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Presented by :

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-THEME-

**TREATMENT OF INJECTION WATER BY
NANOTECHNOLOGY: ISOTHERMAL, KINETIC AND
THERMODYNAMIC STUDY (APPLICATION ON MICRO-
MODEL OF Reservoir).**

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Acknowledgement

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The Prophet (ﷺ) said: who does not thank people is not thankful to Allah
"Narrated Abu Hurayrah"

Following that, we would like to express our deep appreciation and sincere thanks to all those who have contributed, from near or far, to the elaboration of this thesis.

Firstly, we thank my God Allah who gave us the strength and wisdom to complete this modest work.

Our warmest thanks to Dr . Boufades Djamilla, our supervisor, guided and followed us throughout this work. She advised us, encouraged us, and also gave us precious advice and multiple suggestions. Her fruitful criticisms were, for us, a source of enrichment. Her help and availability allowed us to progress in the work and finalize this study. We would also like to express our sincere thanks to the co-adviser Dr² Zakaria Adjou for their support, guidance, and funny moment which assured us to keep going

Our work was carried out in the laboratory of production of the department of production of hydrocarbons, faculty of hydrocarbons, renewable energies, and science of the earth and the universe, CRAPC and Research center Ouargla

We would like to thank all the people who help us to complete the experimental part, our deepest appreciation to Mr. Abdellatif BENSACI , head of the production department for allowing us to for allowing us to carry out our work at the laboratory level of the department. We would also express our gratitude to Mr. GHALI Ahmed for his interest in this work by accepting and agreeing to judge it and to chair the jury of this thesis.

We would like to thank Mr. Chetti Djamel Eddine vice dean of the faculty and Mr. Lebtahi Hamid for their participation in this jury. Their presence is a guarantee for us of a rigorous examination of our work.

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I would not have been able to complete this without some amazing people for whose help I am immeasurably grateful: for my mom Nacira ,my father moheeddin and my grandma mama Salma for tolerance and patience, and for such a very long time; for endless deep conversations and rock steady support in the final stretch to my Lovely sister Ferdous and my dear Brothers Reda and Boubaker for never-ending patience, encouragement. we would also appreciate my sincere thanks to my friends Aimen for his good vibes and help, and Rayene I know you've been tasked with a lot of work recently. It's because I have faith in your ability to get it all done I'm so thankful to have such a supportive colleague and person like you ,a special thanks to all my close friends who motivated me to carry and to be who I am now

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Aimen Sidiikhlef

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I could not have done any of this without you. Thank you all

Rayene Ayat

Dedication

Dedication

I dedicate this project to Allah Almighty my creator, my strong pillar, my source of inspiration, wisdom, knowledge and understanding. He has been the source of my strength throughout this program and on His wings only have I soared.

My great teacher and messenger, Mohammed (May Allah bless and grant him), who taught us the purpose of life, this work is also dedicated to my parents, Moheddin and Nacira and my sister Ferdous, my brothers Reda and Boubaker , who have always loved me unconditionally and whose good examples have taught me to work hard for the things that I aspire to achieve.

Thank you to my academic adviser who guided me in this process and the committee who kept me on track.I also dedicate this dissertation to all my friends who have supported me throughout the process

Abdel Ghani Sendjel

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Aimen Sidiikhlef

Dedication

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There are moments of happiness in life that no poem can summarize.

There is no winter without snow, no spring without flower, and no joy without it being shared.

No one can give me a better gift than the one my parents gave me at every moment, which is "to feel loved". I dedicate this modest work to my dearest people , My lovely parents" dearest father The one who has always been the source of my courage,My dearest mother The one who has always been proud to have me,We don't do big things, but only small ones with immense love.

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Abstract:

Abstract:

The deposition of barium sulfates is one of the major and most serious problems in oil fields, and in particular in the field TFT, the formation of these deposits is the result of the incompatibility between the injection water rich in sulfate anions and the reservoir water which contains barium cations. To solve this problem our work is based on studying the different used methods in TFT field and The final result of the investigation is a combined solution that couples selective separation with a minimum of anti-settling product injections downstream of the sulfate battery separators before the residual water meets the buffer tank .

Keywords: barium sulfates, productivity index Selective separation

Résumé :

Le dépôt de sulfates de baryum est l'un des problèmes majeurs et les plus graves dans les champs pétroliers, et en particulier dans le champ TFT .la formation de ces dépôts est le résultat de l'incompatibilité entre l'eau d'injection riche en anions sulfates et le réservoir.

l'incompatibilité entre l'eau d'injection riche en anions sulfates et l'eau du réservoir qui contient des cations baryum.

l'eau du réservoir qui contient des cations baryum. Pour résoudre ce problème, notre travail est basé sur l'étude des différentes méthodes utilisées dans le domaine des TFT et le résultat final de l'investigation est une solution combinée qui couple la séparation sélective avec un minimum d'injections de produits anti-décantation en aval des séparateurs de la batterie de sulfates avant que l'eau résiduelle ne rejoigne le réservoir tampon.

Mots clés : sulfates de baryum, indice de productivité et séparation sélective

ملخص:

يعتبر ترسب كبريتات الباريوم من المشاكل الرئيسية والأكثر خطورة في حقول النفط ، وخاصة في TFT ، ويكون تكوين هذه الرواسب نتيجة عدم التوافق بين ماء الحقن الغني في أنيونات الكبريتات . وماء الخزان الذي يحتوي على كاتيونات الباريوم.

. لحل هذه المشكلة ، يعتمد عملنا على دراسة الطرق المختلفة المستخدمة في مجال TFT والنتيجة النهائية للتحقيق هي حل مشترك يجمع بين الفصل الانتقائي مع الحد الأدنى من الحقن من المنتجات المضادة للترسيب. فواصل بطارية الكبريتات قبل وصول الماء المتبقي إلى الخزان العازل.

الكلمات المفتاحية: كبريتات الباريوم ، مؤشر الإنتاجية ، الفصل الانتقائي

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Abbreviations

Abbreviations:

CTU: coiled tubing unit

SSV :sub surface valve

SRU: Sulfate Removal Unit

NF : Nano filtration

EIS:electrochemical impedance spectroscopy

EDTA :Ethylene Diamine Tetraacetic Acid

DTPA:Diethylene Triamine Penta Acetic Acid

MIC : Minimum Inhibitor Concentration

TBT :Tube Blocking Test

TFT : Tin Fouy  Tabankort

CPC : Storage and Shipping Center

FGL :Gas lift closure service

HMZ – SUD : Hassi Mazoula South

UTG : gas treatment unit

CS : Separation centers

RVT :Reid Vapor Pressure

CPC :main collection center

Summary

Summary

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General Introduction

General Introduction:

The oil industry aims to obtain the best production rate and to recover the maximum of the oil reserves in place. To achieve this goal, it fights against all the problems that hinder productivity [1]. Due to natural depletion or organic and/or mineral deposits. The sulfate scale can result from changes in temperature and/or pressure during the flow of water.

Flowing from one place to another, but the main cause of sulfate scaling is the incompatibility between the injected water, which has a high concentration of sulfate ions (SO_4^{2-}) and the formation of water, with a high concentration of calcium ions (Ca^{+2}), barium (Ba^{+2}) and strontium (Sr^{+2}) ions, When these two glasses of water mix, a supersaturated brine are created and Ca^{+2} is When these two glasses of water mix, a supersaturated brine is created and CaSO_4 , BaSO_4 , and SrSO_4 are deposited [2].

Thesis Problematic

Drainage assisted by water or gas injection to maintain the general pressure of the of the reservoir. This last technique, called secondary recovery, for technical and economical reasons, it is widely used. Unfortunately, in many cases, there is an incompatibility cases, there is an incompatibility between the formation water and the injected water, which leads to the formation of mineral deposits and corrosions that are particularly harmful to the proper operation of the production facilities [3].

Sulfate deposits, and in particular barium sulfates, which are the subject of our study, are characterized by the clogging of study are characterized by the rapid clogging of the bottom and surface installations.

In order to maintain the operation particularly disturbed by this phenomenon and to reduce the cost of the maintenance of the installations, several techniques were used such as the prevention of BaSO_4 .

Objectives of the study

Until today, the treatment of BaSO_4 deposits remains insufficient for the total inhibition of these inhibition of these deposits and to reach a maximum productivity.

Among the main objectives targeted by this study are:

- The identification of mineral deposits and their arrangement.
- The construction of a simple apparatus allowing determining the physical parameters.

In this context, it was proposed to study the different used methods used in TFT's field. In order to better position the subject of this thesis, the first part is devoted to a bibliographical literature review that presents a general overview of barium sulfates, their deposition and deposition and the different methods of prevention and treatment of barium sulfate deposits. The second part presents an experimental study which includes: the first chapter refers to bibliographic research about barium sulfates problem and its used treatment and prevention, then in second chapter we made TFT's study case where we indicated the used method for barium sulfate deposit (using selective separation). Finally, our work ends with a general conclusion and some perspectives.

Chapitre

I

Bibliographic Research:

Overview :

Among the main problems raised by water injection in oilfields, the physicochemical opposition prevailing between injected water and field water is certainly still the one which is the worst mastered at exploitation level. The deposits produced by the various precipitation reactions generate degradations which are often irreversible and particularly noxious for the reservoir rock and for the deep production equipments as for the surface ones [5].

In the oil field, the deposits produced during operation have caused various problems with all economic consequences the constraints of resulting production. These deposits represent a real problem in slowing down productivity, and against which manufacturers have been fighting for many decades. There are two types of deposits exist in the exploitation

- Deposits of mineral origin contained in the deposit water or the water used during exploitation
- Organic deposits originating from certain materials contained naturally in oil. Undesirable, the deposits change the proper functioning of the installations.

I.1 The different deposits in the oil fields:

I.1.1 Mineral deposits:

I.1.1.1 *Sodium chloride (NaCl)*:

Salt is one of the main operational problems of the exploitation of the Hassi Messaoud field. The change in pressure and temperature during production causes the precipitation of salts. These salts are essentially sodium chlorides (NaCl). To remedy the consequences linked to the salt deposit, preventive and curative technical dumps have been applied, including cable work, Washing with water (periodically or continuously) and Washing of strainer and perfos with jetting (CTU) [6].

Despite the continuous injection of water by concentrics and frequent scraping by the Wire-line, the salts continue to rush, thus causing the total closure of the wells.

In Algeria, Hassi Messaoud the main deposits locate [6]:

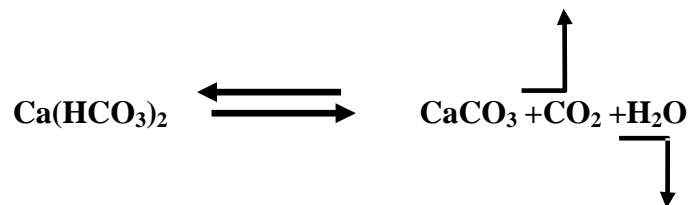
- On tubing walls at different levels.
- The liners between the perforations under the effect of the drop pressure between the pressure of deposit and the bottom of wells.

- At the SSV valve.
- At the level of the water injection valve under the contact effect of the injected water with the produced fluid.
- At the level of the adjustable choke.

- Above the lift gas valve due to the considerable drop in the temperature.
- At the point of contact between the decanted gas at 20° C and the effluent which has a temperature of 100°C.

I.1.1.2 Carbonates (Calcium Carbonates CaCO₃):

Carbonates are due to precipitation by departure of CO₂, by increase in temperature or by a drop in pressure, or by supersaturation for a long time, its formation takes place following the reaction.



The inverse effect of pressure and temperature makes the formation prediction difficult, this is why we will rather seek to use a preventive technique so we can use inhibitors (crystallization retarders), or acid treatments because carbonates are very soluble in acids, it is a solution that will be very little used, because the solubility is accompanied by a release of CO₂, which represents a significant constraint with respect to corrosion [6].



Fig I. 1:Calcium Carbonates CaCO_3 [WELL ONIZ 432, MD660 and OL62]

I.1.1.3 Sulfates:

Sulfates (Calcium Sulfate CaSO_4 Strontium Sulfate SrSO_4 and Barium Sulfate BaSO_4) are the result of two waters. One with alkaline earth ions (barium, strontium, calcium) and the other with sulfate ions (SO_4^{2-}). The deposit is formed at the time of mixing and one of its main characteristics is immediate formation kinetics We find them in formation (because of water injection), and the main risk is to clog drainage areas or to modify the production conditions around the well (perfos, connection hole layer, etc.) [6].Sulfate deposits are three types (Barium/Strontium/Calcium sulfates) (Ba/Sr/CaSO_4).In general, alkaline earth sulfates are not soluble in acids.



Fig I. 2:Calcium sulfate [WELL ONIZ 432, MD660 and OL62]

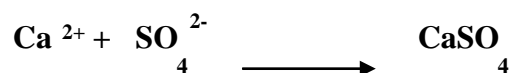
For this, we use a formation inhibitor during the injection of water and water deposit to create a space or an interface. In this case, we can say that the inhibitors acts as a crystallization retardant depending on the concentration [6].

I.1.1.4 Sulfate de calcium (CaSO₄):

Calcium Sulfate salt deposit is one of the common deposits encountered during the exploitation of oil deposits, whose main origin is the incompatibility of water extracted from groundwater, one of the major causes of the formation of calcium sulfate deposits is the drop in pressure that the effluent undergoes along the well. Partial evaporation of the reservoir water can also lead to supersaturation hence rapid precipitation [7].

This poorly soluble salt sees its solubility decrease when the temperature increases despite that, before considering the ultimate solution of chemical treatment, we can try to take advantage of one of these characteristics: its solubility increases with the NaCl content of the solution [7].

Avoid diluting the offending water if possible. On the opposite, we will look for the possibility of mixing with water of higher salinity (unless this enriches unfavorably in SO⁴⁻ or Ca²⁺ ions). If a precipitate persists, we can probably filter it out. The combination between Ca²⁺ and SO₄²⁻ ions gives the formation of a precipitate of calcium sulfate according to the following reaction [6]:



It begins to appear clearly from 100°C. Calcium sulfate, there are three forms that are much more soluble than CaCO₃ which are:

1. (CaSO₄, 2H₂O) Gypsum (dihydrate).
2. (CaSO₄) Anhydrous (anhydrite).
3. (CaSO₄, 1/2H₂O) Hemihydrate.

Most of the calcium sulfate found as deposits in an oil field is in the form of Gypsum: (CaSO₄, 2H₂O). Among the means of control are:

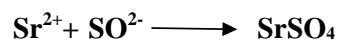
1. Acidification which is effective when the deposits are not too old and therefore not too hard.
2. Polyphosphate-based inhibitors (preventive treatment). [7]

I.1.1.5 Strontium Sulfate (SrSO₄):

The deposit of strontium sulfate or Celestine is much less soluble than calcium sulfate; their reduced solubility is a function of temperature [6].

Precipitation of SrSO₄ can occur by:

1. Evaporation of water.
2. Rise in temperature.
3. Mixture of incompatible waters depending on the reaction:



SrSO₄ deposits are virtually unassailable, even by acids. [7]



Fig I. 3:Sulfate de strontium (SrSO₄) [7]

I.2 Barium Sulfate (BaSO₄):

I.2.1 Definition of barium sulfate (BaSO₄):

This is the most troublesome salt deposit because the solubility limits are very low and the deposits are hard and compact. In general, the problems of barium sulfate deposits arise from the incompatibility of two waters. The reservoir waters may contain barium (Ba²⁺) ions and may come into contact with waters containing sulfate ions (SO₄²⁻). The solubility of barium sulfate (for example) is one hundred percent. Less than that of calcium sulfate. However, the solubility of BaSO₄ increases with the ionic strength of the water. An excess of sulfate ions tends to coagulate the precipitate while an excess of barium ions tends to disperse it. The level of saturation is an important element that regulates the rate of crystallization for barium sulfate. The higher the level of supersaturation, the faster the precipitation [6].

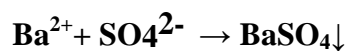
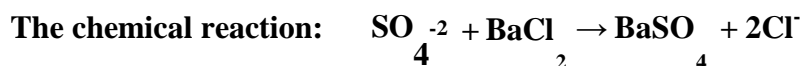


Fig I. 4:Sulfate de barium (BaSO₄)

I.2.2 Conditions of formation of deposits:

An ion exchange in the rock can, among other things, be the cause of the state of saturation of the water. Whatever the case may be, the pressure drop between the deposit and the bottom of the well produces evaporation. Partial of this water, which oversaturates and precipitates crystals. Some have proposed an explanation based on electrical charges. The water droplets containing the seed crystals must carry a positive electric charge, and have a larger dielectric constant than that of the crude in which they swim. The rock is negatively charged due to the presence of clays; likewise, the flow currents in the pipes carry it to a negative potential. Hence attraction and fixation on the asperities. Crystals that have their own polarity are electrically and mechanically retained. Their growth is, subsequently, easy to conceive. Precipitation of barium sulfate is however not limited to oil reservoirs. Deposits can occur on wells, tubings, surface facilities, or in refinery equipment used for crude oil processing [8]



I.2.3 Comparison between the three deposits:

By way of comparison, the solubility of BaSO₄ in fresh water is 2 mg / l, that is to say 10 times lower than that of CaCO₃, 100 times lower than that of SrSO₄ and a thousand times less than CaSO₄, but its solubility increases with the ionic strength of water and can be found in a reservoir water up to 50 mg / l of dissolved sulfates. On the other hand, the size of the crystals increases as the super saturation of the solution is small. The table below gives a comparison of the solubility of barium sulfate and Calcium sulfate, so this table shows that the first one that is formed is BaSO₄

Table I. 1:Solubility and solubility product of three sulfate deposits [8].

Element	BaSO ₄	SrSO ₄	CaSO ₄
Solubility product	$1,1 \cdot 10^{-10}$	$2,8 \cdot 10^{-7}$	$6,1 \cdot 10^{-5}$
Ksp			
Solubility 'S' (mol/l)	$1,05 \cdot 10^{-5}$	$5,3 \cdot 10^{-4}$	$7,8 \cdot 10^{-5}$

Table I. 2:Solubility products of some frequent HMD deposits[8].

Name of the deposit	Ionic product	Solubility products at 25°C
FeS	$[\text{Fe}^{2+}] \cdot [\text{S}^{-}]^2$	$3,2 \cdot 10^{-18}$
BaSO₄	$[\text{Ba}^{2+}] \cdot [\text{SO}_4^{2-}]$	$1,1 \cdot 10^{-10}$
CaSO₄ .2H₂O	$[\text{Ca}^{2+}] \cdot [\text{O}_2^{4-}]$	$6,1 \cdot 10^{-5}$
SrSO₄	$[\text{Sr}^{2+}] \cdot [\text{SO}_4^{2-}]$	$2,8 \cdot 10^{-7}$
BaCO₃	$[\text{Ba}^{2+}] \cdot [\text{CO}_3^{2-}]$	$8 \cdot 10^{-9}$
CaCO₃	$[\text{Ca}^{2+}] \cdot [\text{CO}_3^{2-}]$	$4,8 \cdot 10^{-9}$
MgCO₃	$[\text{Mg}^{2+}] \cdot [\text{CO}_3^{2-}]$	$1,0 \cdot 10^{-5}$

I.3 Deposition of barium sulfates:

I.3.1 The origin of barium sulfates:

As a result of the interaction of the water contained in the HMD reservoir (Cambrian-deposit water which is loaded with Ba²⁺ barium), and the injected water (injection water-Albian- which is loaded with sulfate element SO₄²⁻), it forms the deposition of barium sulfate and gives adverse results on the equipment used during desalting: clogging of wells and corrosion of facilities. These two phenomena have a great influence on the oil extraction process and consequently a decrease in oil production [8].

I.3.2 Characteristics of barium sulfates:

Physico-chemical properties of barium sulfate Barium sulfate has its chemical formula BaSO_4 . These are colorless or white orthorhombic crystals with a relative molecular weight of 233.4, a relative density of 4.5, a melting point of 1580 and a refractive index of 1.637. It is almost insoluble in water with a solubility of 0.00022 to 18 and 0.0041 to 100 . It is slightly soluble in concentrated sulfuric acid and soluble in an alkali metal carbonate solution in which it is converted into barium is insoluble in other types of acids or bases. In nature, it exists in the mineral form of barite [8].



Fig I. 5:Barium Sulfate

I.3.3 Crystal structure of barium sulfate:

The crystals of BaSO_4 as those of SrSO_4 are, on the one hand, orthorhombic with very similar mesh, on the other hand, they are porous in nature with a tendency to absorb foreign ions that can coprecipitate. On the other hand, CaSO_4 is orthorhombic, monoclinic with very different meshes from those of BaSO_4 and SrSO_4 . Barium sulfate crystallizes in the orthorhombic system (Pmma group). Its mesh parameters vary according to the authors. Miyake (Miyake et al., 1978) obtains [8]:

$$a = 8.88 \text{ \AA}; \quad b = 5,46 \text{ \AA}; \quad c = 7,16 \text{ \AA}$$

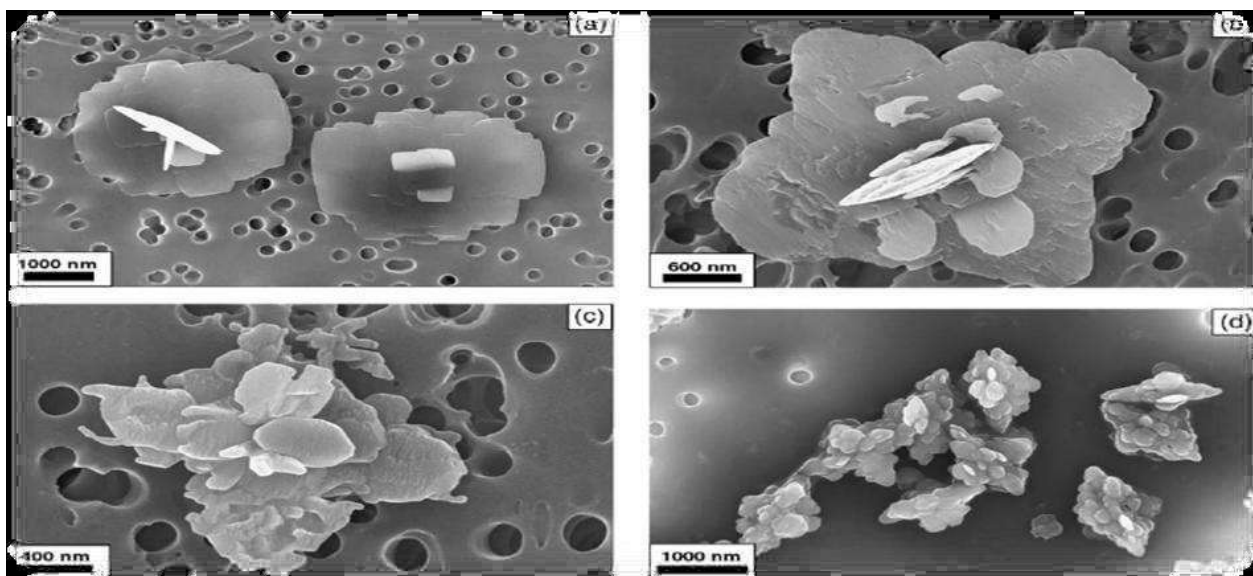


Fig I. 6:Crystal structure of barium sulfate [8]

I.3.4 Solubility of BaSO₄:

Solubility is the ability of a substance, called a solute, to dissolve in another substance, called a solvent, to form a homogeneous mixture called a solution. In thermodynamics, solubility is a physical quantity denoted S denoting the maximum mass concentration of the solute in the solvent, at a given temperature. The solution thus obtained is then saturated. The solubility is expressed in g / L or in mol / L. BaSO₄ is indeed the sulfate salt which has the lowest solubility[8].

At 25°C, Rosseinsky 1958 measured by conductimetry a solubility equal to 1.04×10^{-5} mol / l or 2.5 mg / l.

The solubility product of BaSO₄ at 25 ° C. is 1.10×10^{-10} . The solubility of BaSO₄ in concentrated sulfuric acid (density 1.853) is 15.89 g in 100 g of saturated solution at 25 ° C. The solubility drops rapidly when the sulfuric acid solution is diluted (0.05 g per 100 g of dilute solution containing 83% concentrated acid). The solubility was measured by Kohlrausch, here the results expressed in mg of salt per 100 cm³ of water [8].

I.4 The main causes of deposit formation:

The main causes of deposit formation in oil fields are:

I.4.1 Drop Pressure:

Formation water from the bottom of boreholes as the production process progresses is subject to continuous pressure reduction. When the pressure is sufficiently reduced, certain dissolved gases escape [9].

The decrease in the concentration of one of these gases causes an imbalance leading to the formation of deposits. Indeed, the decrease in carbon dioxide CO_2 for example, disturbs the bicarbonate-carbonate balance, which increases the probability of formation of the deposit of calcium carbonate and the restriction of the flow of fluids [9].

I.4.2 Change of temperature:

Some surface equipment heats up, such as motors or pump heat exchangers, which causes the formation of deposits [10] indeed, for example, the formation of calcium carbonate, in certain equipment, is due to the decrease in its solubility with the increase in temperature.

However, studies have shown that for BaSO_4 , despite the increase in solubility with increasing temperature, barium sulfate deposition forms even at high temperatures [9].

In general, a rise in temperature from 40° to 90° C causes an increase in the solubility of BaSO_4 and a decrease in the solubilities of CaSO_4 and SrSO_4 [11].

$\text{CaSO}_4 \cdot 2\text{H}_2\text{O}$ gypsum has a maximum solubility at 43°C which decreases as one moves away from this temperature value [12] [13].

I.4.3 Change in mineral characteristics:

A change in the mineral characteristics of the waters could lead to the formation of deposits due to the difference in the ionic strengths of the ions in the solution[14].

The total concentration of salts (total salts) in the water is an essential factor. For example, the solubility of calcium carbonate increases with increasing total dissolved salts[14].

The presence of dissolved chlorides (NaCl) or sulfate ions, or other ions than those of calcium in water increases the solubility of gypsum $\text{CaSO}_4 \cdot 2\text{H}_2\text{O}$ or anhydrite CaSO_4 [14].

The solubility of barium sulfate in water is also favored by the presence of dissolved foreign salts [14].

I.4.4 Mixing incompatible waters:

During secondary recovery, water from production wells containing various minerals, mixed after breakthrough with injection water, causes a change in mineral characteristics due to the incompatibility of the two waters, which leads to the deposit formation.

In many cases, instability with respect to calcium carbonates or sulfates and barium sulfate is a direct consequence of this amalgamation, as is often the case in North Sea hydrocarbon fields.

Indeed, when two incompatible waters, formation water containing barium ions and seawater containing sulfate ions, are mixed, the barium sulfate deposit is formed [15].

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The injection of water from the Lias began in 1980. It most often contains sulfate ions, most often in the form of Na_2SO_4 . The reservoir water associated with the oil from the producer reservoir is most often laden with salt and contains strontium and calcium cations and a significant amount of barium in the form of BaCl_2 . The predominant salt is sodium chloride [15].

I.4.4.1 Effect of parameters on BaSO₄ formation:

Scale can occur upstream or downstream of any point in the production system where supersaturation is generated.

Supersaturation can be generated in a single water by changing the pressure and temperature conditions or by mixing two waters incompatible. Changes in temperature, pressure, pH and partial pressure of CO₂/H₂S can also contribute to the formation of a deposit [16].

I.4.4.2 The influence of temperature:

Templeton (1960) studied the solubility of BaSO₄ in sodium chloride solutions at 25 °C and molalities of sodium chloride. He found that at constant ionic strength, the solubility of BaSO₄ increases with increasing temperature and observed that calcium sulfate exhibits an inverse reaction with increasing temperature [17].

The solubility of barium sulfate increases with increasing temperature, increasing the ionic strength of brine and pressure. Consequently, the barium sulfate precipitation was most strongly affected by temperature [18].

Jacques and Bourland, 1983, described a study of the solubility of strontium sulfate in a brine of sodium chloride. Their study showed that the solubility of sulfate of strontium increased with ionic strength and decreased with increasing temperature [19].

I.4.4.3 The influence of pressure:

The variations in pressure cause variations in the concentration of the dissolved gases, and in this case, equilibrium shifts are likely to modify the precipitation conditions. Indeed, the significant pressure variations occur during the rise of the effluents on the surface in the producing wells, which causes partial evaporation of the water leading to rapid precipitation of BaSO₄ and CaSO₄, on the other hand, the reduction of the pressure. Consequently, it promotes the formation of CaCO₃ deposits [20] Calcium, barium, and strontium sulfates are more soluble at higher pressures. Therefore, formation water will often precipitate sulfate deposition when pressure is reduced during production. In addition, the scale can deposit around the well at the level of the perforations in the well. Or in the downhole pump

downstream (if used). Barium sulfate is common at punctures or downstream of chokes, where the pressure is significantly reduced. A pressure drop can cause calcium sulfate deposition. The reason is quite different from that for calcium carbonate. The presence or absence of CO₂ in the solution has little to do with the solubility of calcium sulfate. The solubility of scale formation in a two-phase system increases with increasing pressure for two reasons [18]

I.4.4.4 The influence of pH:

The amount of CO₂ present in the water affects the pH of the water and the solubility of calcium carbonate. However, it doesn't matter what causes the acidity or alkalinity of the water. The lower the pH, the less likely CaCO₃ precipitation is. Conversely, the higher the pH, the more likely precipitation is [18].

Indeed, when we are in the presence of an acid pH, the activity of H⁺ (which originates from the dissociation of weak acids such as (H₂SO₄) is solid. Therefore, it quickly attacks the deposit. On the other hand, the presence of a basic pH causes the formation of oxides which increases the mass of the deposit and decreases the solubility [20].

I.4.4.5 The influence of salinity:

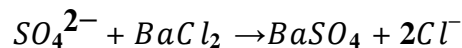
An increase in the concentration of electrolytes accelerates the formation rate of deposits. In the case of dilute solutions, the activities of the various ions present can be assimilated to their concentrations. For water laden with salts, these ions are close enough together to exert significant electrostatic interactions between them; the effect is all the more pronounced as the number and the charges of the ions present are essential, it is characterized by the ionic strength, which is the half sum of the concentrations of each of the ions multiplied by the squares of their charges. The ions are marked as the ionic strength of the solution is essential. It follows from this that the solubility of a salt is increased by adding another salt as long as the two cohabitants do not contain common ions [20] .

I.5 Prevention and treatment of barium sulfate deposits:

I.5.1 Preventive treatment:

I.5.1.1 The subtractive process:

By elimination of deposit-forming ions; example elimination of the sulfate ions SO_4^{2-} contained in the injection water, by precipitating them with $BaCl_2$ following the reaction:



I.5.1.2 The additive process (by Continuous Injection of an inhibitor):

The method of continuous injection of an inhibitor is carried out in injector wells and producer wells.

This technique allows pumping without interruption of an inhibitor bottom of the concentric to a certain depth.

Inhibitor is diluted to achieve good distribution and to avoid precipitation around wells caused by concentrated inhibitor.

I.5.1.3 Squeeze the inhibitor solution into the formation:

Squeeze treatments are one of the most common mitigation techniques tartar. They are generally deployed to inhibit sulfate deposition and in particular barite, which has extremely low solubility and is very hard. Prevention is essential, because sulfate scale only dissolves at a reasonable rate in the best solvents only if sufficient time and temperature are available. Account given the low temperature of the tank, scale removers should not be very effective. Preventive and corrective treatments of scaling are therefore the main plan.

Currently, most treatments are performed using the inhibitor squeeze technique. This technique consists of stopping the production of the well to be treated, then injecting a certain volume of aqueous inhibitor solution into the reservoir and closing it to let the inhibitor adsorb on the rock.

This operation can take anywhere from a few days to a few weeks before returning the well to production, depending on the state of precipitation damage to the reservoir area around the wells.

1. The process of retention of inhibitor molecules on the rock can take place according to different modes, described here :
2. Reversible adsorption of molecules on the rock,
3. Precipitation of molecules on the rock, which can be improved, in the case of phosphate

Inhibitors in the carbonated reservoirs, by injecting a CaCl_2 solution

When production resumes, the inhibitor is gradually released into the water.

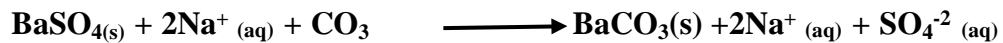
However, to be effective, it must be released into produced waters at a sufficient rate to prevent the formation of deposits. This value is called the Minimum Inhibitory Concentration (MIC): lowest concentration of inhibitor at which deposits do not form/grow.

I.5.2 Chemical dissolution:

Barium sulfate is an extremely resistant scale and, once formed, it is very difficult to remove by acidification. It is not efficiently soluble by acids. A more effective approach for the inhibition of this type of tartar is the use of agent's chelators. Chelating agents are chemicals that form complexes with free metal ions and thus eliminate excess available metal ions to react with anions. Here are some examples of common chelating agents (Ethylene Diamine Tetraacetic Acid) EDTA, acid (Diethylene Triamine Penta Acetic Acid) DTPA gluconic acid, citric acid, and scale inhibitors/dispersants based on polymers such as polyacrylic acid or acrylic acid, copolymers based on maleic acid. The purpose of using chelating agents such as EDTA and DTPA is to convert insoluble barium sulfate into barium carbonate or other compounds it is easier to dissolve than using an acid. Any can control the stability of the metal complex by the hydrogen ion concentration (i.e. pH) [21].

This is most commonly done by dissolving sodium hydroxide in solution to raise the medium pH. An increase in pH will promote the deportation of EDTA and DTPA molecules (i.e. removal of hydrogen atoms) to form $(\text{EDTA})^{-4}$ or $(\text{DTPA})^{-6}$ ions these ion complexes can now adhere to the barium sulfate and remove the Ba^{+2} ions accordingly, leaving the SO_4^{-2} ions in solution [21].

The following chemical reaction occurs when using a chelating agent such as DTPA or EDTA with sodium hydroxide in the solution. Na⁺ is only a spectator ion in the reaction, as shown by the equation [21]:



I.5.2.1 Desulfation of injection water:

In some cases, and depending on the geological characteristics of the reservoir, the sulfates Must be eliminated, in particular when the formation water is rich in Sr⁺² and Ba⁺² ions This makes it possible to avoid the precipitation of barium sulfate and therefore the clogging of the porous rocks of the deposit. Sulfates can be removed by SRU (Sulfate Removal Unit) units consisting of nano filtration / reverse osmosis membranes [21].

These units have the same treatment process [21]:

1. Taken to sea.
2. Coarse sieving at 100 μm.
3. Fine filtration (by ultrafiltration, by Dual Media filtration or using filters with cartridge)
4. Filtration by Nano filtration to eliminate sulfates and achieve concentrations below 40 mg/L.

I.5.2.2 Nano filtration (NF):

The nano filters are implemented according to the principle of tangential filtration with a transfer of material through the membrane due to a pressure gradient that can vary from 10 to 40 bars. The active layer of these nanofilters is made of an organic or inorganic material with a microporous structure with pore diameters of the order of a nanometer [22].

I.5.2.3 Reverse Osmosis (RO):

Reverse osmosis is based on the search for balance in a system. Two fluids with different dissolved solids concentrations that come into contact with each other will mix until the concentration is uniform. When these two fluids are separated by a semi-permeable membrane (which lets through fluid but not dissolved solids), the fluid with the lower

concentration will cross the membrane to join the fluid with the higher concentration. After a while the water level will be higher on one side of the membrane. The level differences called the osmotic pressure. By applying a pressure exceeding the osmotic pressure on the column of fluid, the opposite effect is obtained. Fluids are returned to the first compartment while dissolved solids do not pass [23].

I.5.2.4 Inhibitors:

Scale inhibitors are a category of specialty chemicals used to slow down or prevent the scaling of water systems [24]among them we cite:

EDTA : Ethylene Diamino-tetra-acetic acid which is the most widely used metal ion control agent for the elimination of barium sulfate deposits, Polyelectrolytes are frequently used due to their high efficiency, even in trace amounts, and their very good thermal stability and ability to form a relatively large number important number of coordinative bonds with the cations of the mineral surface[25].

Inorganic and organic inhibitors, inorganic types are very effective; however, their applications may be limited by low solubility and lower thermal stability than phosphonate-based scale inhibitors [26].

Their inhibitory properties are significantly affected by increasing temperature. In addition,they hydrolyze to ortho phosphates with the formation of insoluble calcium salts [27].

Inorganic types include condensed phosphates, such as poly(metaphosphates) or phosphate salts.Suitable organic scale inhibitors are available poly (acrylic acid) (PAA), phosphinocarboxylic acid,sulfonated polymers and phosphonates, Organophosphorus This includes all forms organic scale inhibitors containing phosphorus : ATMP, EDTMP, DETPMP, PEHOMP, HEDP, PPCA[28].

I.6 Curative treatment:

I.6.1 Miling:

This is one of the first methods used to break up thin and fragile scales.It is carried out by mechanical scraping using a scraper. It is used to scrape the walls on which the barium sulfate is deposited, but it can cause cracks in the tubing during the operation. This operation is carried out by the Wireline, Work over and snubbing [29].



Fig I. 7:Crystal structure of barium sulfate [8]

I.6.2 Broach:

A broach is normally used on mechanical cable and is a downhole tool used to remove scale in the upper parts of the tubing to increase the internal diameter and restore cable access to the deeper parts of the tubing well. The broach is shaken up and down to remove scale buildup on the tubing wall. The operation must be repeated with pins of increasing outside diameter, to remove all the scale[30].



Fig I. 8:Broach[30]

I.6.3 Scale Blaster:

Scale Blaster is a mechanical coiled tubing unit employed mainly for cleaning barium sulfate deposits at perforations and obstructions inside the tubing. It consists of using a viscous fluid with a Sand and high pressure[31] .

Scale Blaster = Jet Blaster + gel + artificial sand (Sterling Beads)

The properties of Sterling Beads:

1. Is not abrasive.
2. More effective on very hard deposits, cement plugs.
3. To remove hard and inert deposits such as BaSO₄.
4. Positive and single pass cleaning.
5. Safe technology.

I.6.4 Jett Blaster:

It is used for the elimination of inert BaSO₄ scale, it is a flexible high pressure jet cleaning tool descended by the coiled tubing[32].



Fig I. 9:Jett Blaster[32].

I.7 The used methods for the inhibition of the BaSO₄:

I.7.1 In general ;

The formation of scale during oil production is a world-wide problem, causing considerable production losses and costing hundreds of millions of dollars in remediation and prevention procedures every year. Most of the scale occurring in oil fields forms either by direct precipitation from the water that occurs naturally in reservoir rocks or as a result of chemical incompatibility between the original reservoir formation water and injected seawater. Seawater, typically containing a few thousand milligrams per litre of sulfate ions (SO₄²⁻) and trace amounts of barium (Ba⁺²) and strontium (Sr²⁺), is injected into the reservoir formation during a water flooding process, where it mixes with the formation water which contains significant amounts of Ba⁺² and Sr⁺³. This results in the deposition of sulfate mineral scales of barite (BaSO₄) and Celestine (SrSO₄) on the linings of the pipelines, reducing and even blocking oil flow and in formation pores near the wellbore reducing formation porosity and permeability. It can also coat and damage downhole completion equipment, such as safety valves and gas-lift mandrels

Barite (BaSO₄) is an extremely insoluble mineral and is resistant to both chemical treatments and mechanical techniques traditionally used to remove scale blockage. The direct cost of removing scale from one well can be as high as \$2.5M and the cost of deferred production can be even higher⁴. In most cases, scale prevention through chemical inhibition is the preferred method of maintaining well productivity.

The most important property that any oilfield scale inhibitor must possess is that it has the ability to prevent/inhibit crystal growth at threshold (i.e. below stoichiometric) concentrations. Threshold scale inhibitors interact chemically with crystal nucleation and growth sites reducing the tendency for crystallisation and the subsequent formation of scale at molar concentrations far below those of the crystallising material.

I.7.2 The Dynamic Tube Blocking Test (TBT) method:

The Dynamic Tube Blocking Test (TBT) method is used to evaluate the efficiency of chemical inhibitors to prevent the formation and deposition of mineral scales such as calcium carbonate, as well as calcium, barium and strontium sulfates.

The TBT method aims at:

1. Determining the Minimum Inhibitor Concentration (MIC) required to prevent the formation of scale, and
2. Performing comparative tests with different inhibitors in the same conditions.

Despite some efforts to rationalize the TBT, there is still a lack of methodology for selecting the best inhibitor treatment by this technique. In the TBT method, the differential pressure across a thin steel tube is monitored as a function of time while the two components of the scaling brine are injected at the inlet of the tube. Inhibitor efficiency is measured by comparing the time needed to block the tube in the presence of inhibitor to the time needed to block the tube without inhibitor, i.e. blank time. The main experimental parameters in this method are the capillary geometry, length and diameter, and the flow rate.

I.7.3 Treatment of water associated with oil before its injection into the reservoir

The most beneficial method to prevent the formation of deposits sulfates and no doubt the large-scale use of deposit inhibitors such as polyacrylamides, organophosphates, poly carboxylates, etc. The active parts of these high molecular weight molecules are adsorbed on the active sites of the crystals of freshly formed deposits and they block the growth crystal by increasing the forces of repulsion and decreasing the forces of attraction. Deposit particles formed remain dispersed in solution.

The problem of scale formation in oil field production facilities is encountered as a result of mixing of injection water (Lias) rich in sulfate with formation water (Ordovician) rich in barium. A large number of methods have been developed for the prevention of these deposits. Poly (maleic acid) was studied to ascertain its suitability as an inhibitor of barium sulfate scale deposits. It was synthesized by a free radical solution polymerization. Two different initiators were used namely a potassium persulfate and a redox system composed of potassium persulfate/sodium-hypophosphite monohydrate. Their concentrations were varied to obtain low-molecular weight polymers. Physical and chemical properties of the polymers obtained were measured by infrared and UV/VIS spectrometry, solubility test, viscosimetry,

refractometry, and liquid chromatography. The effectiveness of poly (maleic acid) formulations as scale inhibitor was studied by turbidimetric tests. The most effective inhibitor formulation was found to be that based on poly(maleic acid) prepared via a redox initiating system. This polymer, used at a concentration of 3 ppm, presented the highest effectiveness namely 96% and 88% at room and oil well temperature, respectively, when compared with two commercial inhibitors. Synthesis and characterization of maleic acid polymer for use as scale deposits inhibitors

The electrochemical behaviour of carbon API 5L X70 grade steel electrode towards barium sulfate scaling and scaling inhibitors is investigated in this paper. A study of the carbon steel/injection water interface, with and without inhibitor, was carried out using electrochemical impedance spectroscopy (EIS). The scanning electron microscopy (SEM) and the X-ray diffraction study, in the absence of scale inhibitors, revealed the formation of a thick layer on the surface mainly composed of barium sulfate BaSO_4 . The barium sulfate scale is formed naturally and evolves with the immersion time. EIS spectra, in uninhibited medium, present three capacitive loop corresponding to transfer charge resistance, deposit resistance and porous resistance. The effectiveness of scale inhibitors used in oil fields pressure maintaining systems is evaluated. The EIS spectra in the presence of the inhibitors show the decrease of the resistances reveal that the scaling inhibitors effect is a tendency to form low amounts of barite solid precipitated on the electrode surface and their inhibiting efficiency increases with concentration rise.

The electrochemical impedance spectroscopy is used to study the behavior of the ordinary API X70 5l steel electrode covered with barium sulfate scale. It has been found that after the immersion of the electrodes in the mixture of unsaturated solution containing the injection water (SO_4^{2-}) and formation water (Ba^{2+}), a deposit is naturally formed on the surface. The X-ray diffraction and scanning electron microscopy MEB analysis confirmed that it is the Barium sulfate BaSO_4 compound. The electrochemical impedance spectra in the absence of inhibitors give three capacitive loops corresponding to the charge transfer resistance R_{ct} , deposit resistance $R_{deposit}$ and pores resistance R_{pores} respectively. Increasing resistances with immersion time reveals that the active surface of the electrode is totally blocked by the deposit layer. However, it can be considered as mineral coating against corrosion. The EIS results obtained are in good agreement with those obtained by the surface characterization analysis (MEB and DRX). The inhibition efficiency of scale inhibitors of barium sulfate is determinate by using parameter extracted from EIS spectra. It

value depends on global resistances obtained in the absence and presence of scale inhibitors. The phosphonate is one of the most powerful inhibitors of barium sulfate scaling. This study shows that the inhibitor B (phosphonate) is much effective at low dose and at high concentration its efficiency is limited because of apparition of the micelles. However, the polyacrylate combined to phosphate-ester (inhibitor C) has a satisfying inhibiting effect which increases with increasing of inhibitor concentration [33] .

I.7.4 The deferent treatment of barium sulfate deposits that was carried out:

In recent researches, inhibition of barium sulfate precipitation has been extensively studied using a large number of techniques:

Alex Yi and al [37] studied The Mechanism of Barium Sulfate Deposition Inhibition and the Prediction of Inhibitor Dosage; they find that the increase in temperature enhances the inhibition. (50-150°C/deposition rate constants by 50–95%).

Amer Badr Bin Merdhah [38] studied the Inhibition of barium sulfate scale in high-barium formation water .he found that for high barium ions concentration formation water, apparently PPCA appeared to be the best BaSO₄ inhibitor compares to the others in this study. The efficiency of the scale inhibitor is followed by DETPMP and thirdly PBSI.

In 2020, Mai Chen and al [39] studied the experimental investigation and numerical modeling of barium sulfate deposition in porous media .they found that barium and sulfate react immediately after mixing,SI has a significant influence on scale deposition: permeability reduction increases as SI increases and a small amount of barium sulfate deposition could cause severe permeability reduction.

In 2020, E Lenchenkova and al[40] have developed Technology for prediction of salt deposition in oil production which is a model based on multi-factor correlation and regression analysis for predicting a decrease in the permeability of BHA as a result of the deposition of mineral deposits (barium sulfate). The statistical analysis of the results shows that at medium and high concentrations of barium, the accurately estimates the decrease in rock permeability with determination coefficients of 0.941 and 0.948, respectively.

In 2021 ,Alex Yi-Tsung Lu and al[41] studied the kinetics of Barium Sulfate Deposition and Crystallization Process in the Flowing Tube.they found that according to the

SEM(scanning electron microscope) observations, the crystallization is the main mechanism in barite scale deposition, which indicates that the key crystal growth parameters such as supersaturation would be significant to the deposition kinetics, The observed crystal number densities increased with the solution SI value, which suggests that the nucleationthe process triggers the barium sulfate deposition, According to the nucleation theory, the presence of the foreign the surface may lower the energy barrier (surface tension) to enhance the nucleation reaction. This fact may suggest that the deposition will be triggered by foreign surfaces, The kinetics of barite deposition in a laminar tubing flow is found to be a first-order transport-controlled process, which is contrary to the previously reported barite growth kinetics as a second-order surface reaction. Based on the ion-transport process, The measured rate constants match well with the theoretical diffusion-controlled rate constants from the Graetz–Nusselt theory, which further proved that the reaction is a diffusion-controlled process. The factors related to the ion diffusion such as viscosity, temperature, and ion concentrations are therefore essential to the deposition kinetics and The mechanistic understanding of the deposition process give us the ability to accurately predict the kinetics of barite deposition.

In 2010, Eleftheria Mavredaki and al[42] studied the Initial Stages of Barium Sulfate Formation at Surfaces in the Presenceof Inhibitors.they proved that PPCA is an effective retarder of the barite both at the surface and in the bulk state. On the contrary,DETPMP was not very effective in inhibiting the formation of barite under these specific conditions. However, it cannot be concluded from this type of experiment that DETPMP is ineffective in general.

In 2022, Yuan and al [43] studied the Investigation of sorptive interaction between phosphonate inhibitor and barium sulfate for oilfield scale control .they found that Laboratory studies suggest that the adsorption and desorption processes of DTPMP to and from barite surface can proceed rapidly. The calculated mass-transfer coefficients of adsorption and desorption process are $0.28\text{--}0.34\text{ cm h}^{-1}$ and 0.013 cm h .

In 2009, Amer Badr Bin Merdhah and Abu Azam Mohd Yassin [44] studied the laboratory Study on Precipitation of Barium Sulfate in Malaysia .They found that rise from 40 to 90 °C in temperature causes an increase in BaSO₄ solubility , Permeability decline caused by BaSO₄ scale formation in the porous media ranged from 5% to 19% of the initial permeability, depending on brine composition, initial permeability, temperature, differential pressure, and brine injection period,steepness of these curves generally decreased with

increasing distance from the point of mixing of the incompatible brines, Several factors influencing scale formation had been examined. Increasing temperature, super-saturation, and differential pressure had a detrimental effect on the permeability reduction and constant reaction rate, The formation of BaSO_4 during flow of injection and formation waters in porous media have been proved by Scanning Electron Microscopy (SEM) micrographs show BaSO_4 crystals formation in porous space and The constant reaction rate (K) varies with temperature according to Arrhenius equation.

In 2013, Arash Kamari and al [45] studied the Rigorous modeling for prediction of barium sulfate (barite) deposition in oilfield brines. Therefore, accurate estimation of this deposition type can increase the efficiency of oil and gas production. The model is proposed using a robust soft computing approach. Namely, the least-squares support vector machine (LSSVM). The results indicate that the developed model provides predictions in satisfactory agreement with the reported data. Moreover, it is illustrated that the proposed model can simulate the actual physical trend of the solubility product data KSP, of barite in the oilfield, brines with temperature variation.

Recently, several researchers have investigated different chemical scale inhibitors to minimize scaling precipitation, amongst which nanotechnology has been considered an effective solution. In 2018, Mohammad Jamialahmadi and al [46] studied the Experimental Investigation of the Effect of Silica Nanoparticles on the Kinetics of Barium Sulfate Scaling During Water Injection Process. Results showed that the rate of barium sulfate deposition decreases at higher temperatures. Moreover, permeability reduction reduces with injection rate.

I.8 Conclusion

To conclude this chapter which constitutes a bibliographical research on the deposition of barium sulphates, as well as the various methods of treatment to be curative or preventive, we can affirm that the prevention of the deposits of sulfates remain the adequate solution.

Chaptre

II

TFT's Study Case

II.1. Representation of the TFT region:

The Regional Directorate of Tin Fouyé Tabankort, known as TFT, is an operational unit of the national company SONATRACH, upstream activity, production division created in 1976 as part of the reorganization of the former In Amentas sector.

II.1.1. Site and geographical location:

The Tin Fouyé Tabankort Region is located 1400 km south-east of Algiers and 540 km from the capital of the Illizi wilaya.

Region TFT is located on the western part of the Tin-Hert plateau, on national road N°3 linking Hassi-Messaoud and In-Aminas in the commune of Bordj-Omar-Driss. Its current workforce is about 1000 Agents in addition there are contract agents, it is placed second after Hassi Méssaoud with regard to oil reserves.

The region lies at an altitude of 432 m with an ambient temperature that varies between 0°C and 45°C throughout the year. It is limited by UTM coordinates.

Y1=3110000 Y2=3900000

X1=3100000 X2=400000

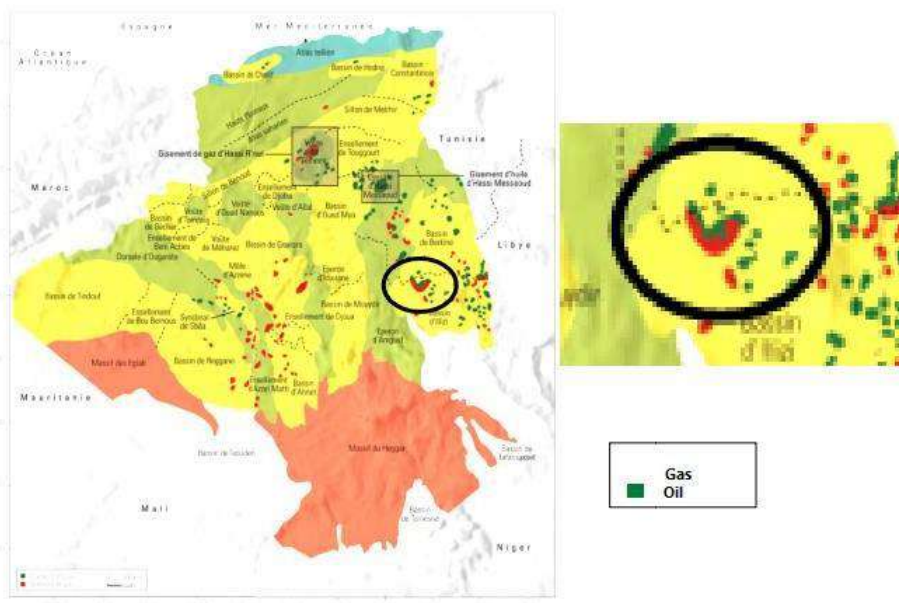


Fig II. 1: Region TFT

II.1.2. The deposit part:

The TFT deposit has two productive reservoirs, the Devonian and the Ordovician. The Ordovician reservoir is 2100 m deep on average, it takes its name from the ancient Celtic tribe of the Ordovices who lived in the region of Wales. The Devonian is an oil reservoir at a depth of 1400 m, it is non-eruptive exploited by artificial modes, it takes its name from the county of Devon in the South West of England.

The Ordovician is the main deposit, it was discovered in 1967. This reservoir is an oil column in the form of an anticline surmounted by the gas-cap to the south and oil to the north, the reservoir extends over 7 to 15 km from north to south and 25 km from east to west. The Devonian is a non-eruptive oil reservoir exploited by artificial modes.

The TFT region is divided into two sectors:

- The northern sector includes the Ordovician and Devonian TFT fields (TAM, AMA and Djoua).
- The southern sector includes the Tin-Fouyé and Mazoula fields.

Presentation of the regional management:

The regional management of Tin Fouyé Tabankort, known as TFT, is part of the Exploration and Production (E-P) activity of the national hydrocarbon transport and marketing company (SONATRACH). It is responsible for the production of oil from the various deposits that exist in the region and the management of all the structures attached to it.

II.1.3. Organization of the regional management:

The TFT region is composed of three types of structures:

II.1.3.1. Technical support structures

It is made up of the following divisions:

- **Implementation Division:** this division deals with projects, their study, monitoring and implementation.
- **Supply and transport division:** its role is to ensure the management of supply, storage and transport.
- **Safety division:** its main role is to ensure the safety of industrial installations and the protection of personnel in accordance with the company's HSE policy.

II.1.3.2. Support structures:

It is in turn made up of the following divisions:

- **Finance Division:** this division manages and prepares the budget, general accounting, analytical accounting, treasury and legal activity.
- **Stewardship Division:** its role is to ensure the management of the base camp (catering, accommodation, laundry, and hostel).
- **Personnel division:** this division deals with the organization of the human resources of the company. It is made up of several departments (the Planning Department, the General Administration and Resources Department, the Management/Payroll Department and the Social Benefits Department).

1.1.1. **Technical structures** It is made up of the following divisions:

- **Maintenance division:** its role is to ensure the proper functioning of industrial equipment.
- **Production engineering division:** its main role is to take care of the wells from their drilling until their total depletion. While monitoring the evolution of the parameters of the deposits and programming the operations necessary to maintain their production.
- **Exploitation division:** it is in charge of the exploitation of oil, gas and water from the wellheads until their dispatch, it is also in charge of the management of the surface installations.

II.1.3.3. Exploitation Division:

The exploitation division is responsible for the exploitation of oil and gas from the TFT field, which has three sectors, the northern sector (TFT ORDO, AMASSAK and DJOUA), the southern sector (TIN-FOUYE and MAZOULA) and the TFR sector. The division also carries out activities in the context of maintaining the pressure of deposits, through the production and injection of water as well as the injection of gas lift. The estimated oil production is around 9000 m³/d. Among the tasks performed by the operations division, we can cite the following: The opening and closing of wells. Reporting problems and anomalies in collection, storage or shipping. Testing of certain well parameters as part of a periodic program, such as: flow rates (oil, gas, water), percentage of water, wellhead pressure.

II.1.4. The various departments of the Operations division:

The Operations division is made up of five departments, which are:

Pressure maintenance department. FGL service (gas-lift closure). UTG service (gas treatment unit). Northern Oil Service. Southern oil service.

II.1.4.1. North Oil Operation Service:

This service operates oil in the northern sector. It includes five separation centers CS1, CS2, CS3, CS4, CS5 as well as the centers of TAM and AMASSAK. The recovered oil is sent to the North Sector Oil Storage and Shipping Center (CPC).

II.1.4.2. Southern Oil Exploitation Service:

This service is responsible for the exploitation of oil in the southern sector. It includes five separation centers MF1, MF2, MF3, MF4, MF5, as well as the CTFN, DJOUA and MAZOLA centers. The recovered oil is sent to the Southern Sector Oil Storage and Shipping Center (CPC/TFY).

II.1.4.3. Associated gas processing unit:

This unit aims to recover flared gases (high and low pressure) from the Ordovician deposit. Its mission is to compress, dry and treat the gas to market it, part of which is used for “gas lift” needs. The processing capacity of this unit is 4.8.106 Sm³/day

II.1.4.4. Gas lift closure service (FGL):

This service ensures the recovery of flared gases at the various centers in the southern sector and the TFT storage center, compression, treatment at GL stations and injection of gas into wells.

II.1.4.5. Pressure maintenance service:

This service ensures the production of water and its injection into the Ordovician reservoir, it includes two TAM and TFNE production stations and two CS2 and AMA injection stations.

II.1.5. The different perimeters of the TFT region:

The TFT field is composed of fifteen (15) operating perimeters, these are represented in the following figure fig will be added

II.1.5.1. History and development of the TFT field:

The first discoveries in the TFT region date back to the 1960s, the first deposit to be discovered was that of T.F.Y in 1961, then those of HASSI MAZOULA south and north in 1963, T.F.Y north and DJOUA in 1966, TFT ORDOVICIEN in 1967 and finally TAMENDJELT and AMMASSAK in 1970.

The dates of discovery of the TFT fields and their commissioning are presented in the following table:

Table II. 1: Dates of discovery and commissioning of the various TFT field tanks

Perimeters	Date of discovery	Date of commissioning
Sector	North sector	
TFT ORDOVICIEN	1967	1968
AMASSAK-TIRARIMINE	1970	1974
TFT ZONE 100	1966	1967
TFT ZONE EST	1968	1968
DJOUA OUEST	1966	1968
TAMENDJELT	1970	1974
EAU LIAS	1966	1980
Sector	South Sector	
TIN FOUYE	1961	1963
TIN FOUYE NORD	1966	1966
TIN FOUYE OUEST	1963	1963
HASSI MAZOULA NORD	1958	1965
HASSIMAZOULA SUD	1963	1966
HASSIMAZOULA B	1966	1967

Discussion :

- The TFY deposit is located in the southern part of TFT and is exploited by the gas lift technique.
- The AMASSAK deposit is located 32 km away in the northwestern part of TFT.
- The exploitation is done by using the technique of pressure maintenance by water injection.

Chapter II : TFT's Study Case

- The deposit of DJOUA is located in the south-eastern part of TFT, the exploitation is done by electric submersible pumps.
- The deposit of TAMANDJELT is located at about 16 km northwest of TFT, The HASSI-MAZOULA deposit (north, south and Mazoula B) is located in the southern part of TFT, the exploitation is done by electric submerged pumps and mechanical pumps (the balances).
- The Ordovician reservoir produces the largest part of the region's production, its operation exploitation began in November 1968. Until 1975, 52 wells were drilled, of which 49 were producers, the area covered by the drilling was only 40% of the area of The oil production in 1974 reached 2583929 tons, and 4713227 tons in 1977.
- The production started to drop due to the decrease in pressure of the deposit, which leads to the depletion of the reservoir energy, the pressure maintenance project is introduced

In 1980. The production continued to fall until 1419874 tons in 1983. The results started to began to show from 1984 when it was produced 1733058 tons, 4238644 tons in 1991, 3838587 tons in 2002 and in 1991, 3838587 tons in 1994 and 3400423 tons in 1998

Several oil recovery techniques have been used in the TFT region to increase the recovery rate. Primary recovery, where production occurs naturally naturally (eruptive wells). Secondary recovery, where techniques are used to increase production, such as increase production, such as pressure maintenance by water injection and activation modes such as activation methods such as gas lift, electric pumping and balancing.

II.2. Water injection:

Water injection is the oldest secondary recovery process and remains the most widely used (80% of the oil produced was produced by water injection). It increases oil recovery by improving the scavenging or displacement coefficient. But, apart from this secondary recovery objective, water injection can be used to:

Maintain reservoir pressure if the expansion of the aquifer (or gas-cap) does not provide enough energy. It is not a question of secondary recovery strictly speaking but of maintaining pressure, and this is the case of the Amasak field.

If necessary, eliminate the salt water contained in the production if its discharge on the surface poses particular problems.

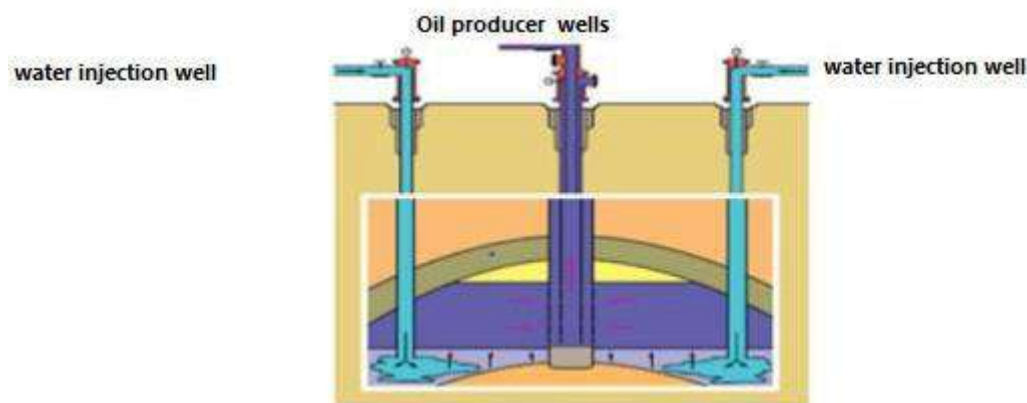


Fig II. 2:Secondary recovery by water injection

II.2.1. The different water injection techniques:

The relative arrangement of the injection and production wells depends on the geologic aspect of the reservoir, its type (fluid content) and the importance of the volume of impregnated rock that you have to sweep. There are two injection localization schemes, which may possibly be used simultaneously on certain tanks.

- Grouped injection or the wells are grouped locally.
- Dispersed injection or injection and production wells are interleaved.

II.2.1.1. A. Grouped injection:

In a fairly steep reservoir, the aim is to arrange the injection wells in such a way that gravity makes the movement as regular as possible. In cases where a deposit has a gas-cap and an aquifer, it is interesting to inject either gas into the gas-cap or water into the aquifer near the oil-water interface, c is peripheral water injection. In the case of water injection, the producing wells located down-dip will often be converted back into an injector when the water has invaded the corresponding zone.

II.2.1.2. Dispersed injection:

This type of injection corresponds to the low-dip reservoir and extends, moreover, if the permeability is poor, on the other hand, offshore, a peripheral injection can lead to a significant distance between wells. To obtain a uniform scan, the producer and injector wells are then distributed according to a fairly regular pattern: it is a question of dispersed or distributed injection in the oil zone.

Different configurations are used, the wells are implanted in a direct line, or staggered with in particular 5-well (Five spot), 7-well (Seven spot) or 9-well (Nine spot) patterns.

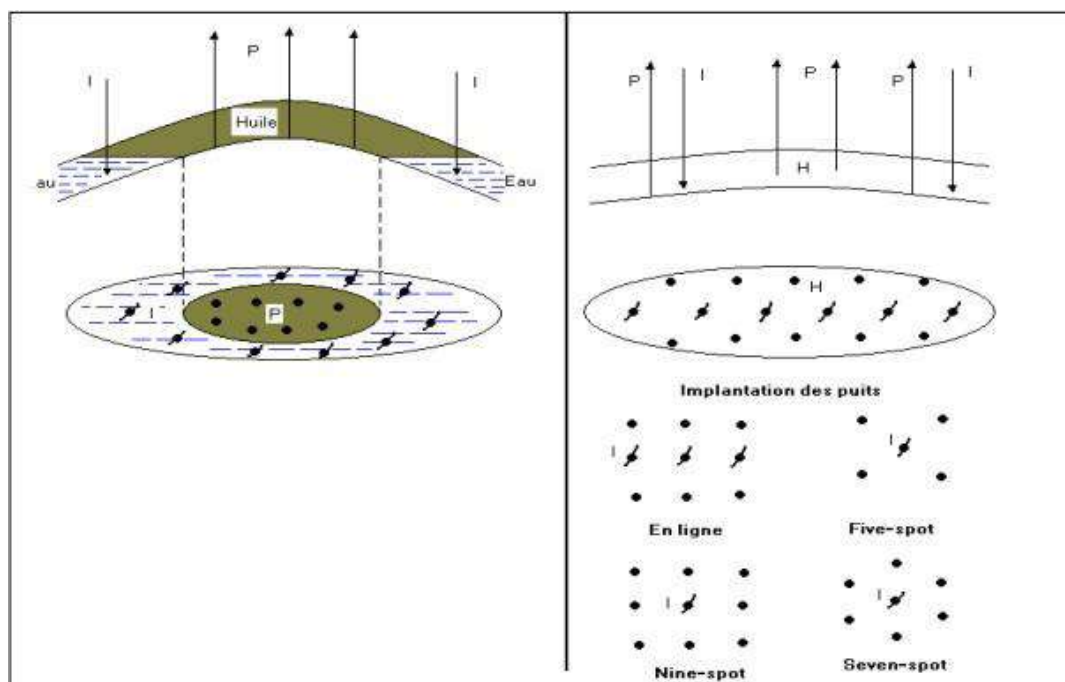


Fig II. 3: Grouped injection & Dispersed injection

II.2.2. History of oil production and water injection at TFT:

The natural depletion of the deposit is explained by the decrease in pressure in the reservoir rock due to the withdrawal, which led to a decrease in the oil scavenging coefficient. Insufficient natural sweeping in the deposit prompted the input of artificial energy to enhance recovery. The method used in the TFT region is water injection and it is done by the grouped technique.

The majority of injection wells are initially oil-producing wells. As the water front advances, the wells reached by the latter are converted into water injection wells.

show the effect of the injection of water into the Ordovician reservoir at the level of the TFT field on the oil production, the variation of the latter has a direct link with the scavenging coefficient. The higher the production, the better the coefficient.

II.3. Existing deposits:

II.3.1. TFT Bearing:

The TFT deposit looks like an oil ring, capped by a large gas cap. The roof of the Ordovician reservoir forms a monocline with an East-West direction and a North dip.

The analysis of the map in isobaths at the top of the Ordovician and at the wall of the layer proves that the deposit has a structure divided into blocks.

Drainage mode: expansion of dissolved gases and gas cap. Water injection from 1981. The deposit is currently partly exploited by gas-lift.

II.3.2. Tin Fouyé deposit:

It is presented as a high zone, extremely complex, composed of different structures, the highest of which is that of TIN FOUYE, the largest by its dimensions (306) and its impregnated height (160 m at TFY 18). In the TFY deposit, drilling revealed accumulations of undersaturated oil in the Paleozoic series, mainly in the Devonian F.6 reservoir, which includes an active aquifer and gas in the Ordovician, unit IV. The Devonian reservoir is operated by gas-lift.

II.3.3. Amasak deposit:

The AMASSAK deposit is located 25 km West - North West of the TFT deposit. The Ordovician reservoir appears as a monocline sloping to the northeast and intersected by several submeridian accidents; these accidents act as compartment boundaries for oil accumulation. Oil and gas have been discovered in Ordovician unit IV-3, which is the main reservoir in this area.

- Water injection from 1995.

II.3.4. Djoua deposit:

The DJOUA deposit, located 30 km South East of TFT, is in the form of an elongated North / West - South / East anticline affected by a fault in the same direction. It produces oil mainly in tank F 6 (units C1, A-VIII and M1-X) by electric pumping.

II.3.5. Tamendjlet deposit:

The TAMENDJELT reservoir, located about 6 km northwest of TFT, is in the form of two major structural units, separated by a large accident composed of a series of relay faults; from South to North we can distinguish: - An anticline - A monocline plunging towards the North - West, The exploitation of the F 6 reservoir is done by gas-lift.

II.3.6. Hassi Mazoula North deposit:

The Devonian F6 reservoir appears as a flattened anticline, slightly elongated from South - South / East to North - North / East, and is linked to the major "Mazoula - Belouda" accident. The exploitation of the F6 reservoir is done by electric pumping.

II.3.7. Hassi Mazoula South deposit:

The HMZ - SUD deposit is in the form of an anticline bounded by two faults to the east and west, the throws of which are around 100 m.

Currently, only the F6 tank produces oil by electric pumping.

II.3.8. Hassi mazoula "B" deposit:

The HMZ B deposit is in the form of an elongated North-South anticline, the eastern flank of which is faulted. The structural closure is about thirty meters long and its area is 4.4 km². It was highlighted by the presence of oil in the F6 reservoir and gas in the Ordovician reservoir.

II.4. TFT's barium sulfate deposit problem:

The Tin Fouyé Tabankort field is located in the northeast of the Illizi basin, 1200 km southeast of Algiers. The Ordovician reservoir was discovered in 1967, produces oil and gas, has an average porosity of 9% and an average permeability of 52 md .

The problem of barium sulfate deposition came a few years after the construction of pressure maintenance in 1980 and the start of water injection as part of the secondary recovery of oil reserves.

The incompatibility of the injection water and the formation water gave rise to this serious problem, which in turn led to a series of problems and problems in the operation and surface installations.



Fig II. 4: Barium Sulfates in TFT

II.4.1. Barium sulfate:

Barium sulfate is a white precipitate insoluble even in strong acids, resulting from the reaction of sulfate ions with barium ions.



The BaSO₄ can be converted into solution by transforming it into BaCO₃ which is then dissolved in acid.



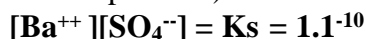
In practice, the indicated transformation is carried out by heating BaSO₄ with a saturated sodium carbonate solution (wet method). As BaSO₄ is less soluble than BaCO₃, which is also formed in this reaction, it is reversible and can only be achieved by repeated treatment of the precipitate with Na₂CO₃ solution.

Barium sulfate can also be transformed into carbonate by melting it in a crucible with a mixture of Na₂CO₃ & K₂CO₃ in 5 to 6 times the quantity (dry method).

II.4.2. Characteristics:

II.4.2.1. The solubility product:

During the study of qualitative analysis, it was found that the solution of a hardly soluble electrolyte becomes saturated when the product of concentrations of its ions becomes equal to a constant value (at a given temperature) called solubility product K_s .



If the solubility product is lower than K_s the solution is not saturated, it will be possible to dissolve a certain amount of barium sulfate. Otherwise the solution becomes saturated and a deposit may form.

In conclusion, the formation of a precipitate occurs only if the product of the concentrations of the corresponding ions exceeds the value of the solubility product of the compound at a given temperature.

II.4.2.2. Influence of temperature:

The effect of precipitation is defined primarily by the value of the solubility product, but the value of this solubility product is constant only at constant temperature.

We often find cases where the precipitate obtained at low temperature redissolves at high temperature, it is obvious that in such cases the temperature has a very strong influence on the degree of precipitation.

II.4.3. Origin :

The barium sulfate problem at TFT dates back to four years after the start-up of the pressure maintenance system, during the recovery of an oil producing well (TFT 211) where a total plugging of the downhole equipment was observed. The formation of this product, which is harmful for the installations, disturbing for the production, undesirable and annoying for the operator, results from the mixture of injection water containing in its composition the sulphate ions and the formation water containing the barium ions, whose identification is confirmed by qualitative analyses in the laboratory.

II.4.3.1. Chemical composition of water: [47]

Compositions	ZARZAITINE LIAS		ORDOVICIEN	
	TFT 621	TFT 610	TFT 97	CS5 HP
Cations (mg/l)				
Na ⁺	750	910	42000	37500
K ⁺	48	53	4160	2200
Ca ⁺⁺	189	230	34373	27955,8
Mg ⁺⁺	67	79	3599	3830,4
Ba ⁺⁺	00	00	1064	752
Sr ⁺⁺	00	00	1040	1162,5
Fe ⁺⁺	7,3	Trace	73,5	263,2
Total	1061,8	1272	86309,5	73663,9
Anions (mg/l)				
HCO ₃ ⁻	190,3	195	36	15,9
CO ₃ ⁻	00	00	00	00
SO ₄ ⁻	1136,6	1156	00	00
Cl ⁻	833,9	1206	134113	127113,2

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Samples Parameters	TFNE Water collector		TFNE Production station output		TFNE HP output		TFNE LP output		TFNE Output Storage	
	8,3		8,4		7,7		8,1		8	
pH à 20 C°										
Cations	Mg/l	Méq/l	Mg/l	Méq/l	Mg/l	Méq/l	Mg/l	Méq/l	Mg/l	Méq/l
Ca ⁺⁺	346,69	17,33	310,62	15,53	282,56	14,12	278,55	13,92	300,6	15,03
Mg ⁺⁺	86,33	7,1	103,36	8,5	102,14	8,4	111,87	9,2	94,84	7,8
Na ⁺	1241,22	53,96	1241,22	53,96	1208,96	52,56	1208,96	52,56	1133,4	4927
K ⁺	34,2	0,87	53,2	1,36	48,57	1,24	48,57	1,24	48,57	1,24
Sr ⁺⁺	4,63	0,1	4,23	0,09	4,34	0,1	4,25	0,09	4,28	0,09
Ba ⁺⁺	0	0	0	0	0	0	0	0	0	0
Fe ⁺⁺	Tr	Tr	Tr	Tr	Tr	Tr	Tr	Tr	Tr	Tr
Total		79,36		79,44		76,42		77,01		73,43
Anions	Mg/l	Méq/l	Mg/l	Méq/l	Mg/l	Méq/l	Mg/l	Méq/l	Mg/l	Méq/l
Cl ⁺	1769,3	49,89	1733,84	48,89	1556,56	43,89	1556,55	43,89	1521,1	42,89
Co ₃ ⁻	0,00	0,00	3,6	0,12	0,00	0,00	0,00	0,00	0,00	0,00
HCO ₃ ⁻	171,41	2,81	157,38	2,58	153,72	2,52	155,55	2,55	152,5	2,5
So ₄ ⁻	1468,71	30,59	1478,17	30,79	1351,93	28,16	1389,02	28,93	1403,15	29,23
Total		83,29		82,38		74,57		75,38		74,62
Extrait sec (mg/l)	5220		5160		4820		4860		4920	
MES (mg/l)	18		16		14		11		12	
Conductivity (ms/cm)	7,49		6,81		6,86		6,82		6,9	
Turbidity (NTU)	31,3		19,4		45,1		26,2		27,5	
Total	2160,8		2557		134149		127129,2			

Discussion :

From the results obtained by the physico-chemical analyses carried out we can conclude the following:

- > The waters of the TFNE production plant and the CS2 filtration plant analyzed are characterized by a basic pH of about 8:
 - The waters of the TAM production plant analyzed are characterized by a neutral pH of about 7:
 - >The concentration of sulfate anions (S047) is higher than 1 g/l in all waters of the different stations. This important quantity of sulfate can generate hard deposits by combining with barium, calcium, or strontium cations;
 - The absence of barium cations:
 - Absence of carbonate anions in all waters, except for the water at the outlet of the TFNE plant, which is 3.6 mg/l.

- >TSS values of the waters are between 06 and 22 mg/l for the TFNE production plant, between 12 and 21 mg/l for the TAM production plant and between 11 and 14 mg/l for the CS2 filtration plant.

II.4.3.2. Critical precipitation:

Laboratory work was performed on the mixture of the two waters to determine the critical percentages corresponding to the maximum precipitation. This was done according to the following steps:

- Mixing of the two waters.
- Agitation for 15 minutes.
- Filtration and weighing of the deposits obtained.
- X-ray analysis of the deposits

This experimentation led to the following results:

ORDOVICIEN %	20	40	60	80
ZARZAITINE %	80	60	40	20
Deposit mass g	0.5220	1.0270	1.4180	1.3205
Nature on the shelf X	BaSO ₄	BaSO ₄	BaSO ₄	BaSO ₄

Result:

A maximum was recorded at 60% ORDOVICIAN and 40% L

c- Advance of the water front in the deposit:

The rigorous monitoring of the water front advance in the deposit is strongly linked to the evolution of the different indicator parameters over time.

Monitoring parameters :

- **Salinity:** the salinity of the original Ordovician formation water is generally between 200 and 250 g/l, its decrease by dilution following mixing with the injection water, containing a low salinity, is a monitoring indicator that can inform on the advance of the water front.

- Percentage of water:

the percentage of water produced increases as the well is invaded by the water front until it reaches very high levels. This factor can also give an idea about this advance.

- Identification of barium and sulfate ions:

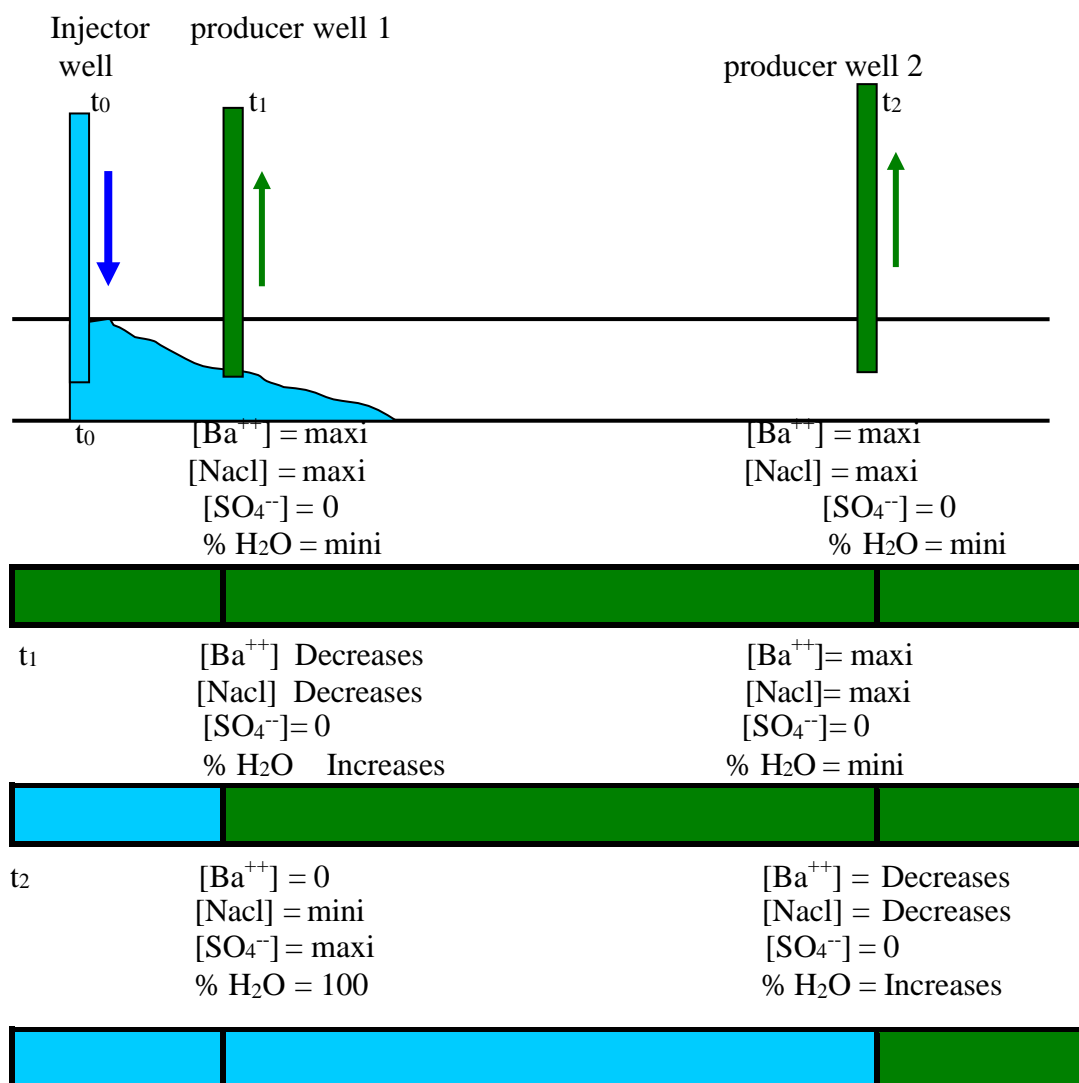
This indicator is characterized by the disappearance of barium ions followed by the appearance of sulphate ions, hence a decisive analysis that serves to separate the producing wells from each other according to the nature of the identified ions, in order to avoid mixtures that could lead to clogging problems in different points of the circuit.

Example of sulfate, barium and salinity analysis.

Table 1:Sulfate, barium and salinity analysis.[49]

Wells	SO ₄ ⁻ mg/l	Nacl g/l	wells	Ba ⁺⁺ mg/l	Nacl g/l
TFT 60	694.6	58.5	TFT 93	441.3	175.5
TFTE3ORD O	962.9	20.5	TFT 66	926.0	245.7
TFTE3DEV O	926.7	11.7	TFT 72	843.6	198.9
TFT 248	564.6	46.8	TFT 79	1124.9	216.5
TFT 16	19.8	140.0	TFT 245	146.7	149.0
TFT 33	357.2	76.0	TFT 62	578.7	216.5
TFT 71	223.0	99.5	TFT 98	715.8	198.0
TFT 03	489.6	111.0	TFT 96	718.9	193.0
TFT 18	447.7	117.0	TAM2ORDO	1119.5	228.0
TFT 97	819.8	129.0	SEP.CS2	805.6	187.0
TFT 65	288.7	87.7	ORDOVI	1100.0	216.0
TFT 30	395.1	70.2			
LIAS	1150.6	2.5			

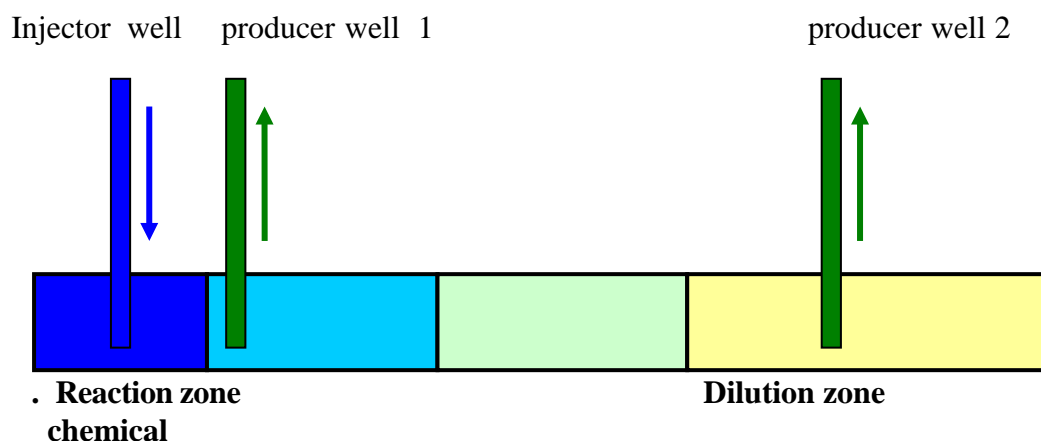
The exploitation of the results obtained from the analyses carried out leads us to establish a report after which, we try to imagine the schematic representation of a vague way the advance of the water front according to time.



II.4.3.3. Deposition of barium sulfate in the deposit:

The critical precipitation of barium sulfate in the deposit occurs in the areas where the injector wells and their approaches are located, during the first contact between the injection water and the formation water, the sulfate ions are eliminated by precipitation, as the water front moves towards the oil-producing wells to be free, further away from the totality of these ions that it contained.

The decrease in the concentration of barium ions is not only due to a chemical reaction with the sulfate ions, but it is also translated by the phenomenon of dilution essentially towards the wells located far from the injection zones.



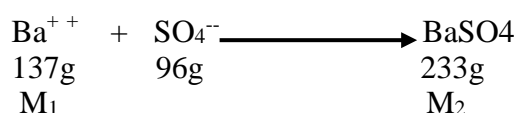
Critical precipitation.
 $[SO_4^{2-}] = \text{maxi}$

Negligible precipitation
 $[SO_4^{2-}] = 0$

Barium sulfate can also be deposited in the downhole equipment (**case of TFT 211**) when the well is located in a contact area between the two waters of formation and injection.

These cases occur in general in wells located near the ridges.

II.4.3.4. Calculation of the clogging rate in the critical area:



M1 :mass of barium in the critical zone.

M2 mass of precipitated BaSO4 in the same zone.

C initial concentration of barium in the deposit.

Mv density of BaSO4.

The clogging rate T is defined as :

$$T = (Vs / Vp) 100$$

With: Vs volume of barium sulfate.

Vp corresponding pore volume.

$$Vs = M_2 / Mv \quad \text{and} \quad Vp = M_1 / C$$

$$T = [(M_2 / M_V) / (M_1 / C)] 100$$

$$T = [(M_2 \cdot C) / (M_1 \cdot M_V)] 100$$

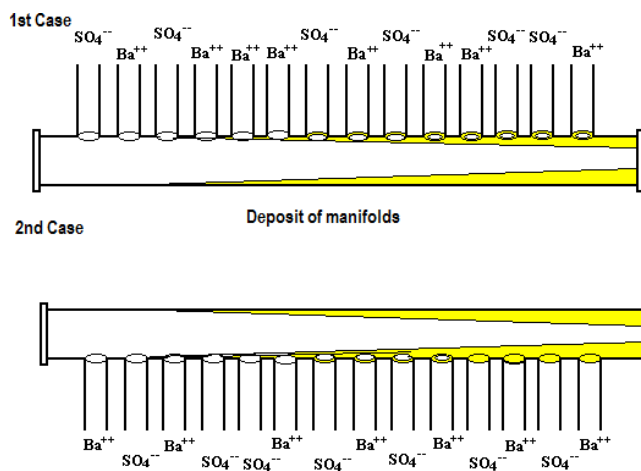
Such that : $(M_2 / M_1) = 1.7$ $C = 1.2 \cdot 10^{-3} \text{ kg/l}$ $M_V = 4.5 \text{ kg/l}$

$$T = 0.045 \%$$

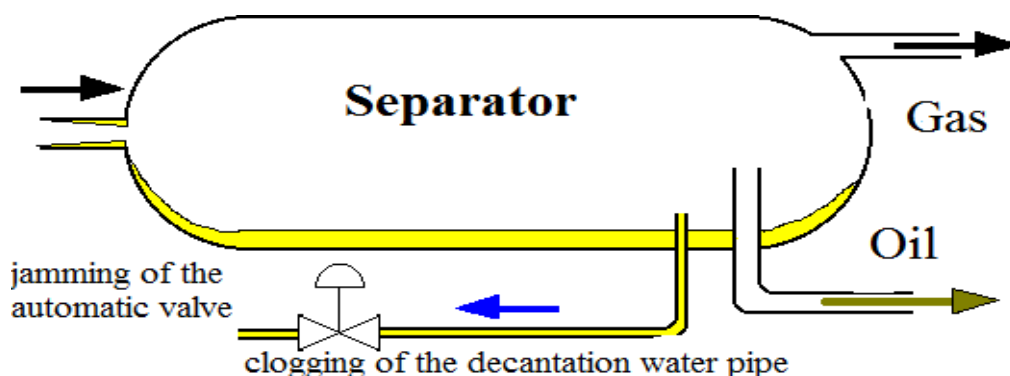
II.4.3.5. Precipitation of barium sulfate in surface equipment:

The deposition of a part of barium sulfate in the surface facilities is done, first, in the manifolds where the precipitation reaction occurs, resulting from the contact of the two waters, the other part is dragged under the effect of the flow of the fluid in the facilities that follow, starting with the separators and ending with the main collectors conveying the crude to the main collection center.

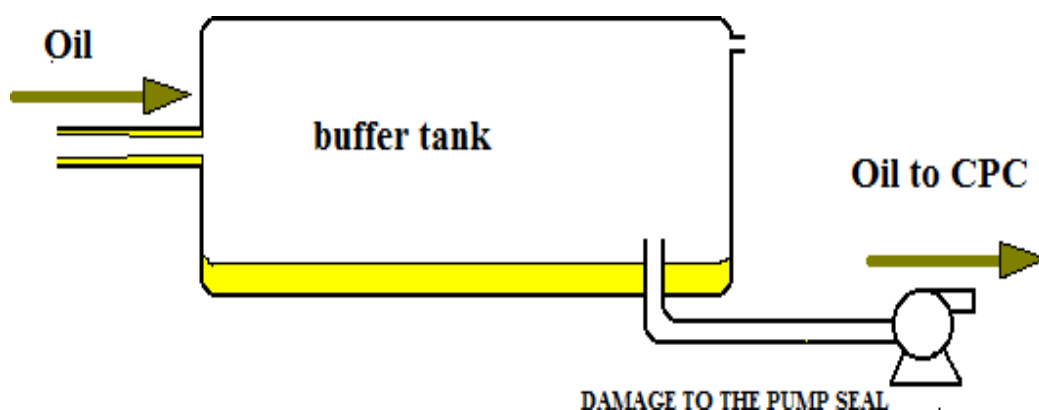
- In the manifolds.



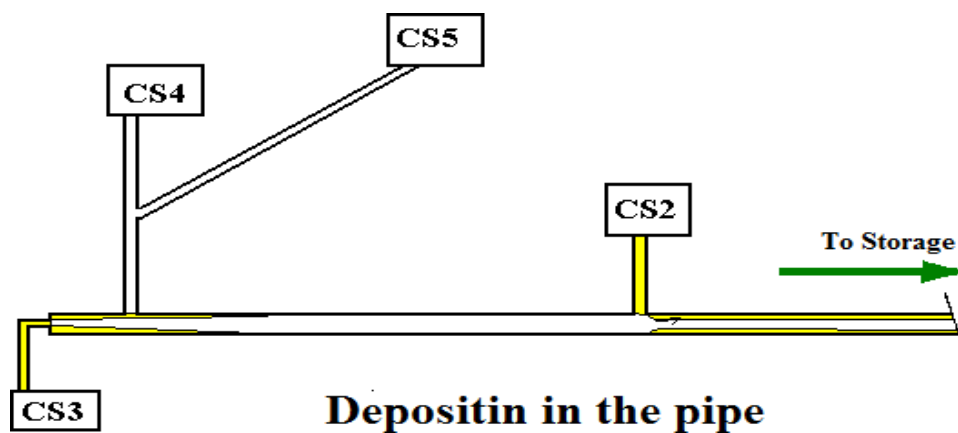
In the separators :



In the buffer tank



In the collections :



II.5. Consequences :

II.5.1. Shrinkage and clogging of pipes :

The barium sulfate is deposited in the pipes in the form of a ring, their internal diameters decrease until they become clogged.

This causes:

- Pressure increase in the separation centers.
- Drop in production by braking or shutting down the wells.

- Increase of the RVT (Reid Vapor Pressure) a characteristic of the shipped crude oil

II.5.2. Settling valve jamming:

As a result, the water produced in the centers will be routed to the CPC (main collection center) where water removal is not easy.

This causes:

- Increase in salinity.
 - Increase in BSW.
- (two characteristics of the shipped crude)

II.5.3. Increase in the frequency of interventions on surface equipment (pumps, valves, pipes, etc.)

- Stoppages of production centers.
- Consumption of spare parts.

II.6. Investigations :

A/ Faced with this situation many efforts have been developed to alleviate this concern, whose investigations have been based primarily on the chemical field, which unfortunately come up against the constraints of applications of an economic and technical nature. Among these products proposed **Aquaprox MD1000** an agent of inhibitor of crystalline growth of the sulphates manufactured by the company **PROTEX** and selected by the CRD of Boumerdes of which its industrial test constitutes the final phase of the researches having for object the verification of the effectiveness of the inhibitory formulation in the conditions of exploitation.

II.6.1. Laboratory test and results: [50]

Inhibitor concentration	INHIBITION % (efficiency)		
	Surface conditions Ambient temperature		Background conditions T = 80 to 85°C P = 120 bars
	After 1 heure	After 24 heures	After 6 heures
100 ppm	83.2	15.2	45
200 ppm	87.8	23.0	48

NB: Turbidity measurements were made using a photoelectric nephelometer colorimeter. PEC 56 M wavelength 440 nm

Treatment with chemical inhibitors

To address the problem of deposition at the TFT area facilities, several studies have been done:

- Carrying out selection tests of deposition inhibitors on water under surface conditions (t° ambient and atmospheric pressure) and bottom conditions (t° 80 ~ 85°C and pressure=120 bars).

Chapter II : TFT's Study Case

- 33 products were tested at different concentrations on a critical mixing ratio which is 60% field water and 40% injection water (maximum precipitation of BaSO₄)
- Out of the whole range of products tested, only AQUAPROX MD1000 (based on phosphonates) gave a relative efficiency of 45% after 6 hours of contact with a dosage of 200 ppm of BaSO₄ .
- It is noted that the presence of the Fe²⁺ ion in large quantities in the field water (200mg/l) strongly disrupts the effectiveness of the inhibitor as a function of time. The inhibitor reacts with the iron by complexing it, which leads to an overdose of the inhibitor resulting in an additional cost.
- The chemical inhibitor solution has been abandoned for reasons related to cost and difficulty of technical implementation

The used inhibitor in TFT are :

corrosion inhibitors :

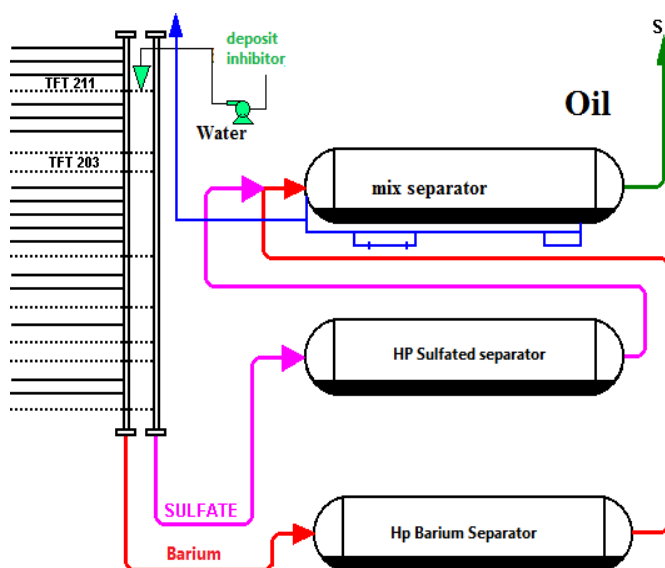
- Norust 720
- **Norust 486**
- CHIMEC 7130

Bactericide :

- CHIMEC 7162
- Bacterm 443

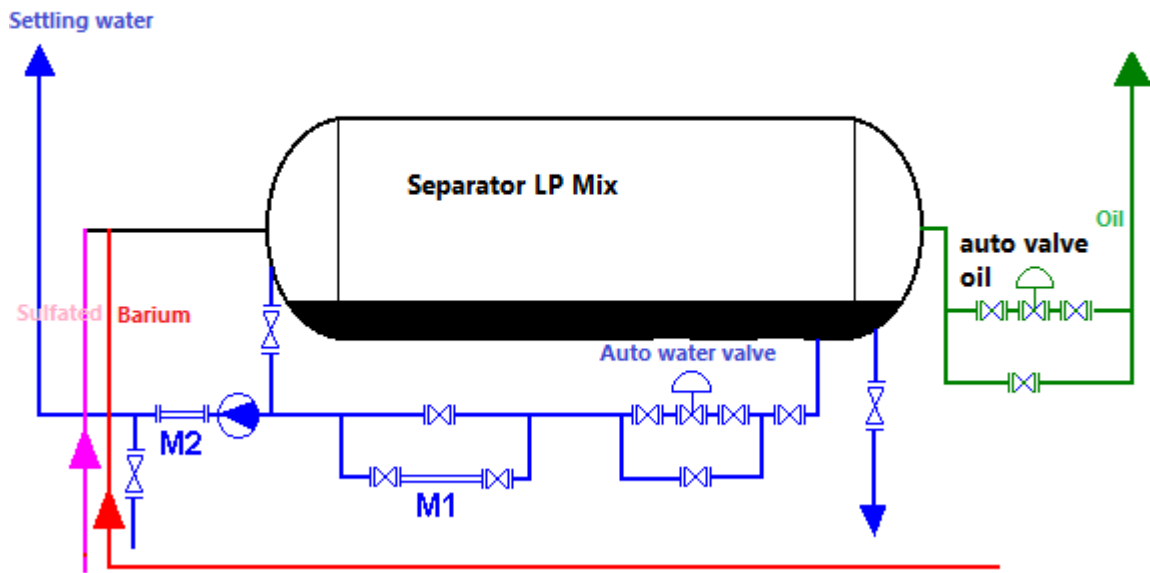
II.6.2. Industrial test

The deposition inhibitor was injected into the manifold of the sulfated wells and the condition of the internal surface of the two sleeves M1 and M2 was checked.



Fluid flow diagram

schema of the deposit control area



separation centre n°3

II.6.2.1. Results:

- Absence of deposit on the mobile sleeve M2 checked chronologically on the 1st, 4th, 5th, 7th, 9th day of the test.
- Normal operation without anomaly of the automatic and manual valves of the water and oil circuits.
- Absence of deposits on the M1 sleeve left in place since the beginning of the treatment.

These three results qualitatively confirm the effectiveness of the **Aquaprax MD1000 product**.

II.6.2.2. Application constraints :

- Concentration of injected product too high (200 ppm), which generates considerable consumption.
- Stoppages of pneumatic injection pumps, especially during cold periods.
- Delays related to the supply of chemical products.

II.6.2.3. Selective Separation:

Chapter II : TFT's Study Case

It consists in separating the sulfated wells from the barite wells, on two similar installations, in which the two incompatible waters are decanted and then drained to sludge through two different paths.

The production of the crude from the two batteries are joined in front of buffer tanks.

Separation procedure:

The separation procedure is based on the identification of the sulfate ions present in the produced water of a well, whose production is, subsequently, transferred to the sulfated battery in order to avoid any undesirable precipitation.

Example of Separation Center No. 3 :Monitoring of hydrated wells for selective separation:

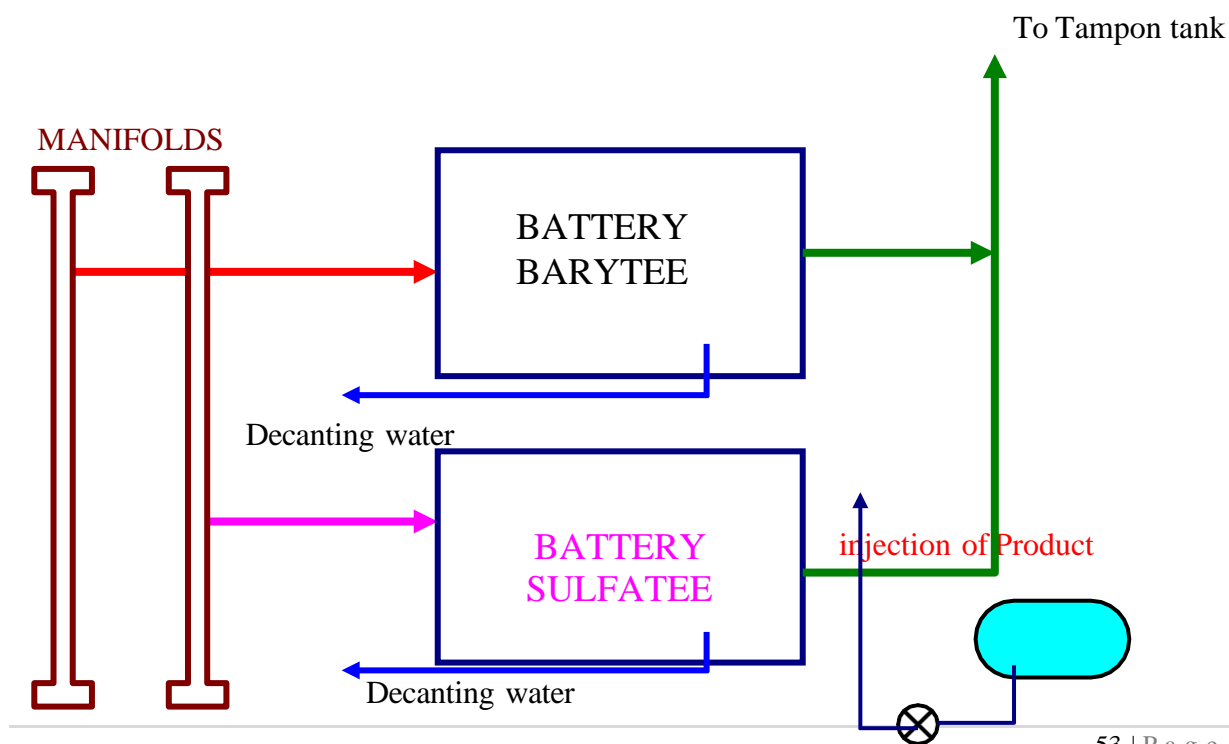
	Q oil m ³ /j	Q water m ³ /j	% water	Salinity	Nature of wells	Date of the test
TFT 8	5,7	18,4	76,35	158	Barium	26/10/97
TFT 12					Injected	
TFT 34	30,4	247,1	89,04	135	Sulfated	03/12/97
TFT 35	33,8	126,8	79,00	58,5	Sulfated	02/11/97
TFT 36	121	00	00		Barium	17/03/99
TFT 39	8,1	54,7	87,1		Sulfated	28/09/97
TFT 40	108,7	0,6	0,55	117	Sulfated	05/12/98
TFT 42	41,5	10,3	19,88	35	Sulfated	05/12/98
TFT 43	106	00	00		Barium	
TFT 45	179,5	0,1				20/11/98
TFT 46	112,4	00	00		Barium	
TFT 50	120	0,20	0,17		Barium	
TFT 52			100		Injector	
TFT 53	13,7	46,3	77,17	111	Sulfated	31/01/96
TFT 54	1,1	52,3	97,94	64	Sulfated	27/03/97
TFT 55	100	0,1	0,1		Barium	
TFT 71					Flooded	22/09/91
TFT 72					Flooded	06/08/92
TFT 73	94,8	15,5	14,05	58,5	Sulfated	28/12/98
TFT 74	112,9	00	00		Barium	
TFT 201					Injector	
TFT 202					Injector	
TFT 203	98,1	41,00			Sulfated	03/01/98
TFT 210	63,8	0,8	1,58		Barium	
TFT 231	37,3	47,6	56,00	65	Sulfated	27/01/98
TFT 254	13,6	46,6	78	47	Sulfated	18/09/98
TFT 287	100,5	00	00		Barium	23/01/99

Ordovician sulfate wells:

N°of wells	Q oil m ³ /j	Q water m ³ /j	% water	Salinity	Nature of wells	Date of the test
TFT 34	30,4	247,1	89.04	135	Sulfated	03/12/97
TFT 35	33,8	126,8	79,00	58,5	Sulfated	02/11/97
TFT 39	8,1	54,7	87,1		Sulfated	28/09/97
TFT 40	108,7	0,6	0,55	117	Sulfated	05/12/98
TFT 42	41,5	10,3	19,88	35	Sulfated	05/12/98
TFT 53	13,7	46,3	77,17	111	Sulfated	31/01/96
TFT 54	1,1	52,3	97,94	64	Sulfated	27/03/97
TFT 73	94,8	15,5	14,05	58,5	Sulfated	28/12/98
TFT 203	98,1	41,00			Sulfated	03/01/98
TFT 231	37,3	47,6	56,00	65	Sulfated	27/01/98
TFT 254	13,6	46,6	78	47	Sulfated	18/09/98

II.7. Conclusion :

The final result of these investigations is a combined solution that couples selective separation with a minimum of anti-settling product injections downstream of the sulphate battery separators before the residual water meets the buffer tank .





General Conclusion and perspective

General Conclusion and perspective:

Among the major problems encountered in oil fields around the world, and in particular in the TFT field, we find the deposits of Barium sulfates. These mineral deposits result from the incompatibility between the water injection water (albian) rich in SO_4^{-2} sulfates and the formation water (Cambrian) rich in barium Ba^{+2}

The current solution for these mineral deposits is a combined solution that couples selective separation with a minimum of anti-settling product injections downstream of the sulfate battery separators before the residual water meets the buffer tank

The production of the crude from the two batteries are joined in front of buffer tanks.

These results open up a certain number of work perspectives:

Further studies are needed in the future to reduce the uncertainty about the risks and impacts of using anti-deposit for injection water treatment in oil fields.

We recommend economic study for the installation and the anti-deposit .

The use of membrane filtration methods such as Nano filtration, reverse osmosis to desulfate the injection water

Periodic analysis to identify mineral deposits and in particular barium sulfate.

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