University KASDI-MERBAH Ouargla

Faculty of Applied Sciences

Department of Process Engineering

Thesis

Submitted to obtain a diploma of

MASTER'S DEGREE

Field: sciences and technologies.

Branch: Petrochemical Industries.

Option: Petrochemical Engineering.

Presented by:

Tlili Abderahmane

Subject:

Study of the efficiency of the oily wastewater treatment process at WTC.

Discussed in public

Infront of the jury composed of:

BENABDESSLAM Soulef	MCA	President	UKM Ouargla.
BAMEUR Lotfi	MAA	Examiner	UKM Ouargla.
CHAOUCH Noura	Pr	Reporter	UKM Ouargla.

Academic year: 2022/2023

University KASDI-MERBAH Ouargla

Faculty of Applied Sciences

Department of Process Engineering

Thesis

SUBMITED TO OBTAIN A DIPLOMA OF

MASTER'S DEGREE

Field: sciences and technologies.

Branch: Petrochemical Industries.

Option: Petrochemical Engineering.

Presented by:

Tlili Abderahmane

Subject:

Study of the efficiency of the oily wastewater treatment process at WTC.

Discussed in public

Infront the jury composed of:

BENABDESSLAM Soulef	MCA	President	UKM Ouargla.
BAMEUR Lotfi	MAA	Examiner	UKM Ouargla.
CHAOUCH Noura	Pr	Reporter	UKM Ouargla.

Academic year: 2022/2023

Dedication

I am honored and delighted to dedicate this work to those who have supported and inspired me throughout my life

my dear mother limam Fatima

my dear father Tlili M Belkhir,

my dear sister Hamida

All my dear brothers and sisters

my extended family

the Tlili household, and limam household

my teachers, my dear friends, and all those with whom I share a relationship of love and admiration.

I would also like to express my heartfelt gratitude to everyone who has contributed, whether near or far, to the success of this work. Your contributions, be they direct or indirect, have played an integral part in the culmination of this work.

TLILI ABDERAHMANE

Appreciation

Before all i thank A LLAH for the blessings of exictence and guidance

After that I would like to thank:

my supervisor Dr. Chaouch Noura, Professor in the Department of Process Engineering, Faculty of Applied Sciences, Kasdi Merbah University, Ouargla. i would like to express my heartfelt gratitude for her valuable assistance, patience, guidance, and encouragement throughout this research work. Her critical insights and wide experience have been invaluable to the success of this work. May God bless her with a long and healthy life.

All the members of the jury, we extend our gratitude for their kindness and willingness to evaluate our work.

My cousin Tlili Bouhafs

all the workers of the zarzaitine association Sonatrach/Sinopec

The engineers and operators of the WTC MR BOUAOUAOU Toufik, Bichi Fouad, Toumi Marwa, Mr.Kamal,Mr.Laid and special tanks to madam Mezian Roumaissa Their knowledge, skills, and professionalism have played a significant role in the smooth operation of the project.

Contents

Contents

Contents

List of Figures

List of Tables

List of Abbreviations

Abbreviation	Signification
WTC	Wastewater treatment Centre
PAC	poly aluminum chloride
NIA	North in Aminas
GOR	Gas oil ratio
CS	Separation center
FGL	Lift gas closing unit
NMWIC	New main water injection center
WTC	Water treatment center
PGS	Pressure gravity separators
DMF	Dual media filter
FMF	Fine media filter

List of Symbols

Symbol	Name	Unit
pH	Potential hydrogen	/
BOD	biochemical oxygen demand	mg/L
COD	chemical oxygen demand	mg/L

General introduction

General introduction

In light of the expeditious advancements observed within the industrial sphere, substantial quantities of liquid discharges, harboring diverse assortments of organic pollutants, radionuclides, toxic metal ions, and anthropogenic nanoparticles, are being released into the surrounding ecosystems.[1],[2] Water, being the paramount natural resource indispensable for the survival of animals, plants, and humans, assumes a position of utmost significance[3].

Concurrently, the global populace continues to grow steadily, resulting in an escalation of pollutant disposal into both industrial and municipal wastewater systems.[4] This is primarily attributed to a multitude of factors encompassing agricultural byproducts, industrial contamination, and human-generated residues. Among the diverse forms of effluents generated, the presence of oil-in-water emulsions assumes prominence due to their copious generation from activities such as petroleum refineries, petrochemical plants, crude oil spills in marine environments, and wastewater originating from discarded cooking oil.[5]

Even since ancient times, wastewater treatment processes (WWTPs) have been known to be effective in water recycling and reclamation.[6] as time passes and industries grew water contamination and its treatment have emerged out as an escalating challenge globally. Most oil producers were interested in developing treatment methods as a result several modifications in wastewater management practices were adapted gradually.[7],[8]

The Sonatrach/Sinopec association as a collaboration between two giants in the oil and gas industry has taken into responsibility the valorization of produced wastewater in order to minimize the environmental impact to a reasonable level, henceforth the development of the WTC (Wastewater Treatment Center) located in the Zarzaitine field Ain-Aminas, Ilizi southeast of Algeria.

Thus, the purpose of our thesis is to study and analyze the effectiveness of the process exploited at the WTC detect problems concluding by proposing recommendations.

Chapter I

Generalities on oily produced wastewater

1-Definition of Wastewater

Wastewater, commonly referred to as sewage, is an amalgamation of household waste, human and animal excreta, industrial effluents, stormwater, and groundwater infiltration. It essentially constitutes the outflow of utilized water from a community. By weight, wastewater is composed of 99.94% water, as reported by the Water Pollution Control Federation (1980). The remaining 0.06% is made up of materials that are either dissolved or suspended in the water. Wastewater represents the major source of water supply for a community after it has been contaminated by diverse usages. As such, it is imperative to understand the nature and composition of wastewater, in light of its potential impacts on public health and the environment.[9]

2-Classification of wastewater

Wastewater is generally divided into two primary categories:

2.1-Domestic Wastewater

Domestic wastewater pertains to the discharge resulting from human activities, including food preparation, cleaning, and laundry. This type of wastewater is typically produced in significant amounts and is rich in carbon, nitrogen, and phosphorous.**[2]**

2.2-Industrial wastewater

Industrial wastewater refers to the discharge those results from manufacturing activities, such as those involved in the petroleum industry and production of food, cosmetics, and paints etc. This type of wastewater typically contains various chemical and biological pollutants in varying concentrations. Some of these pollutants are considered micro-pollutants and pose a significant risk to human health.[10]

Oily wastewater is delineated as a wastewater stream that encompasses fats, oils, and greases, accompanied by a diverse array of dissolved substances, both organic and inorganic, as well as suspended particles, all present at notably high concentrations.[11]

Untreated disposal of oily effluents into water streams, land, and sewer lines leads to various detrimental consequences. The hazardous environmental impacts associated with oil wastewater can be attributed to several factors:

i) The mortality of fish and other aquatic organisms,

ii) The inhibition of photosynthesis in algae and aquatic plants,

iii) Adverse ecological effects on the distribution of flora and fauna in the aquatic environment,

iv) Potential mutagenic and carcinogenic effects on human health,

v) Inhibition of plant growth.

A primary negative consequence of these waste discharges is the formation of an impermeable layer on the water's surface due to increased biochemical oxygen demand (BOD) and chemical oxygen demand (COD) in water bodies.[12] The impacts of oily wastewater extend beyond those mentioned previously and include additional detrimental effects such as the degradation of natural landscapes, diminished agricultural productivity, soil contamination, pollution of surface water and groundwater resources, blockage of sewage systems, and reduction in light penetration and dissolved oxygen levels. Furthermore, certain components of oily wastewater are highly toxic and carcinogenic, posing risks to the kidneys, liver, and other organs.[13]

3- Characteristics of produced wastewater

The wastewater generated during the exploration and production of fossil fuels is among the most extensive industrial waste streams globally. This water is produced not only during crude oil extraction but also in other forms of fossil fuel recovery, including shale gas, oil sands, and coal bed methane.[14] Produced water comprises a mixture of reservoir water, natural formation water, injected water, and any chemical additives employed during the production and treatment processes. It is imperative to recognize that produced water represents a significant environmental challenge that requires a comprehensive understanding of its composition and impacts on the environment.[15]

Produced water is a mixture of various compounds, besides hydrocarbons, that can impact water management. The composition and concentration of these compounds vary between fields and production zones. Concentration is measured in milligrams per liter (mg/L), or parts per million (ppm). Analyzing these constituents is vital for understanding their environmental and health effects.[16]

3.1-Dissolved solids

Produced water contains dissolved solids, with concentrations varying widely based on geographical location, as well as the age and type of the reservoir. Concentrations can range from less than 100 mg/l to over 300,000 mg/l. The dissolved solids found in produced water consist mainly of inorganic constituents, specifically sodium cations and chloride anions.[17]

3.2-Precipitated Solids (Scales)

When pressure, temperature, or composition changes, certain ions found in produced water can react to form precipitates. These troublesome ions can cause deposits to form in produced water-treating equipment, tubing, flowlines, and vessels. [16]

3.3-Sand and other Suspended Solids

Produced water commonly contains other types of suspended solids, such as formation sands and clays, stimulation (fracturing) proppant, and various corrosion products. Produced sand is typically oil-wet and poses a disposal challenge. [16]

3.4-Dissolved Gases

The primary gases detected in produced water are natural gas, which consists of methane, ethane, propane, and butane, as well as hydrogen sulfide and carbon dioxide. These gases can be present in the reservoir and can become saturated in the water at relatively high pressures. [17]

3.5-Oil in Wastewaters

After intimate contact between oil and water, oil can contaminate the water by existing in the aqueous phase in various forms. [18]Oil content is commonly classified based on its physical form into four categories:

a. Free (floating) oil**:** This type of oil is referred to as free oil, which can rapidly rise to the surface of the water under quiescent conditions. The droplet size of free oil is typically greater than 150 microns. **[19]**

b. Dispersed oil**:** Dispersed oil in produced water is typically made up of electrically charged fine droplets that are stabilized by surfactants, with droplet sizes ranging between 20 and 150 microns. This type of oil typically consists of polyaromatic hydrocarbons and alkyl phenols, which are less soluble in water.[8]

c. Emulsified oil**:** This type of oil has a distribution comparable to that of dispersed oil, but its stability is strengthened by the presence of emulsifiers, mainly surfactants, located at the oil/water interface.[8]

d. Dissolved oil**:** The type of oil does not manifest as apparent droplets but instead exists as a chemical solution or as extremely small dispersed droplets.**[20]**

Chapter II

Presentation of the treatment techniques

1-Sedimentation

1.1-Definition

Settleable solids in wastewater are allowed to settle in a large tank due to gravity. The clarified water then proceeds to the next stage of treatment. This secondary treatment process aims to remove sand, silt, clay, and biological contaminants from the water using gravity.[21]

1.2-Principle

The separation of suspended particles is accomplished by exploiting the disparity in densities between the liquid bulk and the solids.[22] Particles possessing a higher density than that of water undergo gravitational settling, accumulating at the bottom of a designated container or tank commonly referred to as a clarifier. Subsequently, these settled solids are extracted from the clarifier, facilitating their removal from the system.[23]

The effectiveness of sedimentation depends on the amount of time the wastewater remains undisturbed in the tank. Coagulants like aluminum sulfate, liquid alum (poly aluminum chloride or PAC), and ferric sulfate can be added to speed up the sedimentation process. The overflow rate plays a role in improving the efficiency of removing solids during primary and secondary clarification. By ensuring that the settling velocity is greater than the overflow rate, the overall efficiency of the process is increased.[24]

1.3-Types of sedimentation

Sedimentation encompasses four distinct mechanisms of settling:

- Discrete settling: the suspension of solids remains in a dilute state without significant aggregation.
- Flocculent settling: the particulates undergo aggregation either among themselves or with the aid of added flocculants, resulting in the formation of larger particulates.
- Zone settling: the particulates adhere to one another and form a cohesive mass or blanket at distinct interfaces with the liquid above them

- Compression settling: The settled particulates accumulate in the clarifiers, forming a compacted structure that provides support for the weight of the settled particles at the bottom of the tank or basin.[25]

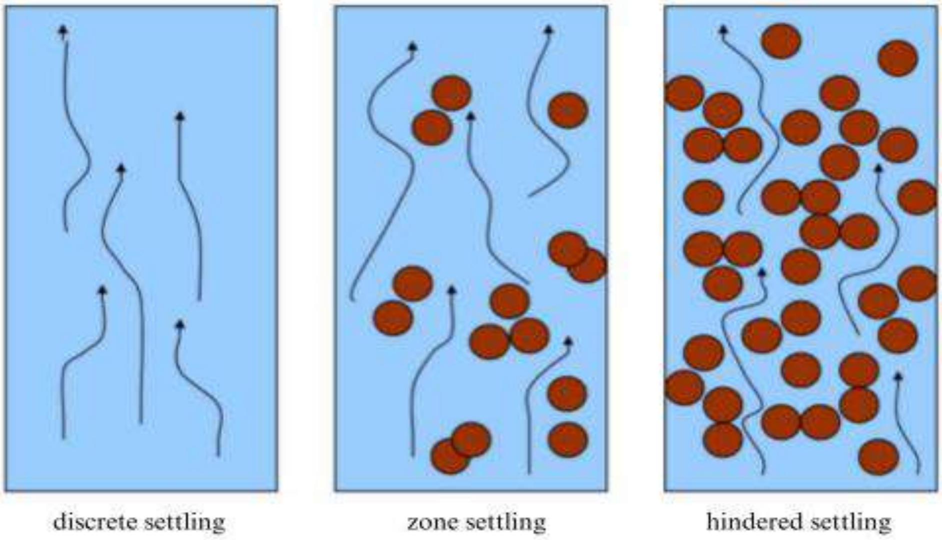

Figure IIII.1: Types of sedimentation settling.

2-Coagulation

2.1-Definition

Coagulation is a fundamental process employed to induce the destabilization of a suspension or solution.[26] Its primary objective is to counteract the factors that contribute to the stability of a system (settleable materials). By implementing coagulation, the inherent stability of the suspension or solution can be overcome, leading to the aggregation and eventual settling of the dispersed particles or colloids.[27]

2.2-Principle

The initial stage of coagulation involves the utilization of coagulants to neutralize the negative charges associated with oil particles, thereby reducing the electrostatic repulsion within the electric double-layer.[28] This phenomenon is commonly referred to as destabilization, as it leads to a decrease in the stability of the system. Subsequently, the destabilized particles initiate a process of development whereby they gradually aggregate and combine to form larger flocs.[29]

2.3-Mechanism

Coagulation mechanisms can be classified into several types:

1. Simple charge neutralization: colloidal particles with evenly distributed negative charges can be completely neutralized by adding an appropriate number of coagulants. The optimal dosage of coagulants increases with the initial concentration of oily wastewater.
2. Charge patching: when heterogeneously distributed charges on colloidal particles create electrostatic attraction, the zeta potential does not reach zero at the optimal dosage, resulting in a wide range of effective flocculation.[30] (The zeta potential indicates the electrical charge on the droplets or particles, which affects their interactions and the overall stability of the emulsion.)[5]

3-Flocculation

3.1-Definition

In water and wastewater treatment plants, flocculation is recognized as the primary physicochemical treatment process preceding any solid-liquid separation unit. This process involves the aggregation of suspended particles, algae, and microorganisms to enhance their density, facilitating subsequent steps such as sedimentation or flotation (utilizing injected air bubbles), as well as filtration.[31]

3.2-Principle

Hydrodynamic conditions play a significant role in the destabilization of colloidal systems, particularly when hydrolysable electrolytes and/or flocculating polymers are present. The aggregation of particles during flocculation involves two sequential processes. [32]

Firstly, the particles must undergo collisions with one another, promoting contact and interaction. Subsequently, under the influence of colloidal forces, these particles undergo grouping or agglomeration, leading to the formation of aggregates.[33]The interplay between hydrodynamic conditions, particle collisions, and colloidal forces is crucial in driving the flocculation process and facilitating the formation of larger aggregates. The global aggregation is represented by the following equation

$$-\,dN\,dt \;=\; \{Collision\ efficiency\}x\{Collision\ frequency\} \;=\; \alpha\ x\ J$$

N: concentration of particles at a given time t

J: collision frequency represents the number of collisions that occur per unit time.

α : collision efficiency, reflects the fraction of the total number of collisions that result in the formation of aggregates.

In the conventional approach, particularly in flocculation, a two-step process involving rapid mixing followed by slow stirring is typically employed. During the rapid mixing step, the destabilizing agent is added to the system. This phase facilitates not only the diffusion of reactants but also the reduction of the repulsive energy barrier between the reagents and particles, as well as between particles themselves. As a result, primary flocs are formed, which play a crucial role in the subsequent kinetics of the process. Once the primary flocs have emerged in the rapid mixing stage, the slow stirring stage is initiated. This stage allows for further growth and aggregation of the flocs, leading to the formation of larger and more stable flocs.[34]

Table II.1: Usual classification of the flocculators

Type	Classification	Example
Hydraulic	Horizontal	Baffles interspersed transversely in the tank
	Vertical	Baffles interspersed above and below the tank
	Helical	Tanks with input and output devices in opposite directions
Mechanical	Rotating	Vertical or horizontal axis rotary vane
	Alternates	Alternating vanes
Pneumatic		Air diffusers

4-Gravity Separation

4.1-Definition

Gravity separation, recognized as the oldest and widely utilized method in water treatment processes, is employed for the separation of suspended materials from water. Traditionally, gravity separation has predominantly involved sedimentation, whereby water is introduced into a spacious quiescent basin and allowed to undergo a prolonged settling period. During this quiescent phase, gravitational forces act upon the suspended particles, causing them to gradually descend and accumulate at the bottom of the basin. This sedimentation process facilitates the effective separation and subsequent removal of the suspended particles, resulting in the clarification of the water.[35]

4.2-Principle

The key parameters governing separation can be ascertained from Stokes law, density difference, droplet size, and viscosity. The efficiency of a gravity separator depends upon the proper hydraulic design and the wastewater retention time.[36]

4.3-Types of gravity separators

4.3.1-API Separators

The separator is composed of a rectangular clarifier equipped with a surface skimmer for removing oil and a bottom rake for solids. The oil layer is usually skimmed off and either processed again or disposed of, while the sediment layer at the bottom is removed using a chain and flight scraper (or a similar device) along with a sludge pump.[37]

4.3.2-Plate Coalescers

To enhance oil coalescence, the stream is directed through a series of parallel angled plates, also known as parallel packs. These plates are typically made of oleophilic polypropylene and are designed to provide a large surface area. The suspended oil droplets in the stream can then come into contact with the plates, facilitating their coalescence into larger aggregates or globules.[38]

5-Filtration

5.1-Definition

The conventional filtration process plays a significant role in water treatment. It involves passing water through a porous filter medium to separate suspended particles. The filter media used can include silica sand, anthracite coal, diatomaceous earth, garnet, ilmenite, or finely woven fabric. This process effectively removes suspended matter from the water.[39]

5.2-Filtration types

5.2.1-Depth filtration

Also known as inner filtration, is a filtration process where a suspension containing particles, such as clay particles, is passed through thick layers of filter media. The suspension is trapped and removed in the voids between the filter media. Notably, the size of the suspended particles trapped is considerably smaller than the void size of the filter media. This type of filtration, referred to as inner filtration or depth filtration, gets its name from the mechanism of particle removal. It is typically used for dilute systems with low particle concentrations (0.1% or less) and finds frequent application in water treatment for clarification filtration.[40]

5.2.2-Cake filtration

Also known as surface filtration, is a filtration process where a layer of sludge called a cake or filter cake forms on the surfaces of porous walls. This cake layer acts as the filter medium, and the suspension is passed through this layer to separate and clarify the suspension. Simultaneously, more cake is formed as the process continues. Since the suspension is removed on the surface of the filter medium, it is referred to as surface filtration. Cake filtration is commonly employed for treating suspensions with higher volume concentrations, such as slurries with concentrations as high as 1% or more. It is particularly useful for sludge dewatering applications.[41]

5.2.3-Membrane filtration

Membranes serve as an alternative method of filtration and are composed of polymer layers with extremely small pores that act as physical barriers, effectively removing particles and pathogens from the incoming water. Membranes are categorized based on the size of their pores and the pressure needed to facilitate water flow through them.[42]

5.2.4-Filter aids

Filter aids are employed in certain cases to enhance the filtration process by modifying the solid phase of the material. These aids can range from specialized products such as diatomaceous earth or expanded silica to various crystalline materials.[43]

6-Adsorption

6.1-Definition

The removal of organic contaminants that are resistant to biodegradation and exist in a dissolved state can be effectively achieved through the process of adsorption. Adsorption is a surface-based phenomenon wherein the contaminants are collected at an appropriate interface, which can be a liquid-gas interface, a solid surface, or a liquid-liquid interface. This process is often employed as a final treatment step to enhance the quality of effluent that has already undergone primary treatment for the removal of a majority of the contaminants.[20]

6.2-Characteristics of adsorbents

Adsorbents are commonly employed in the form of spherical pellets, rods, moldings, or monoliths, with a hydrodynamic radius ranging from 0.25 to 5 mm. These adsorbents must possess key characteristics such as high abrasion resistance, thermal stability, and small pore diameters. These properties contribute to a larger exposed surface area, resulting in a higher adsorption capacity. Additionally, an efficient adsorbent should exhibit a distinct pore structure that facilitates the rapid transport of gaseous vapors.[44] The following are some widely used adsorbents: Silica gel, Zeolites and Activated carbon.[45]

6.3-Types of adsorbents

Industrial adsorbents are typically classified into one of three categories:

- Oxygen-Containing Compounds: These materials, such as silica gel and zeolites, are hydrophilic and polar.
- Carbon-Based Compounds: This category includes hydrophobic and non-polar materials like activated carbon and graphite.
- Polymer-Based Compounds: These adsorbents consist of porous polymers with either polar or non-polar functional groups.[46]

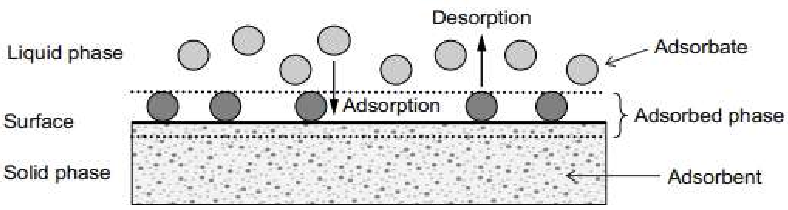

Figure II.2: Basic terms of adsorption

Chapter III

Presentation of the studied region

C

1-Geographical location

The Zarzaitine oil field, located in the In-Amenas Oil Dom, is a collaborative operation between Sonatrach and Sinopec. Established in 1962, this oil field encompasses an extensive oil reservoir stretching approximately 14 km in length and 7 km in width. The average well depth within the field is around 1400 m. The infrastructure of the field comprises well sites, flow lines, infield pipelines, an oil storage center, a natural gas process plant, a water injection facility, and a water treatment and injection facility.***[47]***

The Zarzaitine field is located in the Illizi basin at 1600 km southeast of Algiers, 35 km east of the locality of In Amenas, near the Libyan border at an average altitude of 500 m above sea level, it lies precisely between meridians 9° 20' and parallels 28° 10' and 28° 20' southeast of Algeria. It is made up of oil and gas fields, of disparate positions and sometimes more than 200 km apart.***[47]***

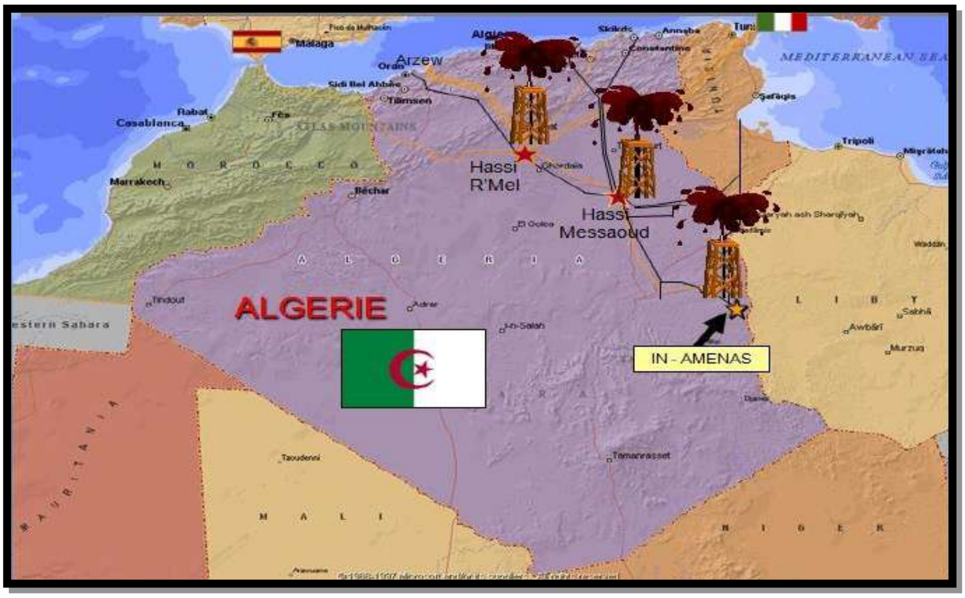

Figure III.1: Geographical position of the In Amenas region.

2-History of the Zarzaitine deposit

- The Zarzaitine Deposit was discovered in 1957 with the ZR01 well drill. The oil was highlighted with the drilling of the ZR2 well in January 1958.
- The discovery of the oil field of Zarzaitine dated 1957 led to the implantation of the first crude oil treatment facilities between 1957 and 1960.
- Of the 268 oil-producing wells that make up the deposit and cover an area of 140km and an average depth of 1400m wells, only some are in production.

- In 1982, Sonatrach decided to build a Gas-lift production unit located close to the storage center in order to supply the oil fields of Zarzaitine, IFN, NIA and the MWIC as well as In Amenas power plant.
- This unit was realized by a Japanese engineering company Mitsubishi in 1984, also drilling the injection wells and building a main water injection site.
- Currently, the Zarzaitine field is jointly operated by Sonatrach and Sinopec (China Petroleum and Chemical Corporation).
- Oil production today is estimated at 3000 m^3/d. And the grouping Sonatrach/ Sinopec not only provides for the completion of new projects but also the renovation of certain essential equipment.[47]

3- Study of the Zarzaitine field

The ZARZAITINE field, with its main Devonian reservoir 'F4, an oil producer, is the most important deposit in the IN-AMENAS region. The greatest accumulations of oil with sometimes gas caps occur in the Devonian (F6, F4 and F2) and wet gas with sometimes thin oil rings in the Cambro-Ordovician.[47]

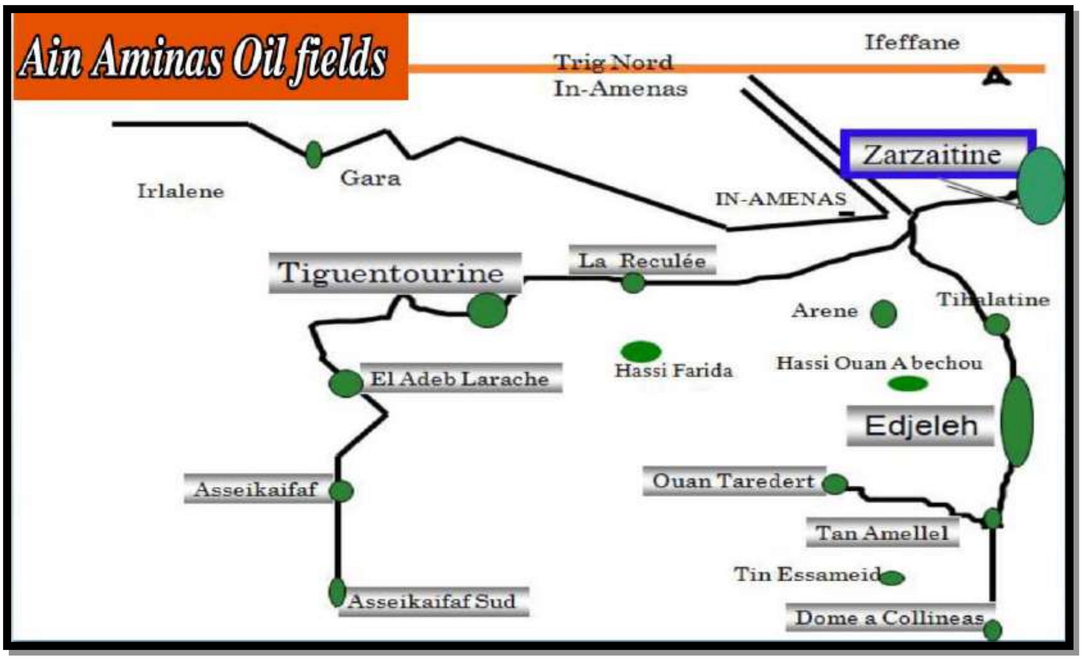

Figure III.2 Oil fields in the In Amenas region.

3.1-Overview

The Devonian Age F4 main reservoir consists of an oil ring surmounted by a cap gas. Its area is approximately 100 km². The oil reserves in place have been estimated at 340 $.10^6$ m^3 and the volume of the gas is 6900 $.10^6$ m^3.

The oil reserves in place of the secondary reservoirs (Carboniferous A, B2a, B2b, B4, B6, B8, D4, D8, and Devonian F2 and F6) are $27.8.10^6$ m^3.

The average depths of the Zarzaitine tanks are as follows:

- For the lower Devonian tank 'F4' the average depth is 1400 m (minimum depth at 1210 m, maximum depth at 1520 m).
- For the upper Devonian tank 'F2' the average depth is 1200 m.
- For the Devonian tank F6 the depth is 1440 m.
- For Carboniferous tanks (A, B2a, B2b, B4, B6, B8, D4) the average depth is 500 m to 920 m.[48]

3.2-Characteristic of the main reservoir F4

- Dimensions of the deposit: 14 km long and 7 km wide.
- Producer Horizons: Main: Devonian F4; secondary: Devonian F2, carboniferous
- Total oil reserves in place (Carboniferous and Devonian): 366.07 10^6 m^3
- Recoverable reserves: 233 361×$10^6 m^3$
- Recovery at 31/12/2011: 150 105×$10^6 m^3$
- Average well depth: 1400m
- Low density (43API) and viscosity (0.515 mPa.s).
- Initial dissolution ratio (gas/oil) is $82.5m^3/m^3$.
- Initial and saturation pressures at the reference coast (-835 m) are respectively 124.5 and 116.9 kg/cm^2.
- Background temperature is:
  - 81°C in the gas-oil interface at -712 m deep.
  - 84°C in the middle of the tank at -835 m.
  - 88°C oil-water interface at -980 m.
- Faulty monoclinal characterized by medium porosity, permeability, and high oil saturation. It is topped by a cap gas and subjected to the action of a non-active aquifer.[48]

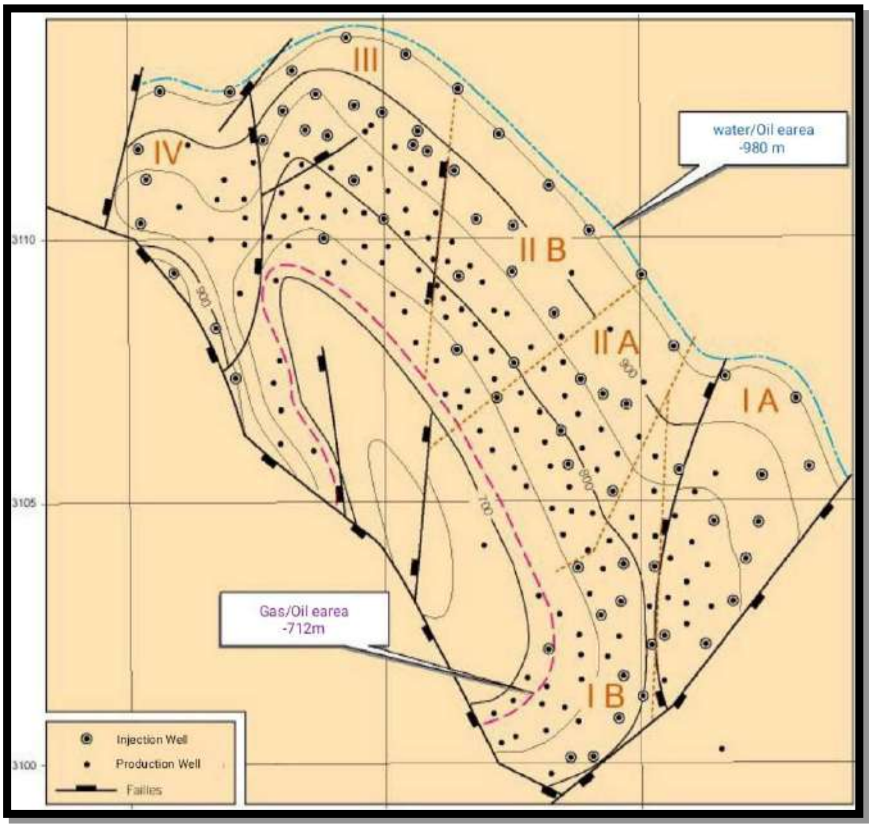

Figure III.4: Map of the Zarzaitine deposit

3.3-Oil production of the Zarzaitine reservoir

- Deposit F4 productivity reached its peak in 1962, with an oil production of 897.5758×10^4 m^3 a recovery rate of 2.64%.
- The secondary reservoirs were successively put into production from 1963 to 1965 (natural drainage system). During this period, several wells have been closed due to their elevated GOR (up to 700 m^3/m^3).
- Currently, the deposit contains 102 oil-producing wells, and the number of injection wells is 57 wells.
- Current oil production is around 3000 m^3/d.
- The cumulative oil production since the origin (extraction since the Zarzaitine deposit was developed) is 149.3×10^6 m^3, representing a recovery rate of around 44% of the reserves in place.

The field was closed for eighteen months beginning in November 2009. All wells (producers and injectors) have been closed following a technical problem on the surface installations. The field was restarted in mid-May 2011 after the surface facilities were restored.[49]

3.4-Problems specific to the Zarzaitine field

Formation of **deposits** on oil-producing wells of the Zarzaitine field, the B.C.W operations (bottom checks by wire-line) often indicate the presence of deposits on the walls of the 2" 3/8 or 2" 7/8 tubing columns and at the well bottoms. These deposits are essentially:

- Barium sulfate (**$BaSO_4$**) (resulting from incompatibility of the injected water with the reservoir water) in paste form or solid on the tubing and/or at the well bottoms.
- Salt on the walls of tubing columns.
- Paraffin on tubing column walls.[48]

4-The surface facilities of the Zarzaitine field

The existing field consists of the following wells, flow lines and units:

- CS1-CS8: different separation centers.
- FGL: lift gas closing unit
- C4: oil storage facility.
- NMWIC: new main water injection center.
- WTC : water treatment center.
- Gas, oil, and water collection networks.[48]

4.1-Separation centers

The Zarzaitine field has seven (07) centers (CS1, CS2, CS3, CS4, CS5, CS7, and CS8). They spread out over a length of about 40 km. These are centers where the separation between the three phases: water/ gas/ crude oil. These centers are equipped with a series of separators allowing field separation of the oil produced by the wells.[48]

The crude passing through the manifold of well arrivals enters the separator. After the separation, the **oil** is sent to the C4 storage center; the **gas** (BP) to the FGL unit and the **water** is sent to the WTC (water A, rich in **sulphate**), Formation water (water F, rich in **Barium**) purges to the mire.[48]

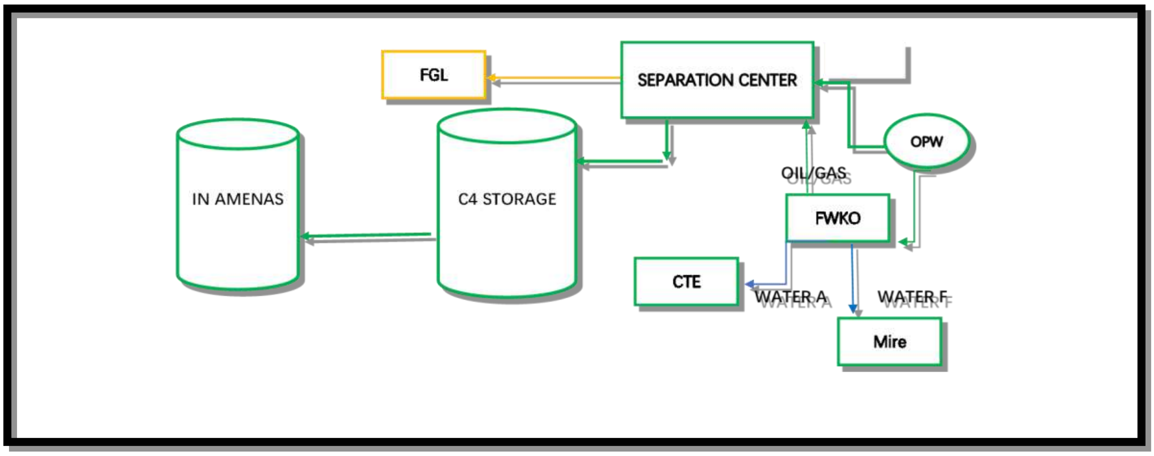

Figure III.5: Operation diagram of the Separation Centers

The separation centers generally include:

- An inlet manifold of well arrivals.
- A separation battery (Separator F and Separator A).
- A test separator (separator + measurement chamber).
- Manifold departure to the storage center.

The three-phase separation (water, oil and gas) occurs at low pressure (max 4 bar, the gas is sent to the FGL center, type A water is recovered by the WTC, F water to a mire, and the oil to the C4. [48]

Figure III.6: Separation Centers

Some oil wells (PPH) produce large amounts of water. FWKO (Free Water Knockouts) separators are installed at the PPH well sites to separate the excessive water, even before arriving at the separation centers, there are currently 56 wells with 25 FWKO separators. [48]

4.2-Lifting gas closure unit (FGL)

The FGL unit was built in 1984, for these objectives:

- Recovers flared gases from water and oil separation centers.
- Pressurize the gas and separates the condensate and water droplets.
- The gas is continuously injected into the wells to lighten the column and thus allows oil or water to rise.

The FGL unit is attached to two different networks:

- ❖ The low-pressure network from the oil/gas separation centers.
- ❖ The medium pressure network from the water/gas separation centers.

This is the most important unit in the field with a capacity of 4300000 stm^3 as the gas is pressed to around 80 bars. And is set to play multiple roles (lifting gas, pilot gas, and comburent for turbines...).

The unit consists of:

- Three identical compression trains including a condensate recovery system, gas dehydration section, separation system and cooling system.
- A regeneration furnaces.
- 04 turns of regeneration.
- A control room, a firefighter’s room, a fire equipment room; and offices.
- A maintenance building.
- An electrical substation.
- A utility building. [48]

Figure III.6: FGL Unit

4.3-Oil storage facility (C4)

The new C4 Storage facility was commissioned in 2012, designed to receive production from all the Separation Centers. crude coming from separation centers crossing the entry manifold is chemically treated and then sent to the bins by a blow case composed of two chambers that operate intermittently (it is also a gas separator). The flushing pressure is 1.5 bars. The separated gas is supposed to be sent to the FGL by an electric compressor.

After a 30-hour decantation in the tanks, the qualified crude is transported to In-Amenas main station SP1 by a line of 14' in diameter and 28 km long. The dirty water at the bottom of the tanks is drained into the settling tank by a line of 8' after having been collected, then lifted by the pumps and sent to the WTC. [48]

The center generally includes:

- Inlet manifold
- Blow case
- Crude oil storage tanks (three tanks, capacity: 26,300m^3, one: 10,000 m^3 and two 7,650 m^3 storage tanks)
- New chemical injection skids with shelters
- Two new crude oil shipping pumps, two boosters with each a capacity of 640 m^3/h.
- A control room powered by the DCS command system, and a guard station.
- Oily Water Recovery Unit.
- Crude oil 'Booster' charge pump and shipping pump.
- Drainage system and a Firefighting system.[48]

Figure III.7: The C4 Storage center

4.4-Main water injection Centre (MWIC)

MWIC is the main water injection site in the field. Commissioned in December 2012, its role is to:

- Receive the water produced by the NIA, IFN and SPL NORD fields (16 total wells) and store it.
- Later the water is injected into the wells using a gas-powered turbopump, (for oil sweeping and holding reservoir pressure).

The unit has an injection capacity of 18,000 m^3/day at a pressure of 86 bars; currently, an average of 9000 m^3 per day is injected at 80 bars. Water is injected into the reservoir through 57 injector wells.

The center generally includes:

- Two water tanks each with a capacity of 2300 m^3,
- Two water injection pumps each with a capacity of 750 m^3/h,
- A Fuel gas system,
- Chemical Injection System (Corrosion Inhibitor Injection Skid, Anti-incrusting Injection Skid, Biocide Injection Skid and Deoxidizing Injection Skid)
- Control Building, and Utilities,
- A Torch. [48]

Currently, only the NIA field (GL powered) is sending water due to electrical pump problems.

Figure III.8: The MWIC.

4.5-Water treatment center and the new main water injection center *WTC/NMWIC*

4.5.1-Presentation of the WTC/NMWIC

The WTC/MWIC was commissioned in December 2012, located in the southeast of the C4 at approximately 300 m, with a processing capacity of 11 000 m^3/day.

Figure III.9: WTC/NMWIC.

The purpose of this unit is:

- Reevaluation of the water produced by the separation centers and the storage center C4 (previously eliminated into the mire).
- Protection of the environment
- Recovery of suspended oil in the water (significant amounts).
- Injection of treated water into injection wells (to maintain the pressure).

The water treatment center is designed solely for the treatment of **A-water** rich in **SO_4^{2-}** (injected via MWIC), and F-type water containing **Ba^{2+}** (originally in the deposit) has to be purged to the mire and then picked up manually.[48]

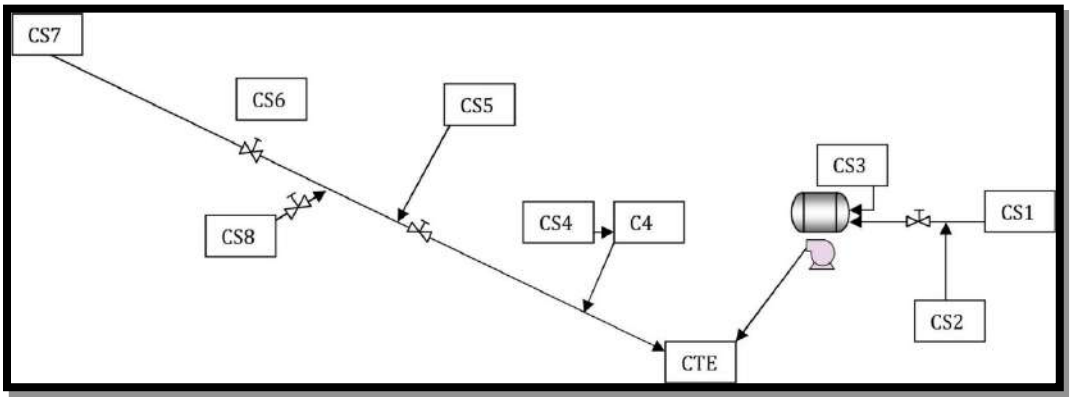

Figure III.10: The WTC's Water Collection System

The activities implemented on the site are as follows:

1) Receiving water from the separation centers and the C4 center via an inlet manifold.
2) Storing water temporarily (10-12 hours) in two storage tanks with each a 1000 m^3 capacity (main separation).
3) Injection of chemical products.
4) Gravitational separation.
5) Filtration.
6) Storage of treated water in two containers with a nominal unit capacity of 2200 m^3.
7) Water injection into wells via 2 pumps driven by 2 turbines.

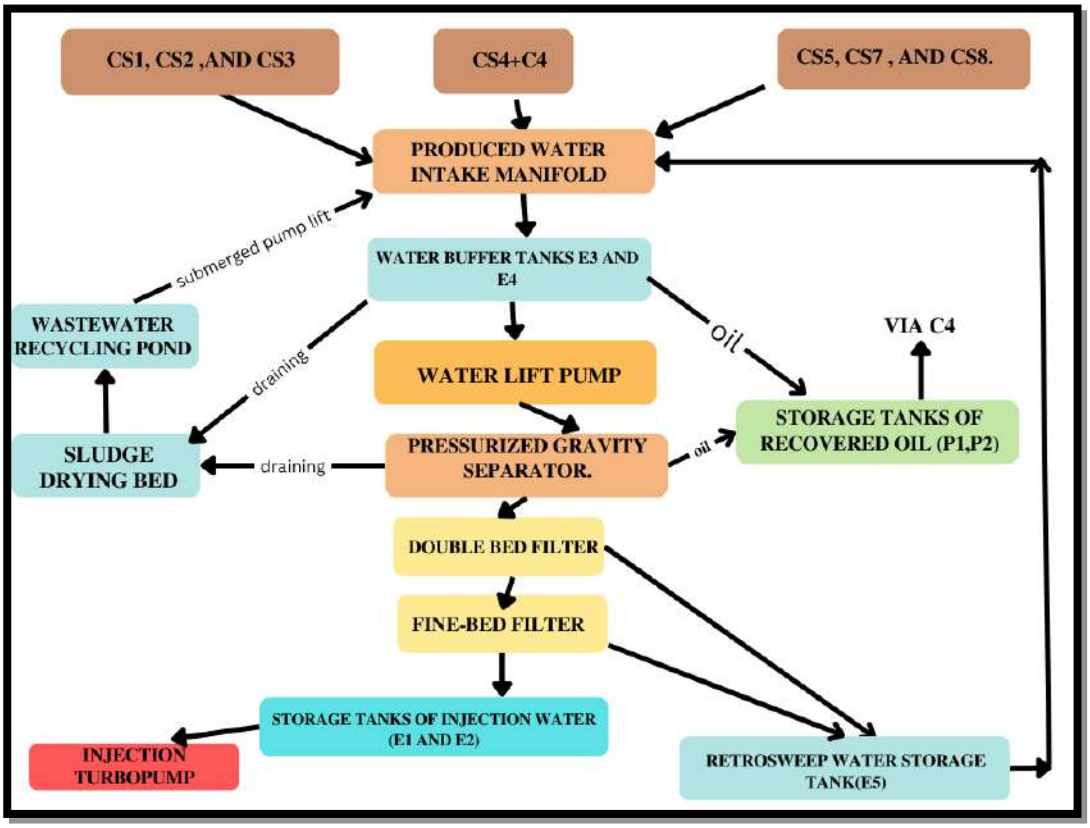

Figure III.11: Diagram of the WTC/NMWIC activity.

4.5.2-Operating parameters

The normal operating parameters for the combined PGSs and Filter Packages are shown below:

Flowrate:	160 to 640 m^3/hr
Temperature:	15/45/65 °C (Min/Norm/Max)
The density of Water:	1,020 kg/m^3
Viscosity:	0.89 cP
Total Dissolved Solids:	30,000 to 50,000 mg/l
Chlorine Content:	>10,000 ppm
Ambient Temperature:	-6 to 55 °C
Total Suspended Solids:	
Inlet:	40/450/750 mg/l (Min/Norm/Max)
Outlet:	$\leq$ 5mg/l
Free Oil-in-Water:	
Inlet:	$\leq$ 80mg/l
Outlet:	$\leq$ 8mg/l .[48]

4.5.3-Description of the process

- The produced water is held in two **produced water surge tanks** (CTE-RM-44-01A/B) then pumped to the p**ressure gravity separators** (CTE-VA-44-01A/B/C/D/E/F) via the produced **water lift pumps** (CTE-PA-44-01A/B/C).
- The produced water enters the vessel at the center through the inlet flow distributor and then flows bi-directionally to each side of the vessel exiting at the vessel ends.

  The vessel has six corrugated packs, three on each side. The corrugated packs reduce the velocity of the suspended solids encouraging them to drop out of the water. The flow profile in the plate packs directs solids downwards towards the base of the vessel. The solids will then settle in the six collection pots at the bottom of the vessel, three to each side. The solids slurry is then intermittently discharged in the **sludge drying beds** (CTE-RB- 44-01A/B/C).

  Dispersed Oil within the produced water is coalesced in the plate packs and will collect at the top of the vessel in the oil collection pots. Oil will be drawn off intermittently and passes to the **slop oil tanks** (CTE-RL-44-02A/B).

  The Pressure Gravity Separators are each fitted with a pressure relief valve, a temperature gauge and a pressure gauge.
- The treated produced water then passes onto the second stage of treatment, five **dual media filters** (CTE-MA-44-01A/B/C/D/E). The dual media filter is a coarse filter designed to take out the larger solids and oil which would normally block a

fine filter. They are each fitted with a pressure relief valve, a temperature gauge and a pressure gauge.

- The produced water then passes onto the third and final stage of treatment, six f**ine filters** (CTE-MA-44-02A/B/C/D/E/F). The fine filter is a polishing filter designed to take out any solids and oil that remain after the dual media filters. They are each fitted with a pressure relief valve, a temperature gauge and a pressure gauge.
- The system operates a fully automated backwash and air scour system on both the dual media filter and fine filter vessel. The treated Backwash water is drawn from one of the water injection tanks and is pumped via variable-speed Backflushing Pumps (CTE-PA-44-02 or CTE-PA-44-03) through the filter undergoing backwash.
- The package is designed for automatic control. All vessels are protected from overpressure by relief valves.[48]

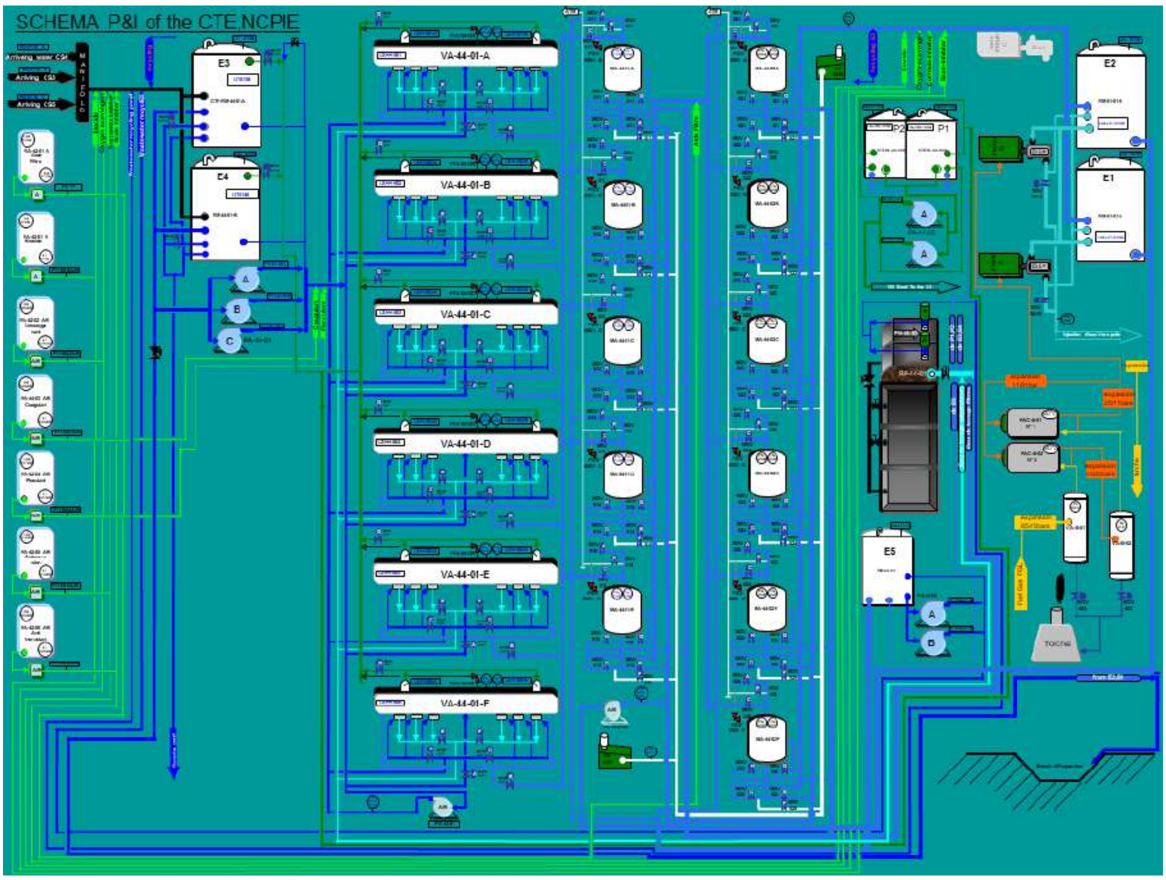

Figure III.12: Schema P&I of the WTC/NMWIC

4.5.4-Process's equipment

4.5.4.1 -Inlet Manifold

The Water Treatment Centre is designed to treat 10340 m^3 of water per day. The water coming from the 7 separation centers and the C4 is collected in the inlet manifold before entering the (02) buffer tankers for decantation, Sampling fittings and magnetic flowmeters are placed on the manifold for regular surveillance and for taking testing samples.[48]

Figure III.13: Inlet Manifold WTC/NMWIC.

4.5.4.2 -Produced water surge tanks

Produced water from the head manifold is received in the surge tank for the separation of oil and suspended solids. Two tanks are installed with a storage capacity of 1000 m^3 each. The residence period of 2.3 hours is considered to reduce the concentration of suspended solids from 750 mg/l to 250 mg/l and the oil content from 150 mg/l to 80 mg/l. Settled suspended solids are automatically discharged by a sludge outlet at the bottom of the tank using time-operated all-or-nothing valves. An oil skimming device is provided on the tank's side with all-or-nothing automatic valves. Water with less suspended solids and oil droplets is then collected exactly from the middle of the tank and then sent to the next section (this part has the least concentration of both due to the principle of decantation).[48]

4.5.4.3 -Produced water lift pump

The produced water lift pumps are installed to supply the produced water from the surge tanks to the pressure gravity separators for the following treatment. One of the pumps will be in service and tow on standby. Each pump has a filter for protection (filters are cleaned when the ΔP is high).[48]

Figure III.14: Water Lift Pumps (CTE-PA-44-01A/B/C).

4.5.4.4 -Pressure gravity separators (PGS)

Pressure gravity separators skid (CTE-UZ-44-04). Six equipments are installed in parallel to distribute the pump's discharge flow rate. Chemicals like coagulant and flocculent are added to enhance the separation efficiency. Teflon packings are used to separate the oil from water by maintaining the superficial packing velocity of 0.2 to 0.5 m/min to achieve proper coalescence phenomena. The water is pumped via an in-line static mixer to the six PGSs. Each vessel is designed to operate at a maximum flow rate of 107 m^3/hr giving an overall maximum flow rate of 640 m^3/hr for the whole package. [50]

Figure III.15: Gravity separators (CTE-VA-44-01A/B/C/D/E/F).

The produced water enters the vessel at the center through the inlet flow distributor and then flows bi-directionally to each side of the vessel exiting at the vessel ends. With no free or dissolved gases present the Separator runs flooded.

The PGS is designed to remove the bulk of the solids present in the produced water. The vessels each have six corrugated packs, and three corrugated plate packs on either side of the inlet, this configuration results in increased removal efficiency.

Suspended Solids being carried within the water pass through the packs, the careful design of the angular plates reduces the velocity of the Suspended Solids encouraging them to drop out of the water. The solids will then settle in the six collection pots at the bottom of the vessel, three to each side.[50]

4.5.4.5 -Dual media filter

The Dual media filter is a coarse filter designed to remove larger solids and oil which could potentially overload the fine filter. The produced water enters the vessel at the top through the inlet distributor giving an even flow distribution down through the layers of media that filter the suspended solids.

The upper 2 layers of the dual media filter are Silica Sand and Anthracite these are the filtration layers, and the lower level of coarse gravel is a supporting layer and ensures an evenly distributed backwash and air scour. The filtration layers are graded in size to create effective deep bed filtration and maximize bed holding capacity. [50]

Figure III.16: Dual Media Filters WTC/ The NMWIC

4.5.4.6 - Fine media filter

The fine filter is a polishing filter designed to take out any solids and oil that remain after the dual media filters. The operating principle is identical to the dual media filter, but the two filtration layers, Garnet and Anthracite, are a finer grade than in the Dual Media Filter.[50]

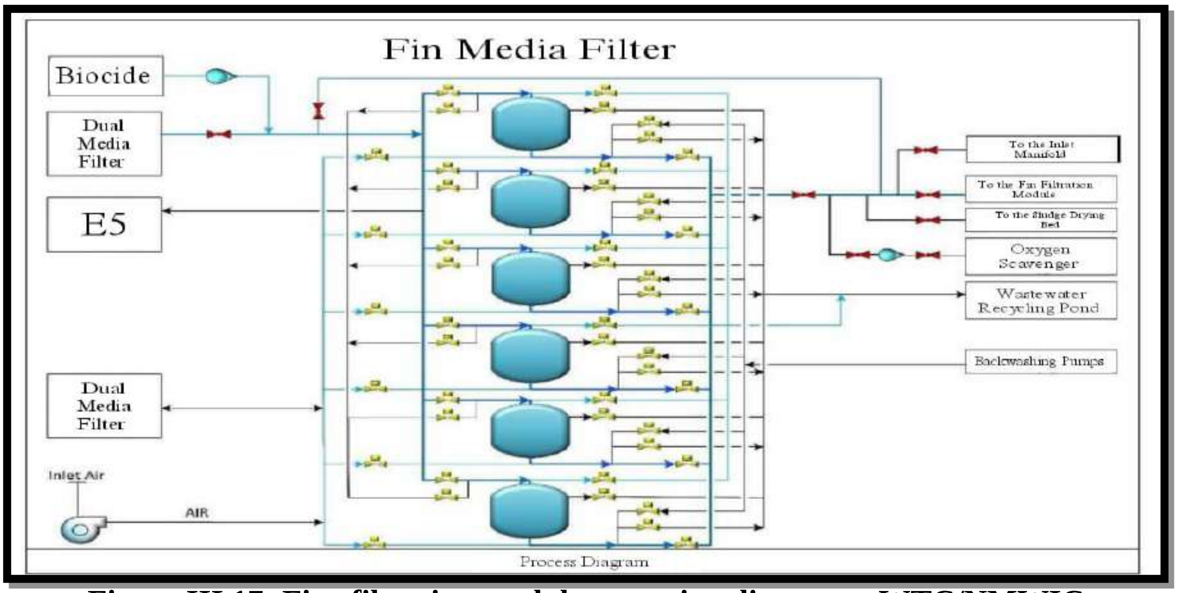

Figure III.17: Fine filtration module operating diagram – WTC/NMWIC

4.5.4.7 -Backward flushing water storage tank (E5)

Water received from the backflushing of filters is stored in the backflushing storage tank. The capacity of this tank is 217 m^3. The back-flushing water collected in the tank is recycled to the inlet manifold by the back-flushing water recycling pump operated automatically by a level transmitter. This pump has a capacity of 100 m^3/hr. This tank is specifically designed with a conical bottom for sludge draining arrangement to the sludge drying bed. [48]

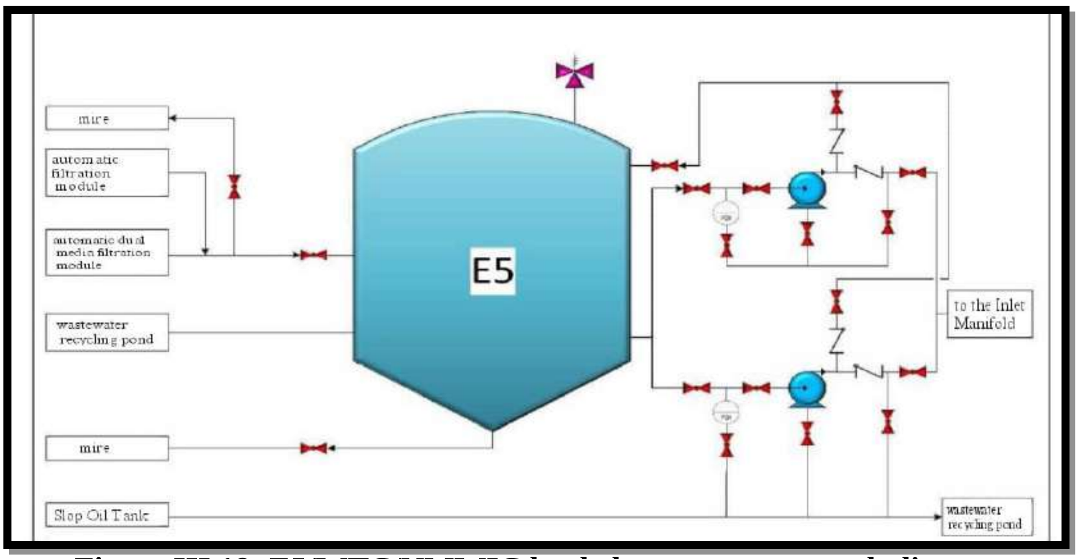

Figure III.18: E5/WTC/NMWIC loaded water storage tank diagram

4.5.4.8 -Recovered oil storage tanks

Tow storage tanks for the oil recovered by the surge tank and the gravitational separators are placed in the unit (**P1**, **P2**). each storage tank has a capacity of 69,5 m^3.

Figure III.19: Slop Oil storage tank P1/P2- WTC/NMWIC

The crude oil collected contains a little amount of water so the tank is equipped with a level transmitter that alerts the operator to change the oil collection to the other tank. The operator then manually purges the water into the sludge drying pool until there is no more water and then transfers the oil to the C4 by starting the lift pump. recovered oil transfer pumps have a capacity of 30 m^3/h. and they operate as one working one standby.[48]

4.5.4.9 -Wastewater recycling pond

Waste water recycle pool is provided to collect all the sampling drains and other produced water streams from the duel & fine media filters. These pools are supplied with 80 m^3 capacity with two compartments in it. Each compartment is mounted with a pump having a capacity of 25 m^3/hr called the wastewater recycle pump. The collected water in waste water recycling pool is sent back to the inlet manifold for the treatment. [48]

4.5.4.10-Sludge drying bed

Sludge released from the surge tank and the PGSs vessels is captured in the sludge drying bed. This section has a sludge storage capacity of 240 m^3 with three compartments. They work in rotation; one is receiving wastewater the second is drying and the third is being cleaned. [48]

The inlet lines of the respective compartments are equipped with manual valves for isolation. The clarified water from each compartment is discharged to the wastewater recycling pond with the help of gravity.[48]

Figure III.20: Sludge drying beds WTC/NMWIC

4.5.4.11-Fire-fighting system

Portable fire extinguishers are placed at a strategic location in the plant. Firewater main ring is routed around the plant with fire hydrant monitors at strategic locations[48].

4.5.4.12-Injection Water Storage Tank (*NMWIC*)

Injection water storage tanks are designed with a residence duration of 4.5 hours. The injection water is corrosive henceforth the injection water storage tanks are equipped with a reinforced vinyl ester inner coating. These tanks are equipped with a drainage device to the wastewater recycling pool during shutdown and maintenance. These tanks are equipped with a level transmitter with an alarm in the control system distributed for the level fluctuation in the tank.[48]

4.5.4.13-Injection gas-powered turbopumps

Injection water is supplied to the aspiration of the turbo pump through a filter. the pump attached to the gas turbine is a **multi-stage centrifugal pump**; Nine stages are used to develop **86 bars** at the pump discharge; the flow rate is 219 m^3/hr. These turbopumps generally work alternatively. The pumps are equipped with a three-way automatic recirculation valve at each pump discharge to prevent the pumps from running at the shutdown pressure. A motorized isolation valve and a magnetic flow meter are provided at the pump's discharge.[48]

Figure III.21: Injection water turbopump WTC/NMWIC.

4.5.4.14- Chemical products injection package

Chemicals required for WTC/NMWIC area are supplied from the chemical injection station located in the WTC area.

Figure III.22: Chemical Injection Zone WTC/NMWIC

These packages are designed to inject chemical liquid into a pipeline or a wellhead. The main performance of this package s is to deliver a constant volume of liquid to a Chemical injection point. They are used to inject the following products [48]:

Table III.1: Chemical products WTC/NMWIC

	Chemical compound	Injection point
1	Corrosion inhibitor	Water Buffer Tank
2	Scale inhibitor	Water Buffer Tank
3	Biocide	Water Buffer Tank
4	Oxygen scavenger	Water Buffer Tank, Fine Media Filter
5	Coagulant/ aid filter	PGS, Dual, Media Filter
6	Flocculant	PGS

Chapter IV

Materials and Methods

1-Equipments

1.1-Orion 3-Star Plus pH Meter

The pH meter consists of two electrodes, the first is a reference and the second is analytical. The determination of pH value is based on the measurement of the potential difference of an electrochemical cell using a pH meter; the difference in potential between a glass electrode and a reference electrode immersed in the same solution is a linear function of its pH according to the Nernst law:

$$E = E_0 + \frac{2,3.RT}{n.F} \times \log a \qquad (1)$$

- E: measured potential (volt).
- **E_0:** constant depending on the reference electrode and internal solution (volt).
- **R:** perfect gas constant (J/mole.K).
- **T:** absolute temperature (K).
- **n:** ion charge.
- **F:** faraday constant (96500C).
- **a:** H+ ion activity in the sample.

The pH of a sample also depends on temperature because of the dissociation equilibrium. Therefore, the sample temperature is always indicated with the pH measurement.

Figure IV.1: Orion 3-Star Plus pH Meter.

1.2- *SS Sentry M-2 Myratek*

Portable automatic device for measuring suspended matter in aqueous solutions on the principle of single-sided light absorption brand is composed of:

- A microprocessor that offers a high degree of flexibility and easy usage.
- Two Sensors using an infrared transmitter.
- Panel
- arrow keys
- MENU Touch
- ENTER button
- ON and OFF buttons
- Screen Lighting Variation Key
- battery-charger connector
- battery-charger

Figure IV.2: *SS Sentry M-2 Myratek*

The Sentry M-2 model has data recording. Up to 50 points that can be saved with a time stamp. Each dot can be labelled with a description at a six-character location.

1.3- TD500

The TD-500D is a dual-channel, handheld fluorometer designed for quick, easy and reliable measurements of crude oil, fuel oil, lube oil, diesel, gas condensates and refined hydrocarbons in water or soil. It is normally used with a solvent extraction method such as the Oil in Water Analysis Procedure. In this method, the target hydrocarbon is extracted into a suitable solvent. The TD-500D measures the hydrocarbon content of the extract and calculates the hydrocarbon content in water.

Figure IV.3: TD500 oil in water meter

The TD-500D responds to the fluorescent aromatic compounds in the target hydrocarbon. The instrument must be calibrated by measuring the intensity of fluorescent light that is generated by a known concentration of hydrocarbons. Once calibrated, the instrument converts the fluorescent light intensity from an unknown sample into units of concentration

2-Reagents

The reagents used in this study are presented in the following table:

Tableau IV.1: Lists of chemicals.

Chemical products	Chemical formulas
Chloric acid	HCl
hexane	C_6H_{14}

3-Sampling

To study the efficiency of the process exploited at the water treatment center, water samples were taken at the manifold, outlet of the buffer tank, pressure gravity separators, dual media filter and turbine outlet.

Samples for testing are taken from perfectly clean and dry glass bottles; the points of withdrawal of industrial water are different from one point to another either at the effluent source or at treatment plants. They intended for storage must be well closed with internal seals in glass bottles to avoid oxidation. These three parameters were chosen as indicators:

- pH.
- Suspended Matter
- Oil Content.

4-Techniques for analyzing oily wastewater

The analyses were done in Sonatrach's laboratory located in the association's life base.

4.1-pH measurement

The pH measurement steps are as follows:

1. A few ml of water is taken from the sample and poured into a spade.
2. Rinse the electrodes in distilled water to give a good contact between the electrodes and the solution to be analyzed.
3. Wait for the pH value to stabilize on the screen.
4. Read the pH value.

Figure IV.4: pH measure.

4.2-Suspended matter measurement

The Sentry M-2 model can work in one of three measurement modes:

a) FAST no data filtering, fast response and tacit reach (useful for measuring depths of coverage levels).

b) CAL1 MLSS -normal 15-second data filtering and low calibration factor range.

c) RAS CAL2 -normal 15-second data filtering and high range of calibration factor.

- First, immerse the probe in clean water, it is important that the water used for zeroing the sensor is clean.

  Distilled water is even better, it is not necessary to use processed water of any type.

  With the sensor submerged for fifteen minutes (15 min) then press "ENTER". The analyzer takes about 15 seconds for zeroing.

- Secondly, the sample reading must be taken from a normal representative water sample.

- Choose the measurement mode (MLSS/CAL1) or (RAS/CAL2) by clicking "MAIN MENU", then use the arrow on the keyboard to move the cursor to the "SETUP" option:

  A menu of ten options will be displayed. Select "MEASURE MODE" to set the measurement mode according to your sample.

- Finally, to return to the "RUN" mode of operation, press the "MENU" key until the "MAIN MENU" is displayed.

- Plunge the probe into the sample for 15 seconds, Use the arrow on the keyboard to move the cursor over the "RUN" option and click "ENTER".

  The analyzer starts to display the TSS value, playback takes about 15 seconds to stabilize.

- Once the SS reading is stable, the operator can record the current SS value.

Figure IV.5: Suspended Matter measurement

4.3-Oil content measurement

Analysis of a sample of water consists of:

- Put in a bottle 100ml of water to analyze and adjust the pH to a value < 2 with chloric acid concentrate. (4 or 5 drops).
- Add 10 ml of hexane and close the bottle.
- Shake strongly for 2mn to extract the squeezed hydrocarbons in the water.
- Leave to settle for about 10 minutes in a funnel.
- Using a syringe fill ¾ of the cup with the sample taken from the bulb and wipe the cup dry.
- Put the bowl in the unit and close the cover.
- Press <Read> and let the device read the value of the response.
- Repeat the reading. Extrapolate this value in the graph and note the concentration of hydrocarbons in ppm.

Figure IV.6: Oil Content Measurement

Chapter V

Results and discussions

1-pH analyses

The results of the pH analysis of oily water samples taken at the outlet of the manifold, Surge tank outlet, pressure gravity separators, dual media filter, and turbine outlet, are grouped in the following graph:

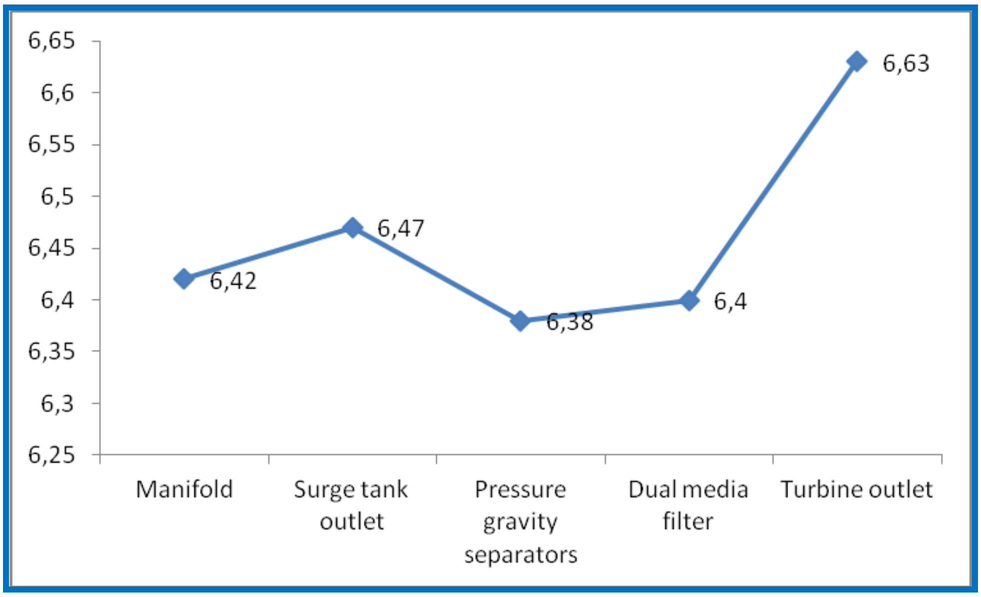

Figure V.1: Changes in pH throughout the process.

The water being treated at the unit is slightly acidic. The pH rises from 6.42 at the inlet manifold reaching 6.63 at the Unit's outlet and drops a bit in the pressure gravity separators because of the effect of the coagulant and the flocculant getting rid of the suspended materials. The biggest two pH rises happen to be at the Surge tanks and the Turbine's outlet wish is preceded by temporary tanks. These pH spikes indicate a lack of hygiene in the tanks, in order to protect the process: the tanks should get purged and cleaned periodically.

The pH of the treated water is within the pH range recommended by the Algerian regulations relating to the discharge of industrial liquid effluents (6.5 -8.5). Nevertheless, acidic pH can be dangerous for equipment as it causes corrosion, anticorrosive methods are highly recommended, the dosage of the corrosion inhibitor being used should be rechecked accordingly, and the sacrificial anodes should be reinforced and changed periodically.

2-Suspended matter

The results of the suspended matter analysis taken through the process are showcased in the following graph.

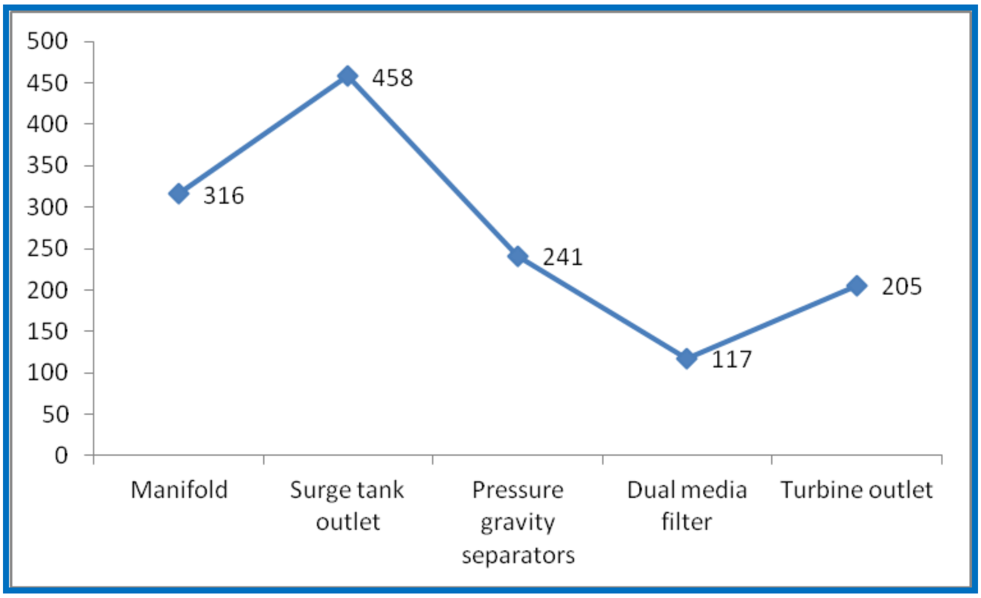

Figure V.2: Suspended matter (mg/l) variation through the process.

The following data were extracted from the analysis result:

Table V.1: Eliminated suspended matter through the process

	Eliminated suspended matter (mg l)	Eliminated suspended matter (%)
Surge tank outlet	-142	-44.93
Pressure gravity separators	217	47.38
Dual media filter	124	51.55
Turbine outlet	-88	-75.21
Total	**111**	**35.13**

The suspended solids entering the center exceed the standard indicated in the Algerian regulations relating to the discharge of industrial liquid effluents (30 mg/l).

The surge and temporary tanks contributed to an increased concentration of suspended matter, there by validating the pH results. The presence of inadequate hygiene and maintenance practices in the tanks poses a detrimental impact on the overall process functionality, potentially compromising its effectiveness and causing damage to the equipment involved.

Due to the surge tank's removal inefficiency the suspended materials proceed to the PGS and the Filters causing them to overperform. The PGS's overperformance explains the clogging of the corrugated packs which led to the inefficiency in oil recovery, it also explains the constant problems in the filters. (They often get clogged and have to be taken out of service).

The concentration of suspended matter at the unit's outlet is at high number. At 35.13% recovery rate, the efficiency of the process is very low. Thus, the treated water cannot be discharged into nature

3-Oil Content

The results of the oil content analysis of oily water samples are grouped in the following diagram:

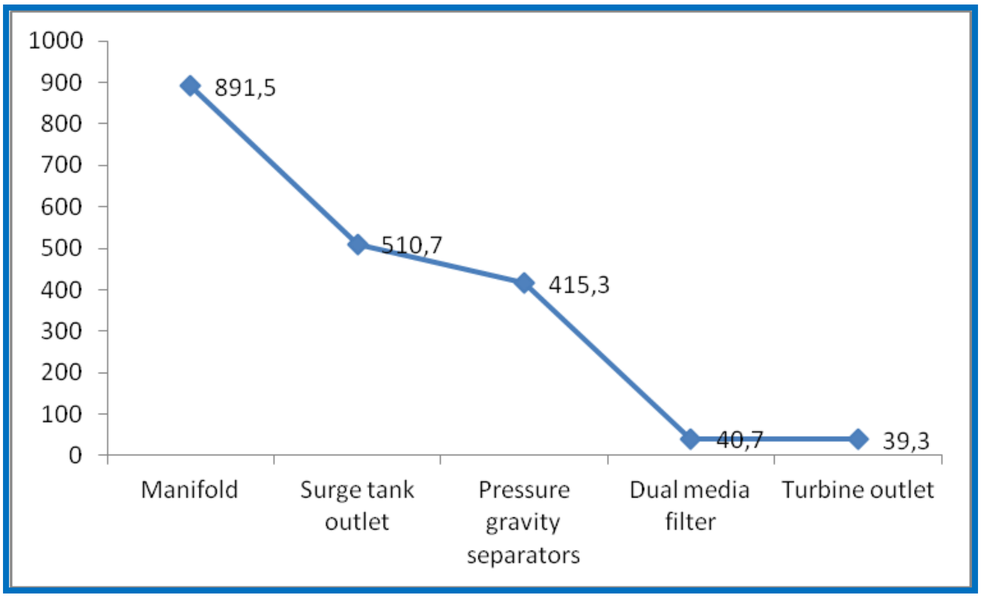

Figure V.3: Changes in the Oil Content (ppm) throughout the process.

In order to study the efficacity of the water treatment center process as well as the efficacity of each section the following data were extracted from the analyses:

Table V.2: Recovered oil through the sections of the unit.

	Recovered Oil (ppm)	Recovered Oil (%)
Surge tank outlet	380.8	42.71
Pressure gravity separators	95.4	18.68
Dual media filter	347.6	90.19
Turbine outlet	1.4	3.44
Total	**852.2**	**95.59**

The oil content at the unit's inlet is significantly higher than the suspected numbers, it is also significantly higher than the norms indicated in the Algerian regulations relating to the discharge of industrial liquid effluents (10 mg/l).

The lower functionality of the surge tank is due to the higher oil content than the norm meaning that the resident time is not sufficient and also due to the lack of hygiene.

The pressure gravity separators exhibit a significant deficiency. This low functionality indicates that the corrugated packs are clogged. To avoid the risk of clogging happening at the next section; filters which are highly sensitive; the corrugated packs must be regularly cleaned or changed if the necessity comes.

The Dual media filter recovery rate is high. It is overperforming, that is because the PGS is not filling its purpose (to protect the Filters and lower the loads on them).

The high total oil recovered highlights the importance of the unit since it recovers an important amount of oil. at 95.59 %, despite the problems occurring and the higher numbers than estimated. The treated water still contains a relatively high oil content that exceeds the standard and therefore limits its discharge into nature

Conclusion

In light of the analysis, we have done of the WTC process, we reached the following conclusions:

- The water being treated at the WTC is characterized by a slightly acidic pH, high turbidity, and high level of Suspended matter and hydrocarbons (oil in water emulsions).
- The unit managed to recover 92.55% of the oil in water dropping the oil content to 39.9 ppm.
- The suspended Matter dropped by 35.13% reaching 205 mg/l
- The contamination in the treated water was still high. it is evident that the treated water does not meet the Algerian standards[51] and requirements for being safely reintroduced into the environment.
- The causes for the low effectiveness of the process were the difference between the supposed numbers at the entry and the actual numbers which were higher by a significant amount and also the lack of hygiene and maintenance to the equipment.
- Following the indicators, we dictated the problem was in the PGS and the surge tanks.

Henceforth, we recommend increasing the resident time of the water in the sedimentation tanks, since the unit was not running at full water capacity, at least one of two surge tanks could have extended resident time.

The dosage of the coagulant/flocculant should be reconsidered according to the noted higher level of turbidity in the entrance of the unity.

The corrugated packs must be cleaned or changed and the water tanks should get cleaned with more consistency.

A whole upgrade applying newer methods such as electrocoagulation[52] and membrane separation[53] should be considered.

Bibliography

[1] G. Crini and E. Lichtfouse, “Advantages and disadvantages of techniques used for wastewater treatment,” *Environ Chem Lett*, vol. 17, no. 1, pp. 145–155, Mar. 2019, doi: 10.1007/s10311-018-0785-9.

[2] A. Demirbas, H. S. Bamufleh, G. Edris, and W. M. Alalayah, “Treatment of contaminated wastewater,” *Petroleum Science and Technology*, vol. 35, no. 9, pp. 883–889, May 2017, doi: 10.1080/10916466.2017.1290653.

[3] R. R. Weerasooriya *et al.*, “Industrial water conservation by water footprint and sustainable development goals: a review,” *Environ Dev Sustain*, vol. 23, no. 9, pp. 12661–12709, Sep. 2021, doi: 10.1007/s10668-020-01184-0.

[4] H. Liang and H. Esmaeili, “Application of nanomaterials for demulsification of oily wastewater: A review study,” *Environmental Technology & Innovation*, vol. 22, p. 101498, 2021.

[5] D. Wang *et al.*, “Stabilization mechanism and chemical demulsification of water-in-oil and oil-in-water emulsions in petroleum industry: A review,” *Fuel*, vol. 286, p. 119390, Feb. 2021, doi: 10.1016/j.fuel.2020.119390.

[6] R. Rashid, I. Shafiq, P. Akhter, M. J. Iqbal, and M. Hussain, “A state-of-the-art review on wastewater treatment techniques: the effectiveness of adsorption method,” *Environ Sci Pollut Res*, vol. 28, no. 8, pp. 9050–9066, Feb. 2021, doi: 10.1007/s11356-021-12395-x.

[7] P. Verma and M. P. Shah, *Phycology-Based Approaches for Wastewater Treatment and Resource Recovery*. CRC Press, 2021.

[8] A. F. Ismail, P. S. Goh, H. Hasbullah, and F. Aziz, *Advanced Materials for Wastewater Treatment and Desalination: Fundamentals to Applications*. CRC Press, 2022.

[9] S. D. Lin, *Water and Wastewater Calculations Manual, Third Edition*. McGraw Hill Professional, 2014.

[10] I. Samy Fahim and L. Said, Eds., *Wastewater treatment: recycling, management, and valorization of industrial solid wastes*, First edition. Boca Raton: CRC Press, 2023.

[11] A. I. Adetunji and A. O. Olaniran, “Treatment of industrial oily wastewater by advanced technologies: a review,” *Appl Water Sci*, vol. 11, no. 6, p. 98, May 2021, doi: 10.1007/s13201-021-01430-4.

[12] G. A. M. Ali and A. S. H. Makhlouf, *Handbook of Biodegradable Materials*. Springer Nature, 2023.

[13] D. P. Tharmaraj, D. J. Shakina, D. R. J. Usha, and D. I. A. Danish, *Industrial Water And Wastewater Treatment*. AG PUBLISHING HOUSE (AGPH Books), 2023.

[14] E. M. V. Hoek, J. Wang, T. D. Hancock, A. Edalat, S. Bhattacharjee, and D. Jassby, *Oil and Gas Produced Water Management*. Morgan & Claypool Publishers, 2021.

[15] A. Stefanakis, Ed., *Constructed wetlands for industrial wastewater treatment*. in Challenges in water management series. Hoboken, NJ: John Wiley & Sons, 2018.

[16] M. Stewart and K. Arnold, *Produced Water Treatment Field Manual*. Gulf Professional Publishing, 2011.

[17] N. Tambo and K. Ogasawara, *Physical and chemical separation in water and wastewater treatment*. London: IWA Publishing, 2020.

[18] *Manuals for Oily Wastewater*. U.S. Navy Civil Enginering Laboratory, Environmental Protection Division, 1983.

[19] J. Coca-Prados, G. Gutiérrez-Cervelló, and North Atlantic Treaty Organization, Eds., *Water Purification and Management*. in NATO Science for Peace and Security Series C. Environmental Security. Dordrecht, The Netherlands: Springer, 2011.

[20] F. Yalcinkaya, E. Boyraz, J. Maryska, and K. Kucerova, "A Review on Membrane Technology and Chemical Surface Modification for the Oily Wastewater Treatment," *Materials*, vol. 13, no. 2, Art. no. 2, Jan. 2020, doi: 10.3390/ma13020493.

[21] S. Roy, A. Garg, S. Garg, and T. A. Tran, *Advanced Industrial Wastewater Treatment and Reclamation of Water: Comparative Study of Water Pollution Index during Pre-industrial, Industrial Period and Prospect of Wastewater Treatment for Water Resource Conservation*. Springer Nature, 2021.

[22] R. Riffat and T. Husnain, *Fundamentals of Wastewater Treatment and Engineering*. CRC Press, 2022.

[23] F. B. Elehinafe, O. Agboola, A. D. Vershima, and G. O. Bamigboye, "Insights on the advanced separation processes in water pollution analyses and wastewater treatment – A review," *South African Journal of Chemical Engineering*, vol. 42, pp. 188–200, Oct. 2022, doi: 10.1016/j.sajce.2022.08.004.

[24] F. R. Spellman, *Handbook of Water and Wastewater Treatment Plant Operations*. CRC Press, 2020.

[25] M. H. El-Naas and A. Banerjee, *Petroleum Industry Wastewater: Advanced and Sustainable Treatment Methods*. Elsevier Science, 2022.

[26] B. Dobias and H. Stechemesser, *Coagulation and Flocculation*. CRC Press, 2005.

[27] J. Bratby, *Coagulation and flocculation in water and wastewater treatment*, Third edition. London: IWA Publishing, 2016.

[28] Environmental Council (Environmental and Water Resources Institute) *et al.*, Eds., *Electro-coagulation and electro-oxidation in water and wastewater treatment*. Reston, Virginia: American Society of Civil Engineers, 2022.

[29] M. L. Davis, *Water and Wastewater Engineering: Design Principles and Practice, Second Edition*. McGraw-Hill Education, 2019.

[30] C. Zhao *et al.*, "Application of coagulation/flocculation in oily wastewater treatment: A review," *Science of The Total Environment*, vol. 765, p. 142795, Apr. 2021, doi: 10.1016/j.scitotenv.2020.142795.

[31] E. Vollan, *Flocculation: Processes and Applications*. Nova Science Publishers, 2018.

[32] H. Demissie *et al.*, "Advances in micro interfacial phenomena of adsorptive micellar flocculation: Principles and application for water treatment," *Water Research*, vol. 202, p. 117414, Sep. 2021, doi: 10.1016/j.watres.2021.117414.

[33] F. Xiao, K. M. Lam, X. Y. Li, R. S. Zhong, and X. H. Zhang, "PIV characterisation of flocculation dynamics and floc structure in water treatment," *Colloids and Surfaces A: Physicochemical and Engineering Aspects*, vol. 379, no. 1–3, pp. 27–35, Apr. 2011, doi: 10.1016/j.colsurfa.2010.11.053.

[34] A. W. W. Association, *Operational Control of Coagulation and Filtration Processes*. American Water Works Association, 2011.

[35] J. C. Crittenden, R. R. Trussell, D. W. Hand, K. J. Howe, and G. Tchobanoglous, *Stantec's Water Treatment: Principles and Design*. John Wiley & Sons, 2022.

[36] J. P. G. R.A P. E., *An Introduction to Oily Wastewater Treatment Engineering*. Guyer Partners, 2021.

[37] N. P. Cheremisinoff, *Handbook of Water and Wastewater Treatment Technologies*. Butterworth-Heinemann, 2002.

[38] M. Fingas, *The Basics of Oil Spill Cleanup*. CRC Press, 2012. [Online]. Available: https://books.google.dz/books?id=bavMBQAAQBAJ

[39] T. Sparks and G. Chase, *Filters and Filtration Handbook*. Butterworth-Heinemann, 2013.

[40] U. S. E. Agency, *2012 Guidelines for Water Reuse*. CreateSpace Independent Publishing Platform, 2015.

[41] T. Sparks, *Solid-Liquid Filtration: A User's Guide to Minimizing Cost and Environmental Impact, Maximizing Quality and Productivity*. Elsevier, 2011.

[42] H. J. Tanudjaja, C. A. Hejase, V. V. Tarabara, A. G. Fane, and J. W. Chew, "Membrane-based separation for oily wastewater: A practical perspective," *Water Research*, vol. 156, pp. 347–365, Jun. 2019, doi: 10.1016/j.watres.2019.03.021.

[43] B. A. Perlmutter, *Solid-Liquid Filtration: Practical Guides in Chemical Engineering*. Elsevier Science, 2015.

[44] H. Athar and B. Ayushman, *Advanced Design of Wastewater Treatment Plants: Emerging Research and Opportunities: Emerging Research and Opportunities*. IGI Global, 2019.

[45] E. Worch, *Adsorption Technology in Water Treatment: Fundamentals, Processes, and Modeling*. Walter de Gruyter, 2012.

[46] C. Tien, *Introduction to Adsorption: Basics, Analysis, and Applications*. Elsevier Science, 2018.

[47] A. Diaf, "Projet professionnel de fin de formation MSP formation avant recrutement specialite: exploitation des hydrocarbures Theme: Amelioration des conditions d'exploitation de l'unite Blowcase.2017," IAP, 2017.

[48] "PROJECT DEVELOPMENT OF OILFIELD ZARZAITINE (SURFACE FACILITY) OPERATION AND MAINTENANCE MANUAL." 2012.

[49] A. Trad, "'Amélioration des procédés de récupération de condensat' (C5+),Projet Professionnel de fin de formation MSP formation avant recrutement," IAP, 2018.

[50] JUTAL, JUTAL Enhydra, and JUTAL Enhydra, "Training Manual,Sonatrach Sinopec Zarzaitine Surface Facility Pressure Gravity Separators and Filters." 2012.

[51] "Journal Officiel de la République Algérienne."

[52] M. A. Jasim and F. Y. A. AlJaberi, "Treatment of oily wastewater by electrocoagulation technology: A general review (2018-2022)," *Journal of Electrochemical Science and Engineering*, vol. 13, no. 2, pp. 361–372, Mar. 2023, doi: 10.5599/jese.1472.

[53] N. U. Barambu, M. R. Bilad, M. A. Bustam, K. A. Kurnia, M. H. D. Othman, and N. A. H. M. Nordin, "Development of membrane material for oily wastewater treatment: A review," *Ain Shams Engineering Journal*, vol. 12, no. 2, pp. 1361–1374, Jun. 2021, doi: 10.1016/j.asej.2020.08.027.

Abstract:

Oily wastewater poses an environmental risk. To minimize damage, treatment techniques have been developed to effectively remove oil and contaminants.

Due to the complexity of the composition and configuration of oils in wastewater, the use of a single technology for complete remediation of contaminants is often inefficient. A combination of technologies can be used for an efficient removal of oily pollutants.

The purpose of this study is to analyze and follow the process exploited at the WTC in order to test and verify its effectiveness, detect problems, and propose optimizations.

Analyses parameters were: PH, Oil Content, and Suspended Matter.The samplings of the wastewater were taken at deferent points thought the process.

The contamination was higher than the Algerian norms therefore it is not safe to introduce to the environment.

Keywords: Oily wastewater, water treatment, coagulation, flocculation, adsorption, sedimentation, Filtration.

ملخص:

تُشكِّل مياه الصرف الملوثة بالنفط خطرًا بيئيًا. وللحد من التلوث، تم تطوير تقنيات المعالجة لإزالة النفط والملوثات بفعالية.

نظرًا لتعقيد أشكال وجود الزيوت في المياه المستعملة الزيتية، فإن استخدام تكنولوجيا واحدة لإزالة الملوثات بشكل كامل غالبًا ما يكون غير فعال بما يكفي. لذا يمكن استخدام مجموعة من التقنيات لإزالة الملوثات الزيتية بكفاءة.

تهدف هذه الدراسة إلى تحليل ومتابعة الطريقة المستغلة في مركز معالجة المياه لاختبار فعاليتها والكشف عن المشاكل واقتراح التحسينات.

تم أخذ عينات من المياه في نقاط مختلفة عبر العملية، وتم تحليلها من حيث الرقم الهيدروجيني وكمية الزيت والمواد المعلقة. من خلال الدراسة تبين أن مستوى التلوث تجاوز المستويات المعتمدة في الجزائر، لذلك فإن طرحها في البيئة غير آمن.

الكلمات المفتاحية: مياه الصرف النفطية، معالجة المياه، التكتل، التخثر، الامتزاز، الترسيب، الفلترة.

Résumé :

Les eaux usées huileuse présentent un risque environnemental. Afin de minimiser les dommages, des techniques de traitement ont été développées pour éliminer efficacement l'huile et les contaminants.

En raison de la composition et de la configuration des huiles dans les eaux usées, l'utilisation d'une seule technologie pour la décontamination complète des contaminants est souvent inefficace. Une combinaison de technologies peut être utilisée pour une élimination efficace des polluants huileux.

L'objectif de cette étude est d'analyser et de suivre le processus exploité au WTC afin de tester et vérifier son efficacité, détecter les problèmes et proposer des optimisations. Les paramètres d'analyse étaient le pH, la teneur en huile et les matières en suspension. Les échantillonnages des eaux usées ont été prélevés à différents points du processus. La contamination était supérieure aux normes algériennes, il n'est donc pas sûr de les introduire dans l'environnement.

Mots-clés : Eaux usées huileuses, traitement des eaux, coagulation, floculation, adsorption, sédimentation, Filtration.