additionally, the substantial increase in the quantity of readily degradable substrates with temperature contributes to this effect [5].

Table (IV.22): Monthly variations of **TP** at raw and treated water from the **WWTP** of Ouargla.

Month / Parameter		JAN	FEB	MAR	APRIL	MAY	JUNE	JULY	OUG	SEP	OCT	NOV	DEC
TP(mg/l)	In	4.9	5.24	3.22	5.62	4.48	4.23	4.5	2.66	3.54	3.84	4.66	5.44
TP(mg/l)	Out	3.32	3.38	3.43	4.24	3.4	3.71	2.62	2.66	3.04	2.6	4.62	3.38
Standard(AS)		10	10	10	10	10	10	10	10	10	10	10	10
Standard (WHO)		1	1	1	1	1	1	1	1	1	1	1	1

Table (IV. 23): Monthly yields of the average of **TP** at **WWTP** of Ouargla.

Month	JAN	FEB	MAR	APRIL	MAY	JUNE	JUL	AUG	SEP	OCT	NOV	DEC
Yield (TP)	32,28	35,49	-0,65	24,55	24,1	12,29	41,77	/	14,12	32,29	0,85	37,86

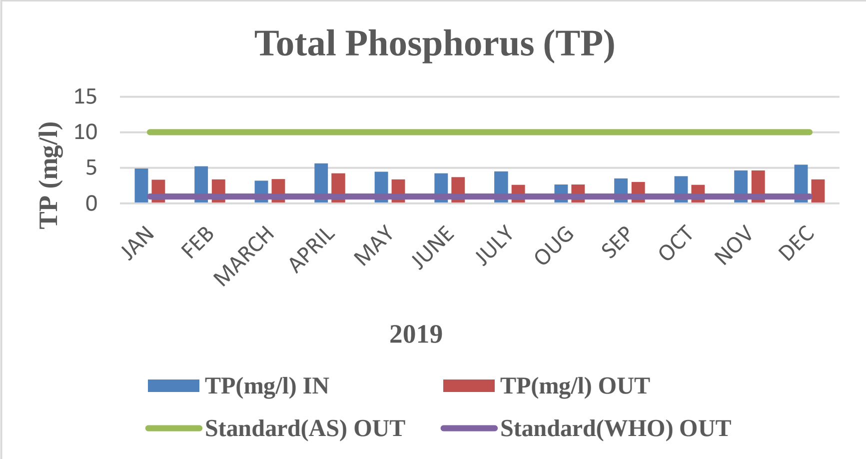
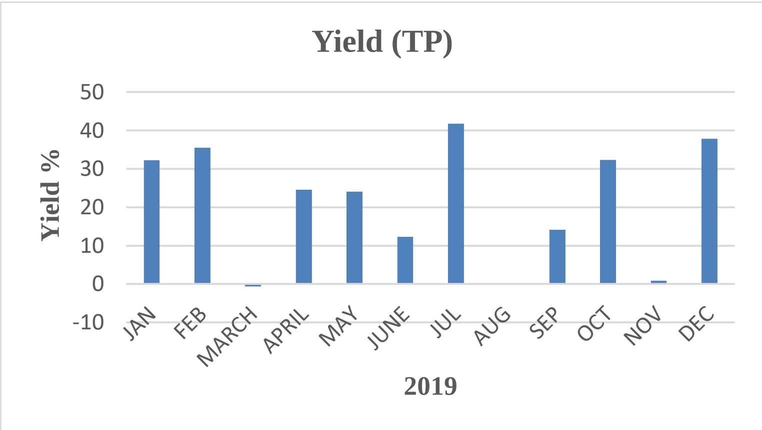


Fig (IV. 12): a- Monthly variations of **TP** at raw and treated water from the **WWTP** of Ouargla.



b- Monthly yields of the average of **TP** at **WWTP** of Ouargla.

IV. 4. 13. Total Nitrogen TN:

From the figure **(IV.13)** we notice that the total nitrogen concentration fluctuates in the station, as the average yield in the Ouargla station is estimated at **-9.35 %.** From the results obtained in the figure **(IV. 13)** the average total nitrogen in the used water is **60 mg/l** as it fluctuated between the maximum value of **125.55 mg/l** recorded in April and the minimum value of **34.90 mg/l** in September. As for treated water the average total nitrogen is estimated at **65.61 mg/l**, oscillating between the maximum value of **122.85 mg/l** recorded in April and the minimum value of **32.60 mg/l** recorded in September. These values are outside **(WHO).**

These results suggest that the concentration of **TN** in winter is higher than in summer and spring, indicating that it is not possible to eliminate ammonium nitrogen entirely. Some of it may be oxidized to nitrates. However, this is not considered a drawback if treated water is used for irrigation, as the nitrogen acts as fertilizer, improving nitrogen balance awareness **[5]**.

Table (IV.24): Monthly variations of **TN** at raw and treated water from the **WWTP** of Ouargla**.**

Month / Parameter		JAN	FEB	MAR	APR	MAY	JUNE	JULY	OUT	SEP	OCT	NOV	DEC
TN (mg/l)	in	60.6	48.8	52.2	125.5	35.4	52.6	52.6	48.6	34.9	96.4	48.2	67.2
TN (mg/l)	out	56.8	51.3	71.2	125.8	91.6	65.2	65.2	42.8	32.6	60.0	41.8	86.0
Standard (WHO)		50	50	50	50	50	50	50	50	50	50	50	50

Table (IV.25): Monthly yields of the average of **TN** at **WWTP** of Ouargla.

MONTH	JAN	FEB	MAR	APR	MAY	JUNE	JULY	OUT	SEP	OCT	NOV	DEC
Yield TN (%)	6.27	-5.12	-36.39	2.15	-158.75	-23.95	-23.95	11.93	6.59	37.75	13.27	-27.97

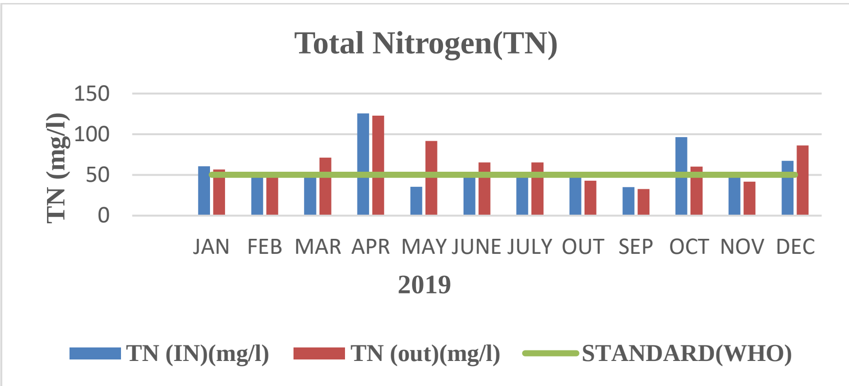
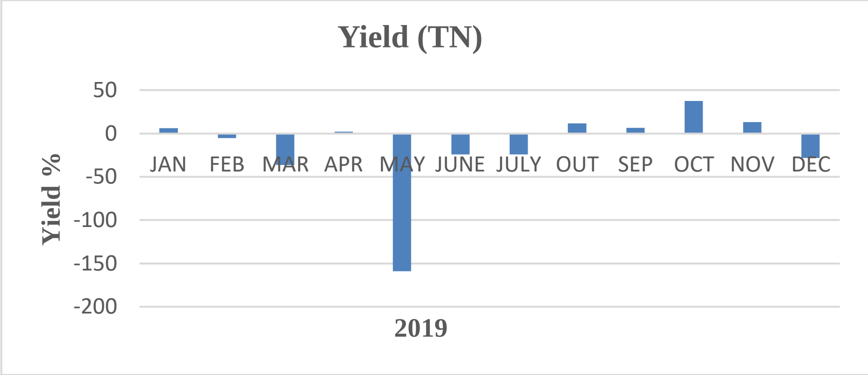


Fig (IV. 13): **a-** Monthly variations of **TN** at **WWTP** of Ouargla**.**



b- Monthly yields of the average of **TN** at raw and treated water from the **WWTP** of Ouargla

IV. 4. 14. Ammonium ($NH4^+$):

Through the figure **(IV. 12)**, it is observed that the concentration of ammonium in treated water is higher than in wastewater, with an average reduction in the plant of **-6.58%.** According to the results shown in the figure **(IV. 12)**, the average ammonium concentration in wastewater is **30.68 mg/l**, fluctuating between a maximum of **39.28 mg/l** recorded in April and a minimum of **21.4 mg/l** in February. As for treated water, the average ammonium concentration is **32.74 mg/**l, fluctuating between a maximum of **43.6 mg/**l recorded in March and a minimum of **24.92 mg/l** recorded in July. These values are outside **AS** and **WHO** standards. The decrease can be attributed to nitrogen consumption from the biomass of plant residues, with factors affecting nitrogen –fixing bacteria growth (substrate content, temperature, dissolved oxygen, and **PH**. Explaining the decrease in ammonia levels with increasing temperature, while simultaneously correlating with an increase in **pH**.

Table (IV. 26): Monthly variation of **NH_4^+**at raw and treated water from the **WWTP** of Ouargla.

Month / Parameter		JAN	FEB	MAR	APRIL	MAY	JUNE	JULY	AUG	SEPT	OCT	NOV	DEC
$NH4^+$ (mg/l)	in	34.4	21.4	31.2	39.28	25.4	29.2	31.75	24.2	30.4	30.36	36.8	33.4
$NH4^+$ (mg/l)	out	35.8	30.51	43.6	42.3	29.6	27.8	24.92	25.2	29.8	29.8	35.4	38.2
Standard (WHO)		0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5

Table (IV. 27): Monthly yields of **NH_4^+** at **WWTP** of Ouargla.

MONTH	JAN	FEB	MAR	APRIL	MAY	JUNE	JULY	AUG	SEPT	OCT	NOV	DEC
Yield $NH4^+$ (%)	4,06	-42,6	-39,4	-7,7	-16,5	4,7	21,5	-4,13	1,97	1,84	3,8	-14,3

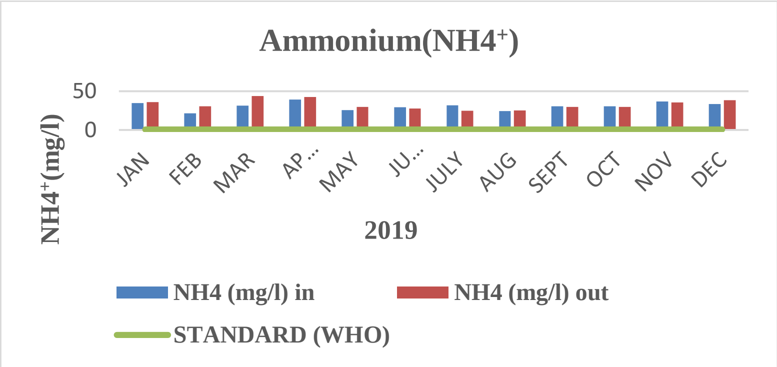
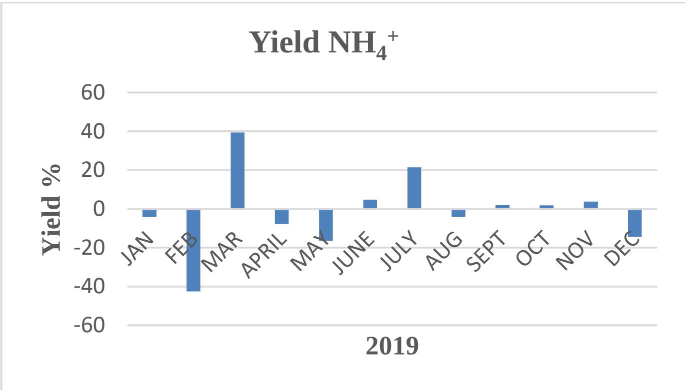


Fig (IV. 14): **a-** Monthly variation of **NH_4^+**at raw and treated water from the **WWTP** of Ouargla.



b- Monthly yields of **NH_4^+** at **WWTP** of Ouargla.

IV.4.15. Identifying heavy metal pollution:

The presence of heavy metals in urban wastewater is significant, they can exist in the form of ions and organic and inorganic groups in solutions or absorbed in sediments or airborne particulates **[8]**.

Regular supply of unstable wastewater can lead to the accumulation of essential trace elements for plant and animal growth, such as iron, manganese, zinc, copper, boron and molybdenum. Wastewater also brings other toxic metals to the station, such as lead, chromium, cadmium, mercury, and aluminum **[9]**.

Table (IV. 27) illustrates the average concentration of various heavy metals present in the water, such as lead; cadmium, copper, chromium, and nickel, contained in water are recorded, residual and purified waste from the **WWTP** in the period **(2019).**

Table (IV. 28): Monthly variation of heavy metals in raw wastewater and treated effluent from the **WWTP** of Ouargla.

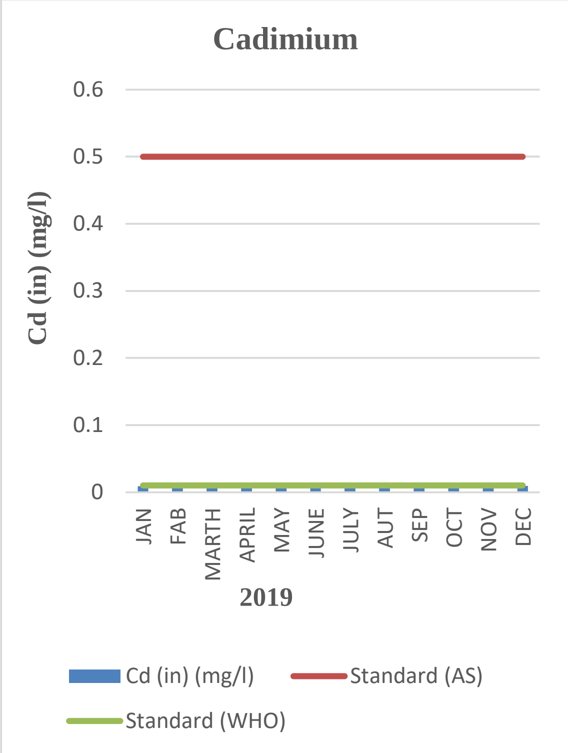
Variation	Cd	Cu	Pb	Cr	Ni
Input (mg/l)	0.0454 - 0.0555	0.0198 - 0.0263	0.00190 - 0.00300	0.00893 - 0.00946	0.00390 - 0.00510
Output (mg/l)	0.008737-0.009560	0.106-0.220	0.00180-0.0320	0.001000-0.001210	0.2109-0.2500
Average (in) (mg/l)	0.0501	0.0230	0.00234	0.00920	0.00409
Average (out)(mg/l)	0.008994	0.167	0.00235	0.001137	0.2197
AS	0.5	5	10	1	2
WHO	0.01	0.2	5	0.1	0.2

a. Cadmium Variations (Cd):

Cadmium is considered one of the highly toxic heavy metals that accumulate in living organisms through the food chain. One of the most tragic water pollution incidents involving cadmium is associated with contaminated water used for irrigating rice paddies. Many peoples have died as a result of cadmium accumulation in the body **[10].**

The results indicate that the Cadmium contents in raw water range from **0.0454 mg/l** the lowest recorded value was in June to **0.0555 mg/l** the highest recorded value was in October, with an average of **0.0501 mg/l**, these value are higher than those found in another study on the Aerated lagoons process in Ismailia **(Egypt)** (**0.0003 mg/l)** **[11].**

Regarding treated liquid waste, the cadmium values recorded are much lower than the average raw water **0.008994 mg/l**, ranging between **0.008737 mg/l**, the lowest value was recorded in July and **0.009560 mg/l**, the highest value was recorded in December. These value are within **AS (2012)** and **WHO (1971).**



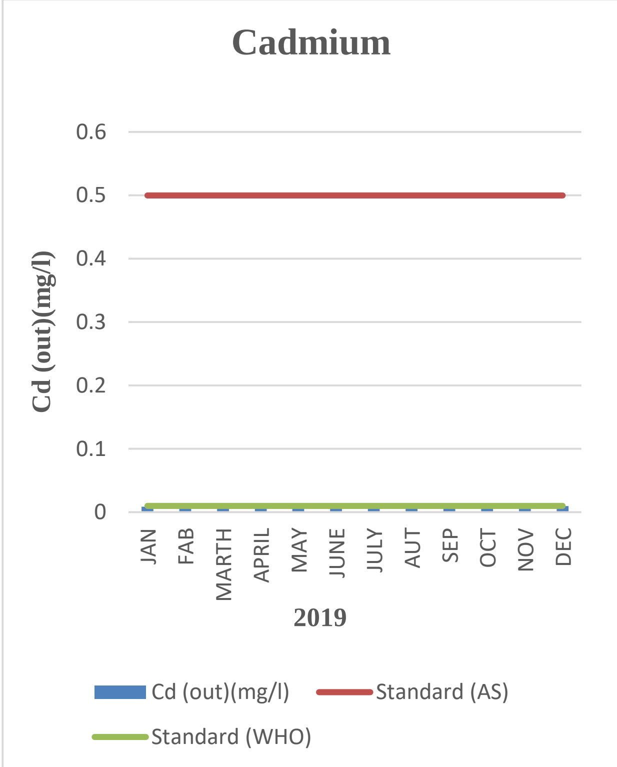


Fig (IV. 15): a. Monthly variations of Cadmium in raw water from WWTP of Ouargla	**b.** Monthly variation of Cadmium in treated water from WWTP of Ouargla

b. Copper variations (Cu):

The values of copper concentrations in raw water show fluctuations of this parameter between **0.00198 mg/l**, the lowest recorded value in April and **0.0263 mg/l**, the highest recorded value in February, giving an average of **0.0230 mg/l** for the year **2019**. These value were lower than those found in another study of water originating from domestic and industrial discharges in the city of Batna, Wadi Al-Furzy, which were **2.29 mg/l [12].**

The increase in copper content in wastewater is attributed to discharges from industrial activities such as textile manufacturing, tanning, and battery production. This is one of the waste disposal methods found in large quantities in urban waste, with levels ranging from **0.01 to 0.75 mg/l [12, 13].**

As for treated water, the copper concentration fluctuates between **0.110 mg/l,** the lowest recorded value in October, and **0.220 mg/l,** the highest recorded value in December, with an average of **0.167 mg/l** throughout the year. These values confirm the ineffectiveness of air basins in reducing copper levels in treated water. However, these values obtained fall within the standard of **(AS)** and **(WHO)** (see appendix). Therefore, the clean water from the Saïd Otba station is suitable for irrigation purposes.

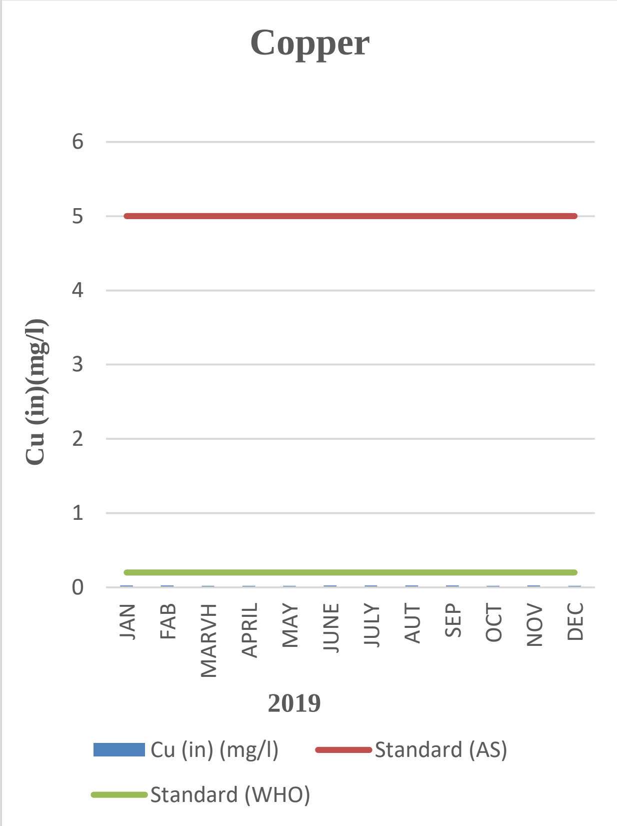
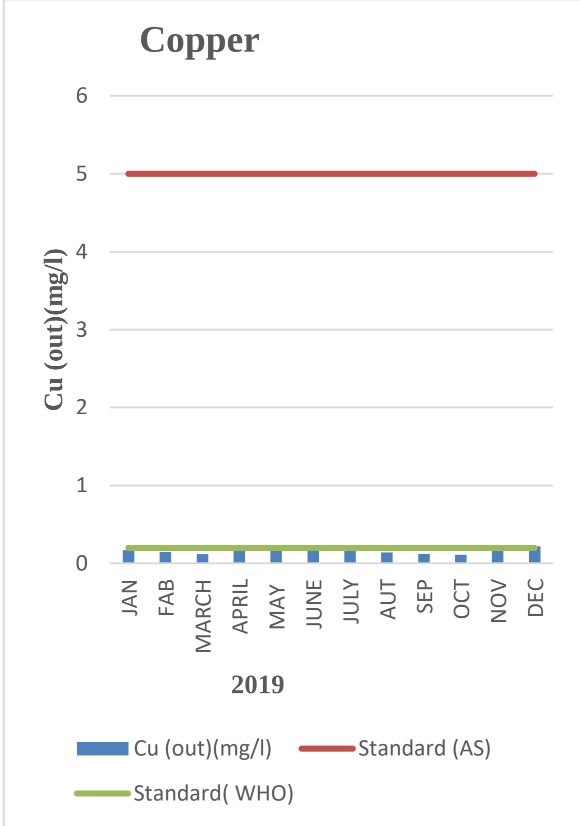
	

Fig (IV. 16): a. Monthly variations of Copper In raw water of **WWTP** of Ouargla	**b.** Monthly variation of Copper in treated water of **WWTP** of Ouargla.

b. Lead variations (Pb):

The concentration of lead range between **0.00190 mg/l,** the lowest recorded value in April, and **0.00300 mg/l,** the highest recorded value in May, with an average of **0.00230 mg/l**. These values are lower than those found in another study on the air basin process in Ismailia **(Egypt 0.02 mg/l) [11].** The treated water had a range of **0.00180 mg/l** lowest recorded value in April to **0.00320 mg/l** highest recorded value in May, with an average of 0.00235 mg/l. These values are lower than the standards set by the **(AS) (2012)** and **(WHO) (1971) (see appendix).** As a result, the purified water from the Saïd Otba station is suitable for irrigation purposes. According to **(Cadillon 1989),** lead is naturally present in small quantities and contributes to environmental pollution. Its solubility is higher at a lower acidity level **pH< 7**. The increase in water temperature helps in the dissolution of lead <and the poor condition of the wastewater networks has contributed to the enrichment of this water with this element.

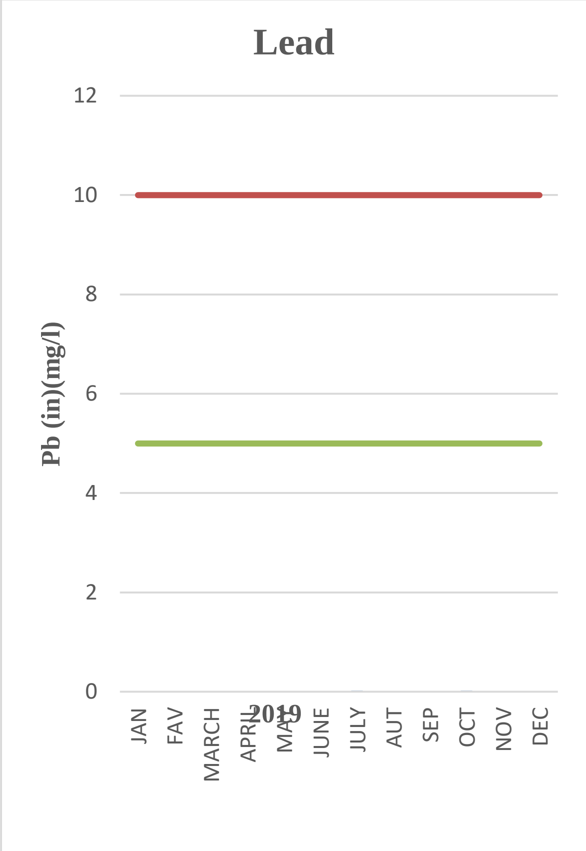
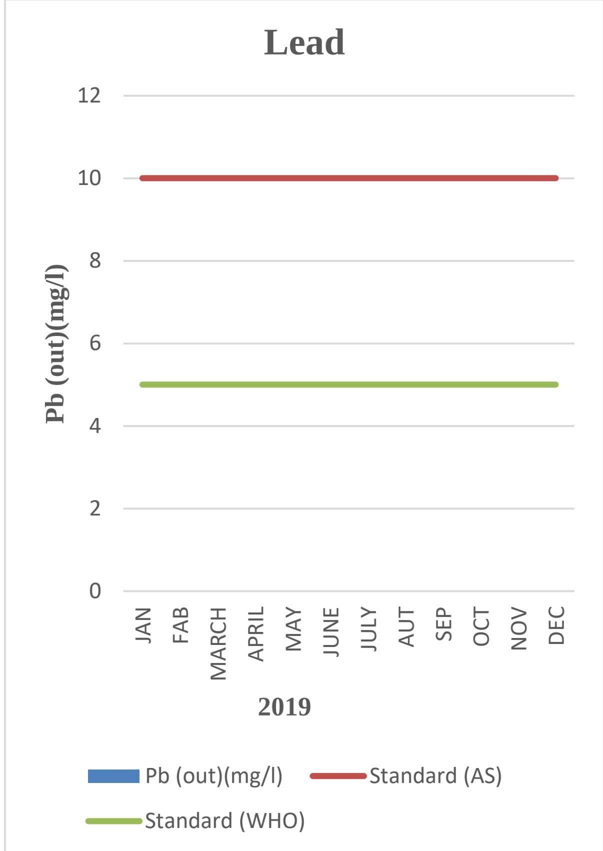


Fig (IV. 17): a. Monthly variation of Lead in raw Water of WWTP of Ouargla.



b. Monthly variation of Lead in treated water of WWTP of Ouargla.

c. Chromium variation (Cr):

The obtained results indicate a variation in the concentration of total Chromium in raw water, ranging from **0.00893 mg/l** as the lowest recorded value in March to **0.00946 mg/l** as the highest recorded value in June, with an average of **0.00920 mg/l**. These values are slightly higher than those found in another study on aerated lagoon in Ismailia **(Egypt) (0.005 mg/l) [11].** This may be attributed to the importance of discharges from flour manufacturing plants, surface treatment workshops, domestic liquid waste, and surface runoff in urban areas, tanneries, and so on. At the same time, the concentration of Chromium in the treated water range from **0.001000 mg/l** the lowest recorded value in March to **0.001210 mg/l** with an average of **0.001137 mg/l** throughout the year.

Removing Chromium from wastewater does not pose any difficulties, especially using chemical precipitation treatments, which means there is no radioactive contamination **[14].**

Therefore, the values obtained within **(AS) (2012)** and **(WHO) (1971)** indicate that the water purified from the plant is suitable for agricultural irrigation.

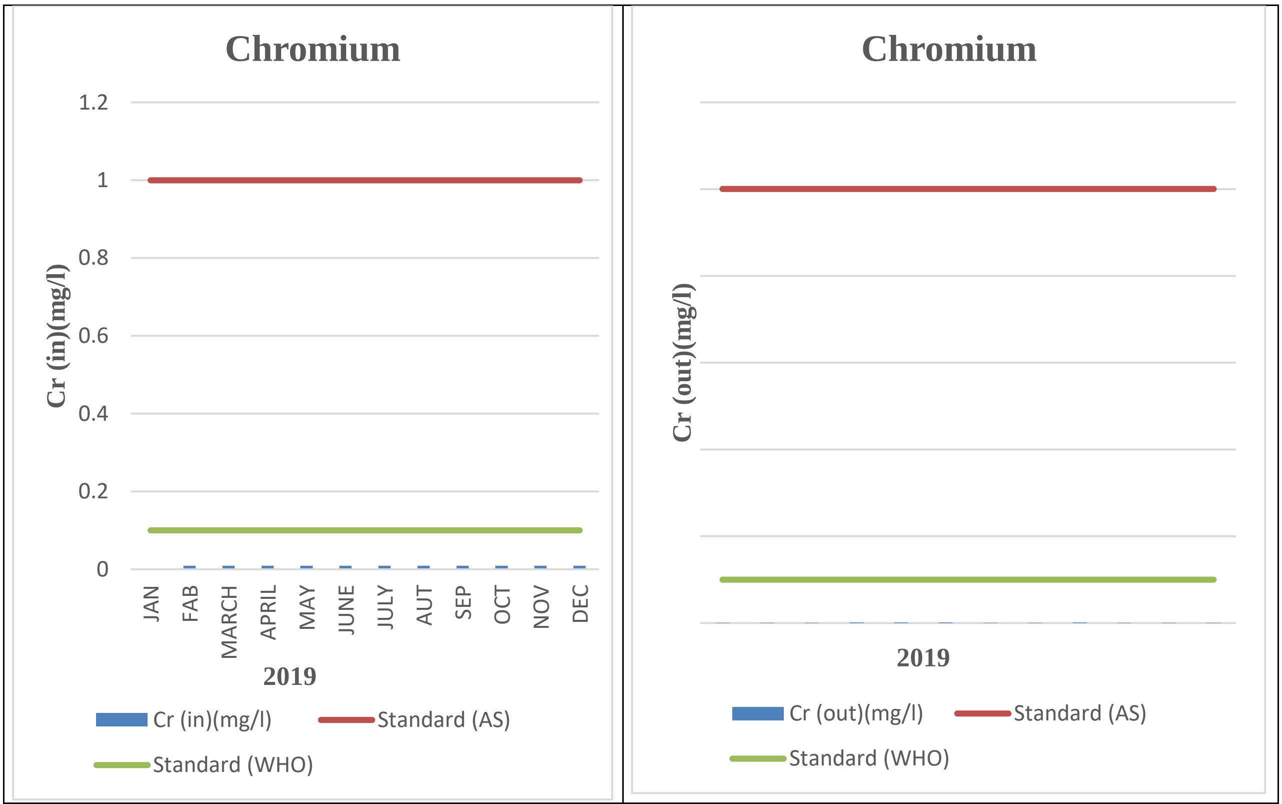
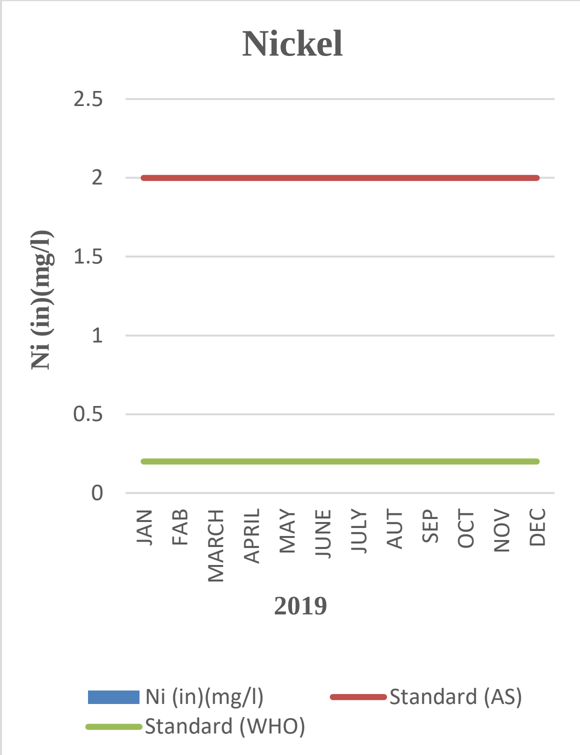


Fig (IV. 18): a. Monthly variation of Chromium in Raw water of **WWTP** of Ouargla. **b.** Monthly variation of Chromium in treated water of **WWTP** of Ouargla

d. Nickel variations (Ni):

The results indicate that Nickel concentration in raw water ranged from **0.00390 mg/l**, the lowest recorded value in May, to **0.00510 mg/l**, the highest recoded value in September, with an average of **0.00409 mg/l**. These concentrations were slightly lower than those obtained in Ismailia **(Egypt) (0.0057 mg/l)** **[11].**

The treated water shows a noticeable increase in Nickel concentration ranging from **0.2109 mg/l** as the lowest recorded value in July to **0.2500 mg/l** as the highest recorded value in October with an average of **0.2197 mg/l** throughout the year. Therefore, the values obtained fall within the limits set by the **(AS) (2012)** and **(WHO) (1971)** standards. As a result, the water purified from the Saïd Otba station is suitable for irrigation purposes. According to (McClatchy, 1992; Boyd, 1992) Nickel (dissolved and in particle form) is introduced into the aquatic environment through liquid waste, filtered materials, and deposition from the atmosphere after being released from human sources **[15]**.



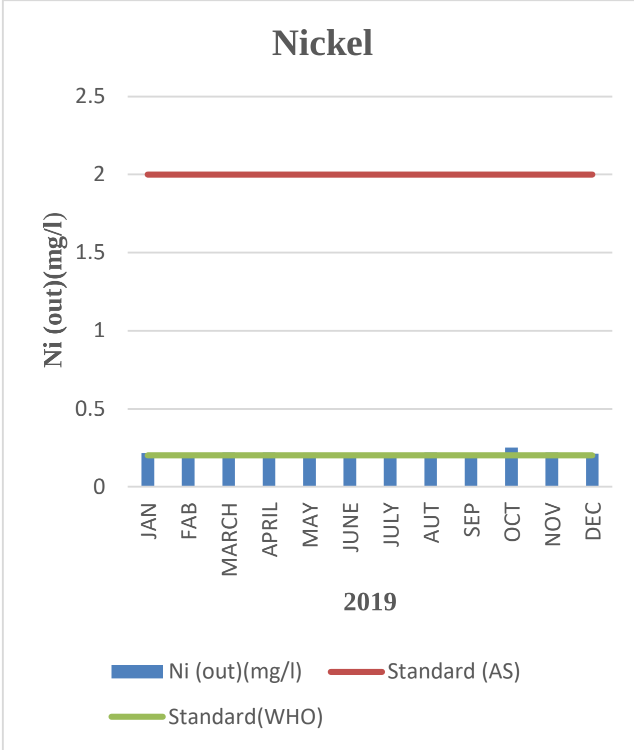


Fig (IV.19):a. Monthly variation of Nickel in raw water of **WWTP** of Ouargla

b. Monthly variation of Nickel in treaded water of **WWTP** of Ouargla

IV.5. Assessment of the quality of treated wastewater by the water quality index (WQI)

In this study, the quality of purified water was evaluated using the **WQI** method. Indeed **9** important parameters in the study of water quality (***pH, T, EC,*** $N - NO_2^-$***,N-***NO_3^-***, , SS, COD,*** BOD_5***, TP).*** Were selected to calculate the Water Quality Index.

IV.5.1. Results of the WQI calculation and water quality assessment:

The relative weight **(Wi)** of each physico-chemical parameter and the constant of proportionality **(k)** are first calculated using the maximum values of the Algerian standard.

Table (IV.29): The annual average of the parameters physico-chemical.

Parameters	T	EC	pH	NO2-	NO3-	SS	COD	BOD	TP
Average (mg/l)	22.63	26.96	7.65	0.14	0.39	85.62	113.62	40.30	3.36

Table (IV.30): Weight of physico-chemical parameters according to the Algerian standard.

Parameters Physico-Chemical	*Unit*	*Algerian Standard*	*Si (value Max Standard Algerian*	*1/ Si*	*K*	*Wi (relative point) Wi= K/Si*
T	°C	30	30	0.033	0.093	0.030
EC	mS/cm	30	3	0.333	0.093	0.030
pH	mg/l	6.5 – 8.5	8.5	0.117	0.093	0.010
NO_2^-	mg/l	0.1	0.1	10	0.093	0.930
NO_3^-	mg/l	30	30	0.033	0.093	0.030
SS	mg/l	35	35	0.028	0.093	0.026
COD	mg/l	90	90	0.011	0.093	0.010
BOD	mg/l	35	35	0.028	0.093	0.026
TP	mg/l	10	10	0.1	0.093	0.0093

K: proportionality constant

$$K = \frac{1}{\sum_{i=1}^{n}(1/S_i)}$$ There fore $$\sum_{i=1}^{n}(1/S_i) = 10.383$$

Then **K = 1/ 10.38** **K = 0.096**

IV.5.2. Numerical application:

Calculating the water quality index for purified wastewater. To calculate this, I used the annual average for each characteristic

Table (IV.31): WQI result.

Parameters Physico-chemical	K	Ci(mg/l)	Si	Qi= (Ci/Si) ×100	Wi (relative weight)	Qi× *Wi*
T	0.093	22.63	30	75.43	0.030	2.26
EC	0.093	26.96	3	898.66	0.030	26.95
pH	0.093	7.65	8.5	90	0.010	0.9
NO_2^-	0.093	0.14	0.1	140	0.930	130.2
NO_3^-	0.093	0.39	30	1.3	0.030	0.039
SS	0.093	85.62	35	244.62	0.026	6.360
COD	0.093	113.62	90	126.24	0.010	1.287
BOD	0.093	40.30	35	115.24	0.026	2.993
TP	0.093	3.36	10	33.6	0.0093	3.124
Total					$\sum(Wi)= 1.1013$	$\sum(Qi \times Wi) = 149.858$

WQI of the wastewater treatment is:

$$WQI = \frac{\sum_{i=1}^{n}(Qi \times Wi)}{\sum_{i=1}^{n} Wi} = 136.07$$

WQI > 100

(This obtained value is due to the high percentage of salinity in the water, and therefore the latter needs further treatment in order to become suitable for agricultural irrigation).

Table (IV.32): Standards used to measure water quality.

WQI value	Water quality	Purpose of uses
0 - 25	**Excellent /A**	**Irrigation**
26 -50	**Good /B**	**Irrigation**
51 - 75	**Regular /C**	**Irrigation**
76 - 100	**Poor /D**	**Attention to irrigation**
>100	**So poor /E**	**Not suitable for irrigation**

WHO, 2018 ; Janshidzadeh and Barzi, 2020 **[16].**

IV. 6. Multivariate statistical study (Physico- chemical):

IV. 6.1. Matrix correlation variable (Physico- chemical) :

The relationships between all variables taken two by two and the correlation coefficients between these different variables are obtained through the correlation matrix **(Table IV.29).** Variables that show the coefficient of **r** > **0.7** strongly correlation while variables that have a coefficient **r** between **0.5** and **0.7** and **r** **<0.5** moderate and weak correlations appear respectively **[17].** Table **(IV.29)** that temperature **T** strongly associated with **pH** **(r =0.7433)** and a lower degree with **COD** **(r = 0.5510)** and weak with ammonium **NH_4^+** **(- 0.7182).** Electrical conductivity **EC** is related less strongly with salinity **Sal** **(r = 0.5299)** and weakly with **BOD_5** **(r = - 0.0342)**. Salinity **Sal** is strongly correlated with Orthophosphorus **PO_4^3** **(r = 0.7445)** and Suspended solids **SS** **(r = 0.7322)**. **pH** has a weak correlation with ammonia NH_4^+ **(r = - 0.6323)**. NO_3^- has a weak correlation with PO_4^{3-} **(r = 0.3939). $PO4^{3-}$** has a weak correlation with **TN (r = 0.4753). NH4+** moderately correlates with **TN (r = 0.5054).**

Table (IV.33): Correlation matrix for the physico-chemical parameters of treated water.

Variables	**T**	**EC**	**SAL**	**pH**	**$O_{2\ diss}$**	**NO_2^-**	**NO_3^-**	**PO_4^{3-}**	**SS**	**COD**	**BOD_5**	**NH_4^+**	**TN**
T	**1**												
EC	0.0779	**1**											
SAL	-0.2216	**0.5299**	**1**										
pH	**0.7433**	-0.0146	-0.3234	**1**									
$O_{2\ diss}$	-0.3669	-0.0095	-0.4243	0.1960	**1**								
NO_2^-	-0.1686	-0.4037	-0.2958	-0.1921	-0.0244	**1**							
NO_3^-	0.2806	0.4063	0.3069	0.3754	0.1026	-0.1133	**1**						
PO_4^{3-}	-0.1916	0.1749	**0.7445**	-0.3272	-0.4157	-0.0194	**0.3939**	**1**					
SS	0.0479	0.4413	**0.7322**	-0.1724	-0.5407	-0.1577	0.1729	0.4226	**1**				
COD	**0.5510**	0.1232	-0.4084	0.2740	-0.2072	-0.0959	-0.0563	-0.4657	0.1628	**1**			
BOD_5	0.2548	**-0.0342**	0.2031	-0.1268	-0.5417	-0.3506	0.1222	0.4373	-0.0219	-0.0397	**1**		
NH_4^+	-0.7182	0.2843	0.4015	**-0.6323**	0.1614	0.0734	-0.1232	0.4630	-0.0980	-0.5715	-0.0514	**1**	
TN	-0.1138	0.3102	0.4143	-0.1506	-0.2826	0.2129	-0.0648	**0.4753**	0.3403	-0.0425	-0.0963	**0.5054**	**1**

Values in bold are different from 0 with a significance level alpha=0.05

IV.6.2. Principal component analysis (Physico- chemical):

Kaiser's **[18]** criterion is used to determine the total number of factors that can summarize the entire dataset. According to this criterion, eigenvalues greater than or equal to 1 are accepted as sources of potential variance in the data.

Table (IV.34): Distribution of inertia between the two axes (**F1×F2**) of the physico-chemical parameters measured ion the Wastewater treatment steps of **Saïd Otba – Ouargla**.

	F1	**F2**
Eigenvalue	**3.8540**	**2.9006**
Variability (%)	**29.6465**	**22.3123**
Cumulative %	**29.6465**	**51.9588**

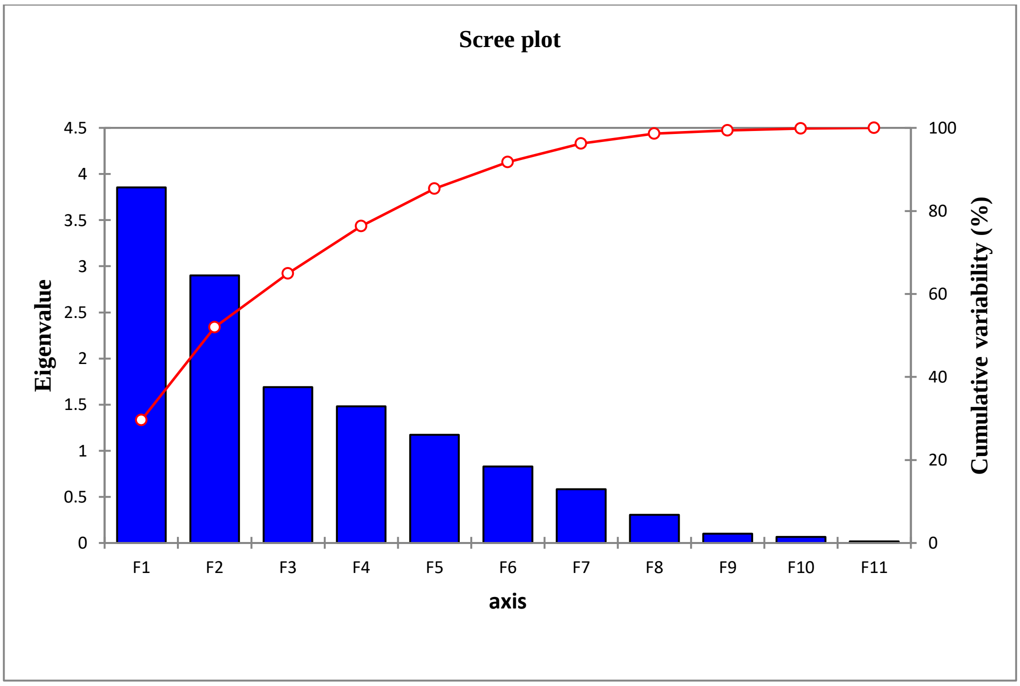
Table (IV.35): Correlations between variables and factors.

	F1	F2
T(out)(mg/l)	-0.4716	0.7915
EC(out)(mg/l)	0.4337	0.3989
SAL(out)(mg/l)	0.8911	0.3098
PH(out)(mg/l)	-0.6001	0.4845
O2 dis(out))mg/l)	-0.3590	-0.5574
NO2(out)(mg/l)	-0.0735	-0.4396
NO3(out)(mg/l)	0.1467	0.4784
PO4(out)(mg/l)	0.8396	0.1826
SS(out)(mg/l)	0.5449	0.5378
COD(out)(mg/l)	-0.4911	0.4898
BOD5(out)(mg/l)	0.2251	0.4102
NH4(out)(mg/l)	0.7067	-0.5658
TN(out)(mg/l)	0.5834	0.0241

The two axes represent **F1** and **F2** (**51.96 %)** of the total variance (**Figure IV.19 A**), the area of the variables of the two-world chart **F1-F2** (**Figure IV.19 B**) shows that this chart expresses **51.96 %** of the total variance. The factor **F1** expresses the greatest variance (**29.65 %**) and is negatively related to **pH** **(- 0.6001)**, **COD** **(-0.4911)**, **T** **(-0.4716)** and to a lesser extent **O_2** (**-0.3590**) and **NO_2** (**-0.0735**) and the **F1** axis shows the source of the pollutant load of raw water due to organic contamination as well as nitrogen contamination. It reflects the pollution resulting from domestic or urban discharge of liquid waste reaching the Waste Water Treatment Plant. **F1** has a strong positive correlation with **NH_4^+(0.7067)**.

The F2 factor accounts for **22.31 %** of the total variance and shows a strong negative correlation with **O_2** (**-0.3590**) and **NO_2^-** (**-0.0735**) and positively with **Sal** (**0.9811**) and **PO_4^{3-}** (**0.8396**). The F2 axis can be considered as an axis that characterizes the removal process phosphorous.

A



B

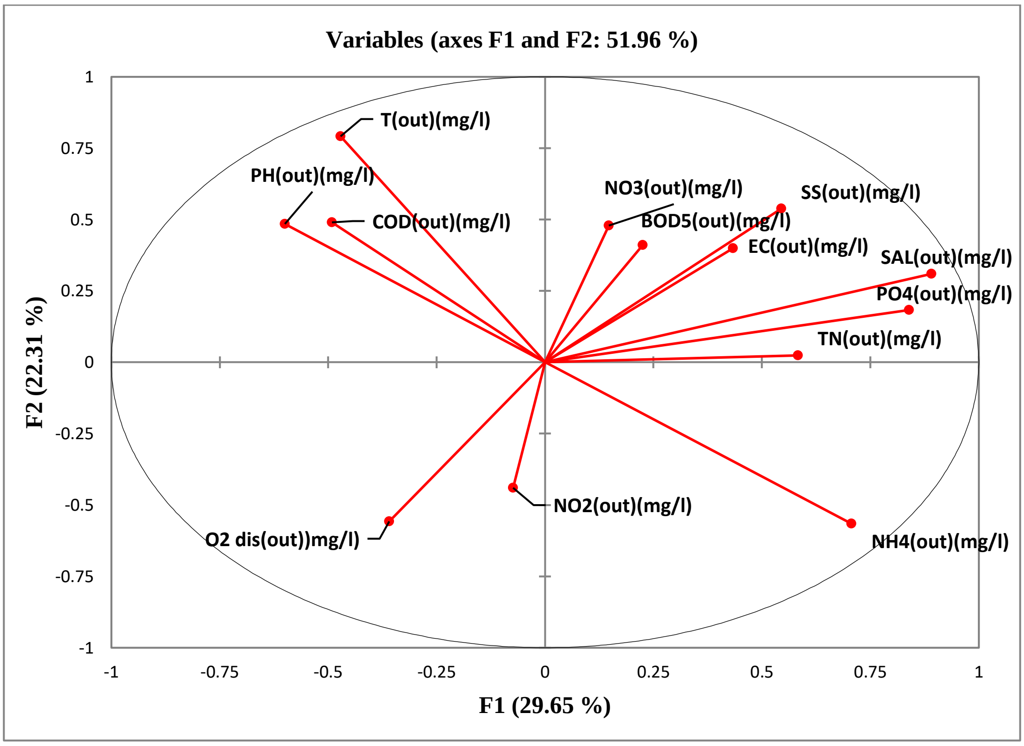


Fig (IV.20): Graphical approach to the **PCA** of physico-chemical parameters in water according to the plan **(F1×F2). A**: Distribution of inertia between the axes; **B**: Factorial map of variables.

IV. 7. Multivariate statistical study (Heavy metals):

IV. 7.1. Matrix correlation variable (Heavy metals):

The relationships between all variables taken two by two and the correlation coefficients between these different variables are obtained through the correlation matrix **Table (IV.31).** Variables that show the coefficient of **r** > **0.7** strongly correlation while variables that have a coefficient **r** between **0.5** and **0.7** and **r** <**0.5** moderate and weak correlations appear respectively **[16]. Table (IV.32)** showing a strong relationship between **Cr** and **Cd** **(r= 0.4605)** and **Cu** **(r= 0.4631)**. **Cd** it has a strong relationship with **Cu** **(r= 0.5265)** and a negative relationship with **Pb** **(r= -0.3087)** and **Ni** **(r= -0.5037).**

Table (IV.36): Correlation matrix for the heavy metals parameters of treated water.

Variables	Cr	Cd	Pb	Cu	Ni
Cr	**1**				
Cd	**0.4605**	**1**			
Pb	0.1262	**-0.3087**	**1**		
Cu	**0.4631**	**0.5265**	0.0357	**1**	
Ni	-0.1137	**-0.5037**	-0.0405	-0.4412	**1**

IV.7.2. Principal component analysis (Heavy metals):

Table (IV.37): Distribution of inertia between the two axes (**F1×F2**) of the physico-chemical parameters measured ion the Wastewater treatment steps of **Saïd Otba – Ouargla**.

	F1	F2
Eigenvalue	**2.2823**	**1.1539**
Variability (%)	**45.6455**	**23.0788**
Cumulative value %	**45.6455**	**68.7243**

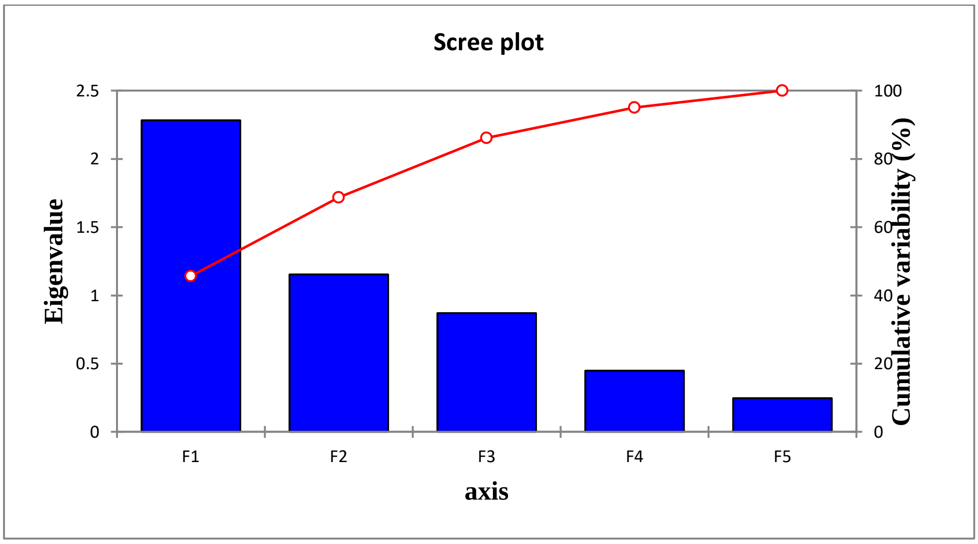
Table (IV.38): Correlations between variables and factors.

	F1	F2
Cr(out)(mg/l)	**0.6517**	**0.3530**
Cd(out)(mg/l)	**0.8560**	**-0.3116**
Pb(out)(mg/l)	**-0.0981**	**0.9500**
Cu(out)(mg/l)	**0.8151**	**0.1721**
Ni(out)(mg/l)	**-0.6714**	**0.0155**

The two axes represent **68.72 %** of the total variance in figure **(IV.20 A)**, while the scatter of variables in the factorial map **F1-F2** in figure **(IV.20 B)** indicates that this map accounts for 68.72 % of the total variance. Factor **F1** represents the largest variance of 45.65 % and is negatively correlated with **Ni** **(-0. 6714)** and to a lesser extent with **Pb** **(-0.0981).**

Factor **F2** represents **23.08 %** of the total variance. It is negatively correlated with **Cd** **(-0.3116)** and strongly positively correlated with **Pb** **(0.9500),** while showing a negative correlation with **Cd** **(-0.3116).**

A



B

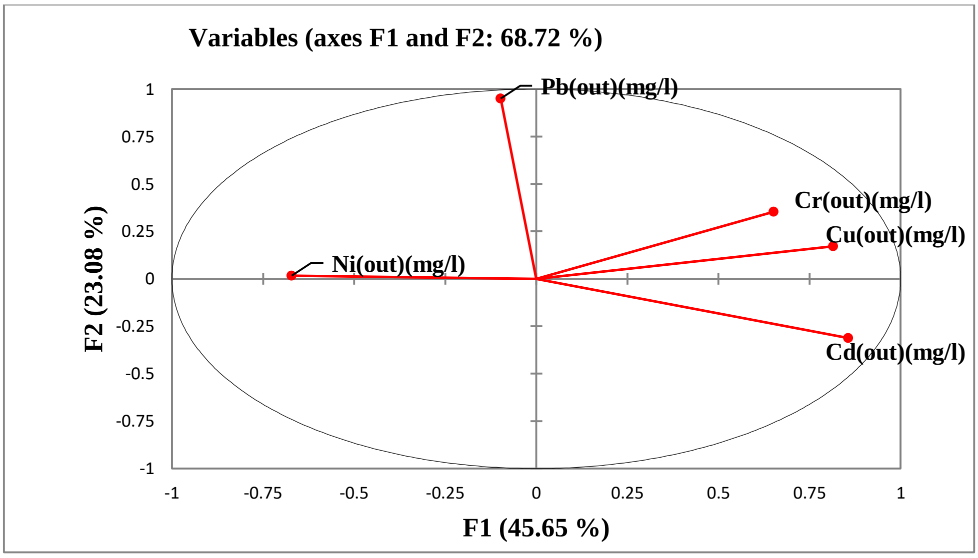


Fig (IV.21): Graphical approach to the **PCA** of heavy metals parameters in water according to the plan **(F1×F2). A**: Distribution of inertia between the axes; **B**: Factorial map of variables.

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General Conclusion

General conclusion:

A field study conducted throughout the year **2019** (from January to December) aimed at evaluating the efficiency of the water treatment plant in Saïd Otba on Ouargla, which operates using the constructed wetlands system. The study tracked the reduction of general pollutants for organic matter (**S**uspended **S**olid, **C**hemical **O**xygen **D**emand, **B**iochemical **O**xygen **D**emand in five days, **D**issolved **O**xygen) and some physical factors such as **pH**, **E**lectrical **C**onductivity, Temperature, and Salinity, as well as nitrogenous compounds (**A**mmonium, **N**itrate, **N**itrite, **T**otal **N**itrogen) and phosphorus compounds (**O**rthophosphate, **T**otal **P**hosphorus), comparing the obtained results with **AS** and **WHO** applied in irrigation.

During this study, the average removal rates of pollutants were recorded as follows: Chemical Oxygen **70.44 %**, Suspended Solids **45.86 %**, Ammonium **- 6.58 %**, Nitrate with an average of **24.52 %,** Total Nitrogen with an average of **57.44 %,** Total Phosphorus yield with an average of **22.70 %,** and Orthophosphate yield with an average of **26.06 %.** On the other hand, these results indicated that this system is affected by climate variations and algae proliferation in the basins. It was also observed that the concentration of heavy metals in raw and treated water complies with **AS** and **WHO** for reclaimed water used for irrigation purposes.

Overall, most pollution factors comply with **AS** and **WHO** for treated water intended for irrigation purposes. The only factor that exhibited significantly high values is electrical conductivity, meaning salinity, which greatly exceeds **AS** and **WHO**.

Two additional methods were conducted for this study:

- ***Water Quality Index (WQI):***

The **W**ater **Q**uality **I**ndex is a highly useful tool for making informed decisions and assessing water quality. Calculating the **WQI** for treated wastewater indicates that the water quality at the plant is unsuitable for irrigation, surpassing the permissible limits in the **WQI** standards with a value of:

$$WQI = 136.07 > 100$$

Primarily due to the salinity of the water.

- ***Statistical Study:***

Principal Component Analysis **(PCA)** enabled the distinction between two main axes, **F1** and **F2**, which collectively represent **51.96 %** of the information. Axis **F1 (29.65 %)** is defined by **NH_4^+, SS**, **SAL**, with lesser association with **pH**, **COD**, **Diss O_2**, **NO_2^-**. Axis **F2 (22.31 %)** is defined by **SAL**, **PO_4^{3-}**, with lesser association with **Diss O_2**, **NO_2^-**. The application of **PCA** indicates that the chemical composition of pollutant loading in raw wastewater is dominated by organic matter, nitrogen compounds, and phosphates. As for heavy metals, **F1** and **F2** represent **68.72 %** of the total variance. **F1** represents the larger variance at **45.65 %** and is negatively associated with **Ni** and to lesser extent with **Pb**, while positively associated with **Cd**, **Cu**, and **Cr**. **F2 (23.08 %)** of total variance is negatively associated with Cd and positively associated with **Pb**, with lesser associated with **Cr**.

Some recommendations and future prospects:

- Searching for a solution to the problem of the presence and proliferation of algae in ponds, which negatively affects the efficiency of removal pollutants.
- Establishing new pipes to separate water entering from urban areas and water coming from factories.
- Providing the plant with more aeration basins to ensure better treatment.
- Providing the city with other wastewater treatment plants with an aerated lagoon system.

Appendices

Fig 1 : Vaccum

Fig 2 : Oxymeter

Fig 3 : Conductivity meter

Fig 4 : Refrigerator, Bottles and OXYTOP

Fig 5 : Balance

Fig 6 : Filtration unit with vacuum Pump

Fig 7 : COD reactor

Fig 8 : pH- meter

Fig 9 : Spectrophotometer

Fig 10 : COD reagents

Table 1: Overal results of physico-chemical analyzes of the Ouargla station during 2019

Month / Parameteres		Jan	Fab	March	April	May	June	July	Aug	Sep	Oct	Nov	Dec
Temperature (°C)	Input	20.75	19.36	22.22	24.5	28.6	30.35	33.10	31.82	30.08	28.54	23.27	21.63
	Output	17.79	15.68	18.57	21.55	25.38	28.76	31.70	28.84	25.96	23.62	18.19	15.52
Conductivity (mS/cm)	Input	23.63	37.17	38.83	49.78	15.64	40.86	27.20	20.95	15.01	16.89	41.80	11.93
	Output	22.30	28.63	36.95	45.28	15.28	43.28	37.20	16.21	15.20	15.28	34.88	13.07
Salinity (mg/L)	Input	10236.5	25765	24828.5	34013.6	9211	24155	16900	13031.8	9414.2	10136.3	23.86	7500
	Output	13309	25685	23166.6	30818.1	8985.7	27980	237	9622.7	8960	8968.1	21.74	7810
pH	Input	7.31	7.26	7.29	7.43	7.70	7.30	7.30	7.31	7.45	7.52	7.51	7.28
	Output	7.26	7.32	7.39	7.48	7.97	8.02	7.78	7.99	7.66	7.64	7.85	7.48
O_2 dissolved (mg/L)	Input	0.75	0.88	1.88	0.96	0.70	0.36	0.47	0.26	0.90	0.59	1.01	1.90
	Output	1.79	1.35	1.31	0.83	1.99	1.83	1.02	1.00	1.90	1.39	6.02	2.83
	Yield %	58.10	34.81	30.31	13.54	64.82	80.32	53.92	38	52.63	50.77	83.22	32.86
$N\text{-}NO_2$ (mg/L)	Input	0.25	0.25	0.12	0.02	0.11	0.09	0.15	0.06	0.13	0.90	0.23	0.16
	Output	0.08	0.06	0.06	0.11	0.05	0.07	0.19	0.05	0.09	0.42	0.04	0.50
	Yield %	80	76	50	/	54.5	22.2	/	16.6	30.76	53.33	82.6	/
$N\text{-}NO_3$ (mg/L)	Input	0.90	0.77	0.19	0.46	0.18	1.27	0.70	0.21	0.59	0.20	0.66	0.25
	Output	0.27	0.02	0.52	0.06	0.15	1.98	0.32	0.12	0.42	0.04	0.37	0.47
	Yield %	70	97.4	/	86.9	16.66	/	54.28	42.8	55.7	80	43.9	/
PO_4^{3-} (mg/L)	Input	3.92	4.06	3.00	5.04	3.28	3.62	3.54	2.20	0.33	1.62	4.48	4.46
	Output	2.92	2.33	3.13	3.73	2.16	3.63	1.11	2.14	2.76	1.41	0.70	3.30
	Yield %	25.5	42.61	/	25.99	34.1	/	68.6	2.72	/	12.9	84.37	26
SS	Input	263	281	154	216	157	154	161	112.5	109	91	82	117.67
	Output	61	165	67.50	133.5	78.67	130.50	94	65.67	69	67.67	28	67
	Yield %	76.8	41.2	56.1	38.1	49.8	15.24	41.6	41.6	36.6	25.63	65.85	43.06
COD (mg/L)	Input	450	561	531	304	314.3	353.2	387.5	359	324	262.93	460	307.33
	Output	106	120.10	97.5	93.5	137.8	109.4	190.15	102.87	109.07	100.73	102	94.40
	Yield %	76.4	78.5	81.6	69.2	56.15	69.02	50.92	71.34	68.25	61.6	77.8	69.2
BOD_5 (mg/L)	Input	143.3	200	200	100	126.67	205	140	160	153.3	195	90	95
	Output	66.67	30	48	40	35	45	40	58.67	44	28	18.33	30
	Yield %	53.47	85	76	60	72.36	78.04	71.4	63.33	71.2	85.64	79.6	68.4
$N\text{-}NH_4^+$ (mg/L)	Input	34.4	21.4	31.27	39.28	25.4	29.20	31.75	24.2	30.40	30.36	36.80	33.40
	Output	35.8	30.51	43.6	42.3	29.6	27.8	24.92	25.20	29.8	29.8	35.4	38.20
	Yield %	/	/	/	/	/	4.7	21.5	/	1.97	1.84	3.80	/
	Input	60.6	48.8	52.2	125.5	35.40	52.6	52.6	48.60	34.90	96.40	48.20	67.20

Table 1: **Extreme standards limited to irrigation water**

Parameteres	Discharge limit values for l'irrigation (FAO, 2003)	Discharge limit for l'irrigation (OMS, 1989)
Temperature (°C)	35	
pH	6.5 -8.5	6.5 -8.5
Electrical Conductivity (mS /cm)	3	< 3
SS (mg/l)	/	< 30
COD (mg/l)	/	< 40
BOD_5 (mg/l)	< 25	< 30
NO_3^- (mg/l)	/	< 50
NO_2^- (mg/l)	< 3	< 1
PO_4^{3-} (mg/l)	/	< 0.94
NH_4^+ (mg/l)	< 3	< 2
Azote kjeldahl	/	/
Azote total (mg/l)	< 50	< 50
Phosphore total (mg/l)	/	/
Phosphates (mg/l)	< 0.2	< 0.2

Table 2: **WHO physico-chemical discharge standards**

Characteristic	Unit	Standard used
pH	-	6.5 -8.5
BOD_5	mg/l	30
COD	mg/l	90
SS	mg/l	30
$O_{2\ dissolved}$	mg/l	5
Zinc	mg/l	2
Chrome	mg/l	0.1
total Azote	mg/l	50
Temperature	°C	30
Phosphates	mg/l	2
Detergent	mg/l	1

Table 3: Specifications of treated wastewater used for irrigation purposes (Algerian Official Journal N° 41, 2012)

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15 juillet 2012

2. PARAMETRES PHYSICO - CHIMIQUES

PARAMETRES		UNITÉ	CONCENTRATION MAXIMALE ADMISSIBLE
Physiques	pH	—	6.5 ≤ pH ≤ 8.5
	MES	mg/l	30
	CE	ds/m	3
	Infiltration le SAR = o - 3 CE	ds/m	0.2
	3 - 6	ds/m	0.3
	6 - 12	ds/m	0.5
	12 - 20	ds/m	1.3
	20 - 40	ds/m	3
Chimiques	DBO5	mg/l	30
	DCO	mg/l	90
	CHLORURE (Cl)	meq/l	10
	AZOTE (NO3 - N)	mg/l	30
	Bicarbonate (HCO3)	meq/l	8.5
Eléments toxiques (*)	Aluminium	mg/l	20.0
	Arsenic	mg/l	2.0
	Béryllium	mg/l	0.5
	Bore	mg/l	2.0
	Cadmium	mg/l	0.05
	Chrome	mg/l	1.0
	Cobalt	mg/l	5.0
	Cuivre	mg/l	5.0
	Cyanures	mg/l	0.5
	Fluor	mg/l	15.0
	Fer	mg/l	20.0
	Phénols	mg/l	0.002
	Plomb	mg/l	10.0
	Lithium	mg/l	2.5
	Manganèse	mg/l	10.0
	Mercure	mg/l	0.01
	Molybdène	mg/l	0.05
	Nickel	mg/l	2.0
	Sélénium	mg/l	0.02
	Vanadium	mg/l	1.0
	Zinc	mg/l	10.0

(*) : Pour type de sols à texture fine, neutre ou alcalin.

ABSTRACT

The aim of this study, which was conducted on the results obtained for the year 2019, is to analyze the results of polluted water purified using the aerated lagoon method for the Said Otba (Ouargla) plant, and to compare the results obtained with Algerian and international standards. By measuring some of the physico-chemical characteristics of wastewater and treated water, the results showed the characteristics of the water discharged to Sebkhet Sefioun (Ouargla), where it was concluded that: The average yield of removing organic pollutants: BOD_5 and COD (73.25%, 70.44%) and SS (45.86%). As for the average yield of removing nitrogenous pollutants: NH_4^+ (6.58%), NO_3^- (24.52%), and TN (7.44%), as for the average yield of removing phosphorous pollutants: TP (22.06%) and PO_4^{3-} (26.06%).

In general, most pollution factors comply with Algerian and international standards, with the exception of electrical conductivity, in other words, salinity, which exceeds admissible limits.

Calculating the water quality index (WQI) showed that the water quality is not suitable for irrigation due to high salinity, as WQI = 136.07 > 100, which is higher than the limit allowed in the standards of the water quality index. The software also addressed the principal component analysis (PCA) to determine two main axes F1 and F2, which together represent 51.96% of water quality index (WQI). the information. Axis F1 (29.65%) is correlated to suspended matter, ammonium, salinity, pH, chemical oxygen demand, dissolved oxygen and nitrate. As for F2 (22.31%), it is correlated to salinity and phosphate, with less association with dissolved oxygen and nitrate. The results indicate that the composition of pollutants in raw wastewater consists mainly of organic matter, nitrogen compounds, and phosphate. For heavy metals, the F1 and F2 axes represent 68.72% of the total variance, as the F1 axis is associated with 45.65% with lead and nickel, while the F2 axis is associated with 23.08% with cadmium, chromium, and lead to lesser degrees.

Keywords: Wastewater treatment, Saïd Otba plant (Ouargla), Aerated lagoon, Algerian and Global standards, Water quality index, Statistical study.

الملخص

الهدف من هذه الدراسة التي أجريت على النتائج المتحصل عليها لعام **2019**، هو تحليل نتائج المياه الملوثة المنقاة بطريقة البحيرات المهواة لمحطة سعيد عتبة بورقلة، ومقارنة النتائج المتحصل عليها مع المعايير الجزائرية والعالمية؛ وذلك من خلال قياس بعض الخصائص الفيزيوكيميائية للمياه المستعملة والمياه المعالجة، بينت النتائج خصائص المياه المصرفة إلى سبخة سفيون (ورقلة) حيث خلصت إلى أن: متوسط مردود إزالة الملوثات العضوية: **BOD_5 و COD (73.25 %، 70.44%)** و **SS (45.86 %)**، أما بالنسبة لمتوسط مردود إزالة الملوثات الأزوتية : **NH_4^+ (6.58- %)** و **NO_3^- (24.52%)** و **TN (7.44%)**، أما بالنسبة لمتوسط مردود إزالة الملوثات الفوسفورية: **TP (22.06%)** و **PO_4^{3-} (26.06%)**.

بشكل عام، تتوافق معظم عوامل التلوث مع المعايير الجزائرية والعالمية باستثناء الناقلية الكهربائية أي بمعنى آخر الملوحة التي تجاوزت الحدود المسموح بها. أظهر حساب مؤشر جودة المياه **WQI** أن جودة المياه غير مناسبة للري بسبب ارتفاع الملوحة، حيث **WQI= 136.07 > 100** وهو أعلى من الحد المسموح به في معايير مؤشر جودة المياه، كما تناول برنامج تحليل المكونات الرئيسية **PCA** لتحديد محورين رئيسيين **F1 وF2** واللذان يمثلان معا **51.96%** من المعلومات. المحور **F1 (29.65%)** مرتبط بالمواد المعلقة، الأمونيوم، الملوحة، **pH**، الطلب الكيميائي للأكسجين، الأكسجين المذاب والنترات. أما بالنسبة **F2 (22.31%)** مرتبط بالملوحة والفوسفات مع ارتباط أقل بالأكسجين المذاب والنترات. تشير النتائج إلى أن تركيبة الملوثات في مياه الصرف الخام تتكون بشكل رئيسي من المواد العضوية، مركبات الأزوت، والفوسفات. بالنسبة للمعادن الثقيلة يمثل المحور **F1وF2** ما نسبته **68.72%** من التباين الكلي، حيث يرتبط المحور **F1** بنسبة **45.65%** بالرصاص والنيكل، بينما يرتبط المحور**F2** بنسبة **23.08%** بالكادميوم والكروم والرصاص بدرجات أقل.

الكلمات الدالة: معالجة مياه الصرف الصحي، محطة سعيد عتبة بورقلة، نظام البحيرات المهواة، المعايير الجزائرية والعالمية، مؤشر جودة المياه، الدراسة الإحصائية.