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The effect of boreholes on the traditional modes of distribution of irrigation water in the South of Algeria, case study Foggaras of Timimoun

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August 2016.

1 DECLARATION

I, **Zeyneb Moulay Omar** do hereby declare that this thesis is my original work and to the best of my knowledge, it has not been submitted for any award in any University or Institution.

Signed____ Date _____________

Zeyneb Moulay Omar

2 CERTIFICATION

This thesis has been submitted with my approval as the supervisor

Signed____Date______________

Prof. H.Bouchalkia

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Dedication

I dedicate this memory:

To my parents my Dear Mustapha and Bhidja, for their patience, their love, support and encouragement.

And have always believed in me and provided me with all the means necessary for me to succeed in my studies.

To my lovely sisters Iman and Meryam.

To my dear brothers Fares and Mohamed.

To all my family

To my friends and colleagues study.

To all those who contributed in any way to this modest work

Dear :Hossam.A.Khamis, Cleus Bamutura, Elhosaoui.A Hderi.H Bouroba Ibrahim, Dasidy, Soulimani Sara.

To the National Agency of water (A.N.R.H) Adrar.

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Acknowledgment

First of all. Thank God Almighty for giving me the knowledge of science and giving me courage and strength necessary to accomplish this modest work.

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Abstract

In the heart of the Algerian Sahara, Timimoun is characterized by arid climate, marked by low rainfall, high temperatures, causing heavy losses by evaporation, these climatic conditions are the cause of the scarcity of surface water in these areas, hence the need to exploit water from underground sources to cover the water needs of the population, agriculture and industry.

Geological and hyrological studies, Carried out on the studey area allowed us to see that the Albian aquifer is considered the only source for fresh drinking water. Modern technology has allowexploitation and the implementation of groundwater the implementation of severed al deep wells without worrying about the future of this non-renewable source.

The traditional irrigation system "Foggara" in the Algerian Sahara allows passage from a nomadic to sedentary. The people gathered around water sources that are located in areas of natural outlets of the water table; created oases.

The study of drainage mechanism of the waters of the Albian aquifer, at the Foggara in the study region, we clearly indicate the causes of drawdown of Foggara, as a result of neglecting and the lowering of the groundwater level, because of over-exploitation.

Keywords:
Timimoun, Albian aquifer, Aride, Foggara, over-exploitation.

Résumé :

Au coeur du Sahara algérien, Timimoun est caractérisée par un climat aride, marqué par de faibles précipitations, des températures élevées, ce qui provoque de lourdes pertes par évaporation, ces conditions climatiques sont la cause de la rareté de l'eau de surface dans ces domaines, d'où la nécessité d'exploiter l'eau de sources souterraines pour couvrir les besoins en eau de la population, l'agriculture et l'industrie.

Les études géologiques et hydrogéologiques, réalisée la zone d'étude nous a permis de constater que l'aquifère Albien est considéré comme la seule source d'eau potable. La technologie moderne a permis l'exploitation des eaux souterraines de la mise en œuvre de plusieurs puits profonds sans se soucier de l'avenir de ce source non-renouvelable.

Le système d'irrigation traditionnel "Foggara" dans le Sahara algérien permet le passage du nomadisme à sédentaire. Les gens se sont rassemblés autour des sources d'eau qui sont situés dans les zones de débouchés naturels de la nappe phréatique; oasis créés.

L'étude du mécanisme de drainage des eaux de l'Albien, au Foggara dans la région d'étude, nous avons conclu par les causes de retrait de Foggara, à la suite de la négligence et l'abaissement du niveau des eaux souterraines, en raison de la surexploitation.

Mots clés :
Timimoun, aquifère Albien, Aride, Foggara, surexploitation.

List of abbreviations :

A.N.R.H: National Agency for Water Resources.

A.E.P: Drinking water supply.

C.T: Terminal Complex.

C.I: Continental midsole.

S.A.S.S: Northern Sahara Aquifer System.

ABHS: South Hydrographic Basins Agency.

WHO: World Health Organization.

UNESCO: United Nations Education Science and Culture Organization.

OSS Observatory of the Sahara and Sahel.

INRA: The National Institute of Agricultural Research of Adrar.

DHW: Direction of Hydraulics of the wilaya.

List of units :

cm: Centimeter.

°C: Degree Celsius.

g: Gram

g / l Grams per liter.

Time: Meter.

m3 Cubic meter.

m3 / h: Cubic meter per hour.

m3 / s Cubic meter per second.

m3 / d: Cubic meter per day

meq/l: milliequivalent per liter.

mg: Milligram.

mg / l: Milligrams per liter.

mS / cm: Milli siemens per centimeter.

ml: milliliters.

min: Minute.

K: Kelvin Degree.

Glossary:

Aghisrou: Channel which is located between the distributor comb and the first well from the Foggara.

Amazer: The removed portion of the gallery during its deepening.

Aud: Stem or plant part.

Chahed: Witness of the building of Foggara.

Chegfa: Measurement tools of flow of the Foggara.

Djemaâ: Council of the tribe or Ksar.

El Hassab: The Accountant of the Foggara which the flow calculations.

Fouaha: Well, Hassi, or cone foggaras wells.

Gourara Region: Timimoun between Aougrout and Zaouiet Debagh.

Guemoun: Small parcel of culture in the garden.

Habba: Seed flow measurement unit of Foggara.

Halafa: Tool for measuring the flow of Foggaras means "by which we swear."

Hamada: rocky plateau.

Hassi: Foggara Wells.

Kasria: Comb diverter triangular or rectangular shape.

Kébira: the big.

Khamas: Metayer, who receives a fifth of the harvest.

Khorga: Hole.

Kial Asfar: Yellow meter.

Kial El Ma: The water meter.

Kirat: Carat, flow measurement unit.

Kraa: Leg extension of Foggara.

Ksar Tower Set constructed conurbation.

Machte: Brush, construction at the end of kasria helps routing parts water.

Majra: Canal of Foggara.

Nfad: drainage gallery that connects all the wells of the Foggara.

Nouba: Output received in a time interval.

Tarha: Extending of Foggara.

Zemam: Register in which information from the Foggara are listed.

3 INTRODUCTION

3.1 General Introduction

Algeria is the largest country bordering the Mediterranean Sea on the African continent. It covers an area of 238 million km^2 of which 8.3 million km^2 is cultivated. It borders the Sahara Desert in the south and so most of the country eighty-four percent has a desert climate. This is in contrast to the north of the country sixteen percent which enjoys a Mediterranean climate. More than ninety percent of the population lives in the North that includes a coastal band along the Mediterranean Sea, plains, mountains and high lands. The annual amount of rainfall, in the North, varies between three-hundred and one thousand millimetre. In the Sahara and south the Saharan Atlas, the annual amount of rain is below one hundred millimetre. [ABHS, 2009].

At the oasis of Gourara (Timimoun) an isolated area of vegetation in desert, recently seen in the evolution of population growth followed by significant human activity covering almost the fields of agriculture, industry and urbanization and tourism, in parallel water needs have increased. To support growth needs of water demand, numerous boreholes were made, adding to the traditional system of collection and water distribution, which is Foggaras, the Hundreds of thousands of cubic meters per year, are extracted from the water table underground of Continental Intercalary. [Djidel et al, 2010]

First objective of this work present the results of a hydrogeological study contains a hydro-chemical and hydrodynamic studies; to better understand the potential water in our study area.

Secondly is to study the effectiveness of irrigation by Foggaras during the last ten centuries. The impact of new technologies of water catchment on the degradation of Foggaras is another subject of this study.

For this, we will rely first on several ways from existing data: from
ANRH (National Agency of Water Resources) of Adrar and the DHW (Water Resources Directorate) Timimoun moreover some data is taken from the measurement from the field at the area of the case study.

3.2 Background

Water is a vital resource for human survival, their health, supply; as well as their agricultural and tourism activities. There are two categories of water present in the earth which are ground water and surface. Water is rare in arid and semi-arid regions because of scarcity of precipitation and extensive evaporation of large quantities of water.
Demand for water is growing faster than the world population, which suggests many shortages and increased water prices in the coming years. Water consumption should increase by 50% between 2007 and 2005 in developing countries and 18% in undeveloped countries, a large part of this increase occurring in the poorest countries, to the extent that more and more people migrate from rural areas to cities, the expected impacts of climate change in this century are the main reason for the expected increase in water consumption. Indeed, climate change is likely to lead to more floods, droughts, and changes in precipitation patterns, these phenomena to hit firt and hardest the poorest populations. (Kirsty Jenkinson).

The scarcity of water is undoubtedly one of the major challenges of this century. According to the Water Resources Institute, there are already more than 232 million people, representing 26 countries, who are starting to suffer from lack of water and by 2032 this figure will exceed the 50% of the world population. In this same vein, the World Water Council, in its 3rd Forum in Kyoto in 2003, had argued that a population of 6 billion people, 1 in 4 do not have access to water quality and enough, that one in two lacks adequate sanitation and every year 7 million people die from waterborne diseases. According to specialists this is due to a quantitative shortages because water is scarce channel. It is also the result of waste, overfishing, climate change, population growth, economic development requirements, its increasing degradation due to economic activity, but especially in its management catastrophic. Given this situation, Algeria is ranked in 16th place of the missing water country (CNES, 2000). Indeed, with an availability of less than 500 m3/ Year / capital, set by the World Health Organization (WHO).

In recent decades, the demand on the water in the Algerian Sahara is one of the largest deserts in the world (2 million km2) grew a significant following the acceleration of economic development on the one hand and the other hand population growth.

The Grand Erg Occidental is full of life by a considerable wind dynamics, threatening erosion and silting peripheral regions. In parallel, the ground beneath is subject to intense hydraulic dynamic where the flows form large underground water tanks. Through their ingenuity, their technical competence and their acute sense of observation, the Oasis Could judicious use of these reservoirs and adapt to water harvesting and its slow return around the erg. The topography of the land as well hydrogeology have been advantageously used without damaging the environment. Through Foggara, it is to capture water by a tunnel system slightly inclined to drain then to the irrigation network (palm grove).

Foggara is a national cultural heritage, or even global, since it only exists in 50 countries worldwide (pnud 1986), with this technique, the oasis turned a middle dry in a moist environment. Foggara is the main body of the oasis of Gourara.

3.3 Problem Statement

The Albian aquifer (Continental Intercalary aquifer). It is contained in the sandy-clay formation of the lower Cretaceous. Chemical point of view these waters are highly mineralized and excessively harsh, with high concentrations of chlorides, sulfates and sodium.The results showed that groundwater quality is poor from the perspective of the potability. The population of the majority of Ksour (village) came to settle in edge of this underground mat enjoying the favorable topographic situation of Water of this layer thereby ending a period of nomadism.

The Foggaras is endangered (degradation, depletion, deterioration of water quality and Low underground water level) Because of local and regional problems mainly related to the operation and management of water, which requires better vision for rational management of this resource to ensure development durable. For this, several recommendations are proposed.

3.4 Objectives

3.4.1 Main objective

The major objective of the project was to study the effect of boreholes on underground water exactly the Fogarra system.

3.4.2 Specific objectives

- The geographic location and characteristics physical of the study area.
- The geological characteristics of the region.
- The study of a traditional way of collection and water distribution which is Foggara.
- Determine the chemical profile of these waters taken at the wells, to assess their chemical qualities and establish a comparing the chemistry between the sectors of Gourara.

3.5 Scope

- The study was undertaken at National Agency of Water Resources of Adrar (ANRH).
- The water samples were collected from many wells and tow Foggara at the case study Timimoun.

4 LITERATURE REVIEW

4.1 Geographical and Physical Context:

In general, the geographical framework represents the orientation of the study area and the physical limits with maps of geographic location.

2.2 Geographic location:

In the heart of the Algerian Sahara (Fig.01), the wilaya of Adrar is located south-west countries with more than 1,200 km from Algiers. It is located between the meridians 2 ° E and 6 ° W, and the parallel 20 ° and 32 ° North. Its total area is 427,368 km2, or about 18% of the global area of Algeria, nearly a fifth area of the national territory. After the first administrative division of 1974, the wilaya of Adrar is composed of 11 daïras and 28 towns, and 294 ksars. The province is divided into four regions from north to south:

- ✓ Gourara.
- ✓ Twat.
- ✓ Tidikelt.
- ✓ Tanezrouft.

It is limited:

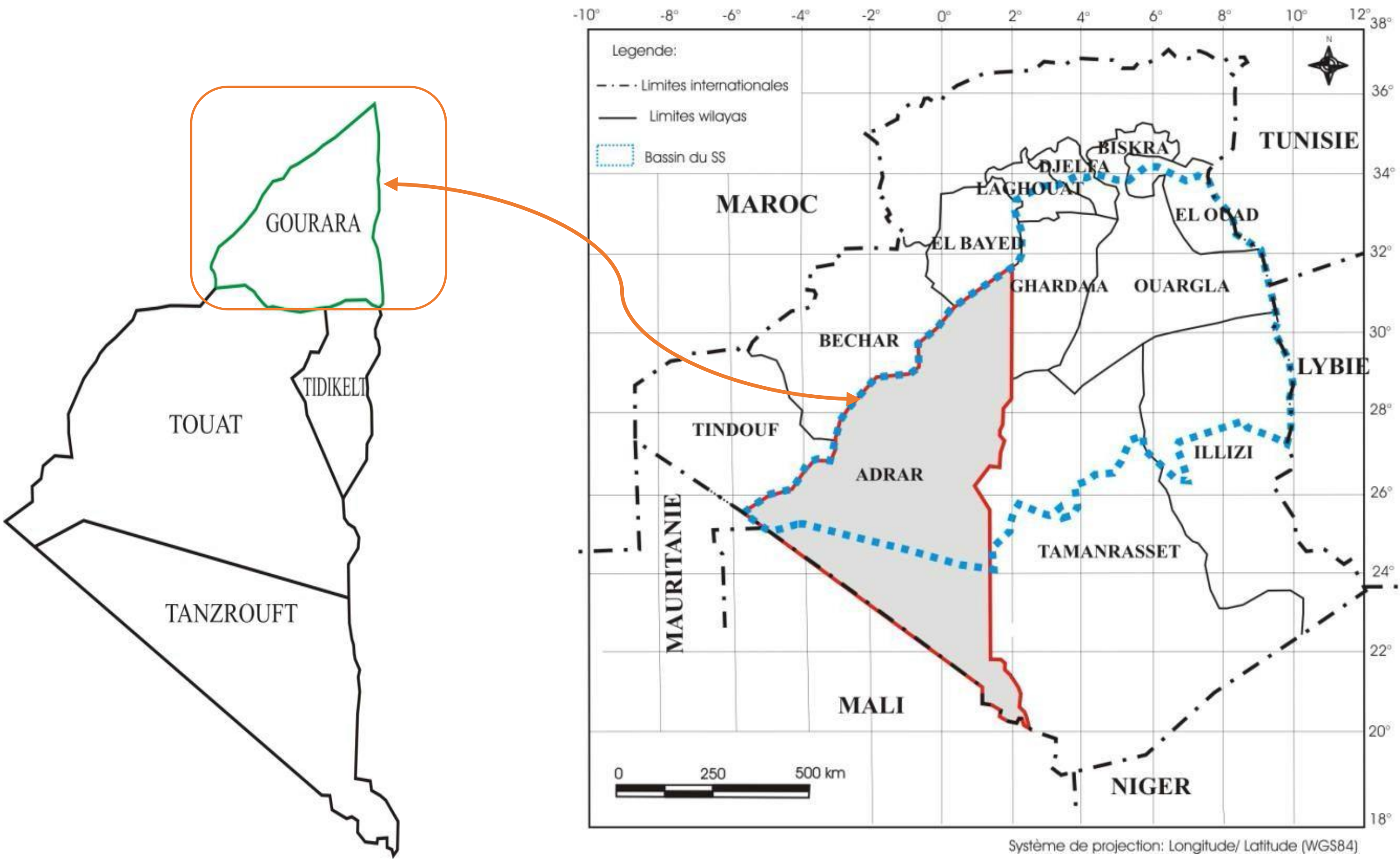
- ✓ To the north by the provinces of Ghardaia and Bayedh.
- ✓ To the west by the province of Bechar and Tindouf.
- ✓ To the east by the province of Tamanrasset.
- ✓ To the south by Mauritania and Mali.

The study area is the northern part of the Adrar. It consists of 13 towns of Oasis, Surrounded by:

- ✓ The Western Grand Erg North.
- ✓ Twat and Saura in the West.
- ✓ The Tademaït plateau South and East.
- ✓ The geographical boundaries of the study area:

Longitude "E"	Latitude "N"
00°14'E and 00°44'E	29°10' and 29°43'N

Table 01: The geographical boundaries of Timimoun



The study area
Fig.01: situation geographic of Timimoun

4.2 Geology and Geomorphology.

Geomorphology:

The study area is characterized by a Saharan terrain that is characterized by huge sandy areas, ergs, dunes covered with crescent-shaped, institutions stony plateaus, Hamada, the Sebkha. All these forms have been shaped over the early Pleistocene to the present, following intensive erosion to which the region was submitted. (Fig02)

The Plateau:

Are in the form of large extended land relatively plane, which located at various altitudes, they cover very large areas, where the action of wind erosion is intense; but they are still carved by ancient valleys. (Khalil and Omari, 2006)
From lithological point of view this plateau is formed of sandstones of Mio-Pliocene; as example Tademaït Plateau (Figure 02), It is characterized by a spreading area and constructive aspect of the non-fruitful Hamada, as well as black stones. It altitude reaches 400m, it is marked ratings wrinkly. because of erosion; with a small slop from East to West with a distance of 100m. This plateau contains numerous shaped depressions of Sebkha (Fig 03) most of them are covered by dunes of sand. (KAIM.A, BELBALI.T 2002).

Sebkha:

These are shallow depressions containing salt water, which dry up during heavy heat waves. Sebkhas are at the level of the lowest points of these regions, and generally locate at the old riverbeds and low land areas (Fig.02). The origin of water in the Sebkhas is partially from the Continental Intercalary aquifer and also from ancient flood.

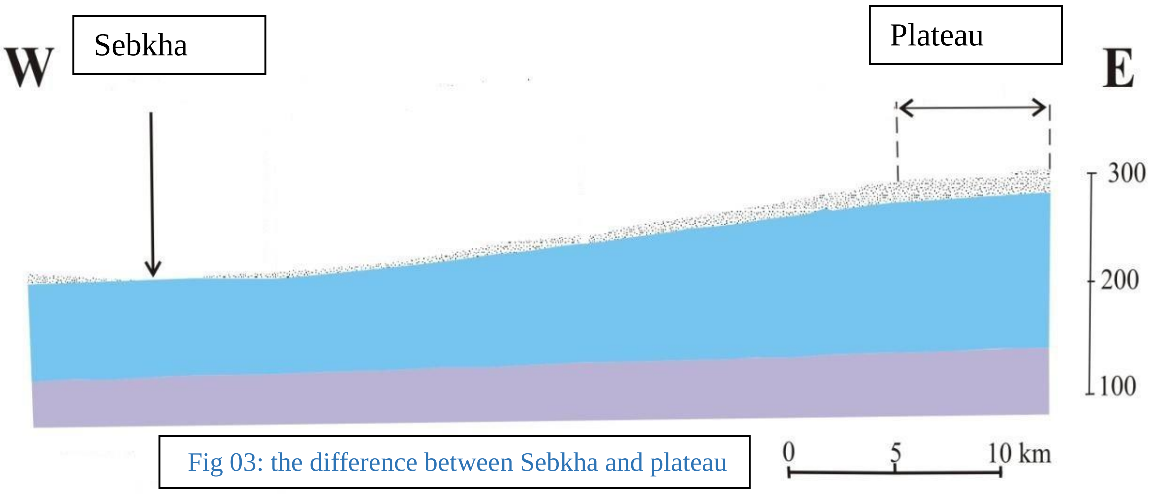


Fig 03: the difference between Sebkha and plateau

Dunes:

Are geomorphic units very important that stand out in a wonderful way. In North and South-west of the study area, large surfaces covered dunes that form the Great Western Erg. (Fig: 02)

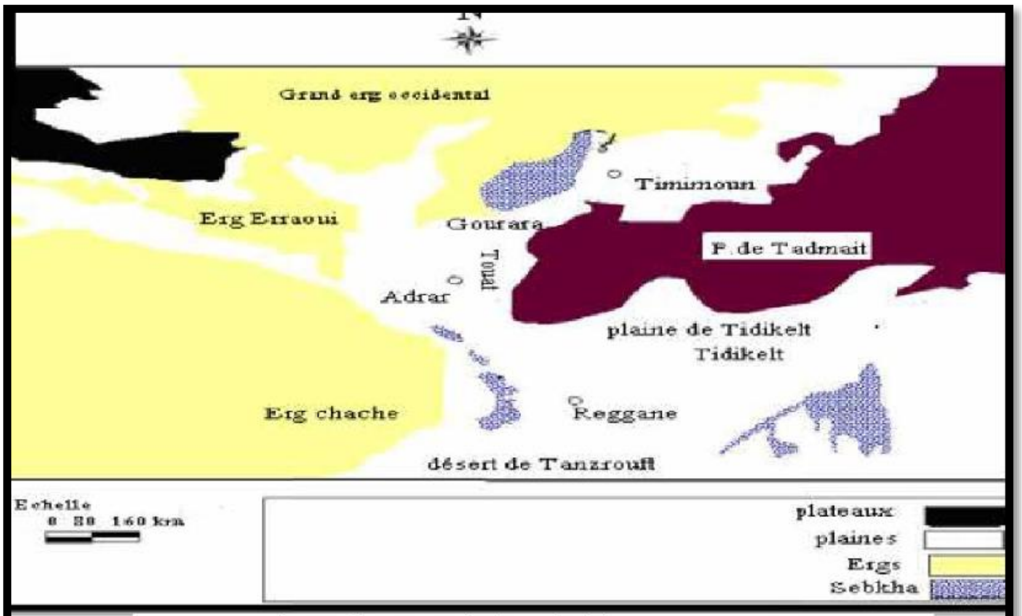


Fig: 02 The geomorphology of Timimoun.

Fig 02: the geomorphology of Timimoun.

4.3 Local geology:

The geological history of Algeria is in the process of global geodynamics of tectonic plates that divide Algeria in two areas:

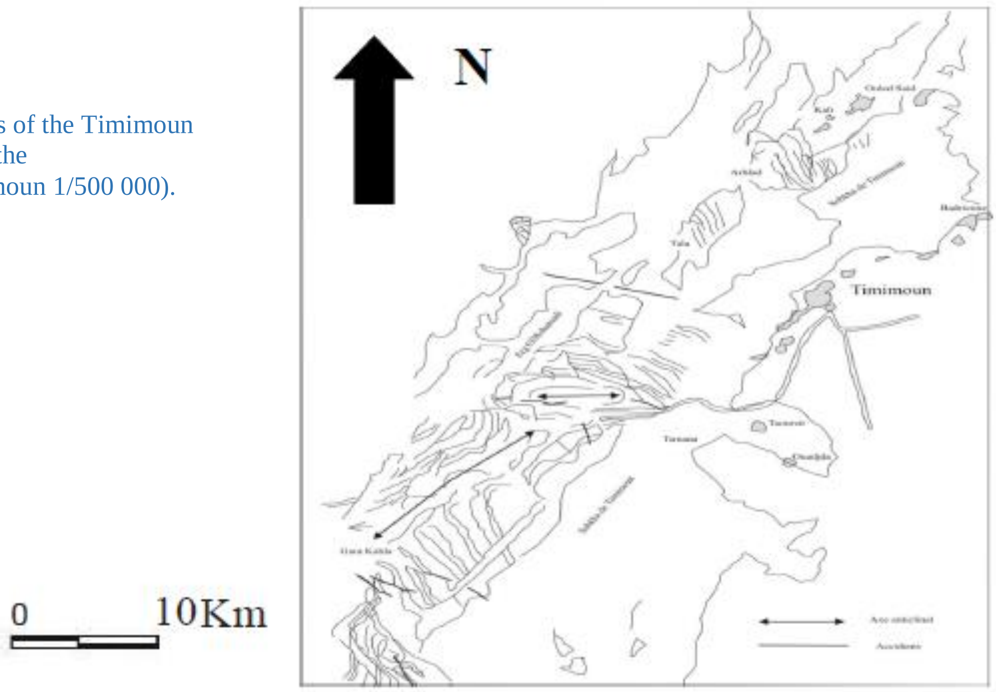
- ✓ In The Northern Alpine Algeria.
- ✓ At The south, the Saharan platform; relatively stable where the tectonic less clear; the basement of the platform is pleated deposits of Proterozoic. The cover is formed by deposits of limestone terrigenous of Paleozoic and continental deposits of Mesozoic and Cenozoic, the Eoliennes alluvial of Quaternary formation and fluvial of Continental Intercalary formation are the most widely in Sahara formation.

In the Timimoun region Paleozoic series located unconformity on a pedestal Proterozoic (Conrad, 1984). It is topped by Mesozoic and Cenozoic deposits (Hammada and Erg); and is represented lithological point of view, the sedimentary series Palaeozoic in the Timimoun basin is presented by thick characterized by series large variations of thicknesses and facies. In the Lower Carboniferous, the Timimoun basin recorded a transgression marine (Conrad, and Pareyn Weyant, 1970), followed by a decrease in "Carboniferous means" (Metchnikoff, 1935-1949). The Tournaisien is mainly clay and sandstone intercalated sometimes by fossil limestone past. The latter is marked by a formation known as the training of "senior Kahla Sandstone". Visean shows a clay sedimentation carbonated few benches of sandstone and silt (Conrad, 1984 Conrad et al, 1985 Legrand-Blain, 2002).

4.4 The tectonic of Timimoun:

Structurally it is based on the work of Matt M (1999), the region of Timimoun is located between two anticlines fold systems dominated by three major directions (Fig.o5). The first system called the northern anticlinal Timimoun is east-west oriented with two accidents directions NW-SE and NNW-SSE.
The second the system called southern anticlinal Gara El Kahla oriented NE-SW, with executive fracturing NNE to NE-SW.

Fig. 04: Map of structures of the Timimoun Basin (map extract from the Geological map of Timimoun 1/500 000).



4.5 Activity of the population

4.6 Agriculture

Timimoun is an agriculture-based town characterized by palm groves, oases and traditional irrigation system 'Foggara', and some new extensions of modern agriculture. This oasis culture system is rotated around plantations palm trees, with or without other crops: cereals, such as food legumes, fodder and vegetable. Table 02 shows the distribution of areas agriculture in the wilaya of Adrar (NEDJAH N. et al. modified).

Designation	Surface in Hectar
Total farm area	337 650
Area used	32 272
Irrigated area	23 814
By gravity	18 814
Aspiration	2 742
By drip	2 258

Table 2. Distribution of agricultural land in the wilaya of Adrar

Water resources used in agriculture are:

- ✓ Foggaras are 918 with total flow of 3680 L/s.
- ✓ Boreholes are 529 with total flow of 9120 L/s.
- ✓ The wells are 4898 with flow of 9820 L/s.

4.7 Trade

A transit trade (barter) with countries characterizes Timimoun region, where agricultural products are traded more like dates, tobacco against many livestock products such as cattle and camels.

Industry. Recently Timimoun region has very vast industrial dynamics with the discovery of gas and oil fields; it became an industrial center.

4.8 Tourism

Timimoun region is characterized as all provinces of the deep south by great tourist activity especially during periods of festivals. Tourism is an attraction because of the presence of several archaeological sites, Timimoune is the most important and great palaces of tourism; but investment in tourism is still low.

4.9 Climatology study:

The climatological study was conducted on data available at ONM Timimoun, which is actually the most representative of our study area "Gourara" and which has a series of lengthy precipitation data. In addition we will focus on two stations, the Adrar and Ain Saleh to better appreciate the climate of the whole wilaya. The climatological summary was made over a period of 28 years (1988-2015).

4.10 Climate parameters:

Temperature:

The temperature is a fundamental factor it generally varies with altitude and the distance from the sea. This factor becomes more important when interacting with other climatic factors.

Table 03: contains the mean monthly temperatures (Max, Min, and Mean) in degree Celsius (°C), for a period of 28 years, from 1988 to 2015.

	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
(T °C) Min	4,8	7,9	11,7	15,8	19,4	24,5	27,7	28	24,2	17,8	11	5,7
(T °C) Max	22	25,4	30,8	35	37,9	43,11	47,7	46	43	35,5	29	25,5
(T °C) Mean	13,4	16,7	21,25	25,4	28,65	33,81	37,7	37	33,6	26,7	20	15,6

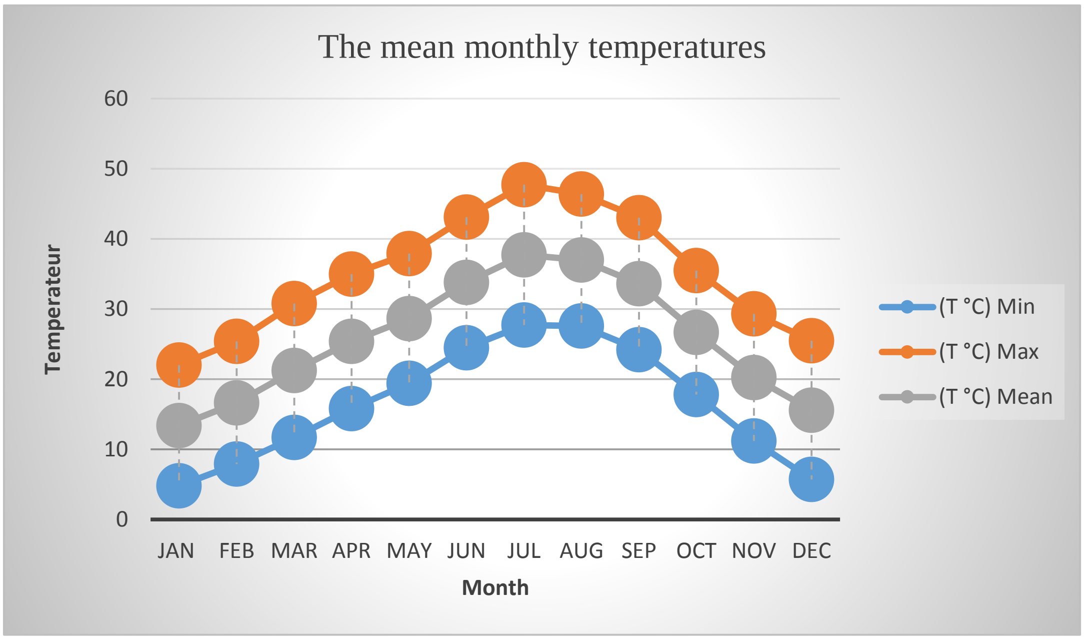
Source: Weather Station TIMIMOUN

According variations curves (fig.05), It appears that January is the coldest month with 13.4 ° C while July is the hottest with 37.7 ° C. The climate of the Gourara region is characterized by two seasons:

- A relatively short cold season characterized by very cold winter nights. This is the plant germination season extends from October to April.
- A hot season from May to September.

The sudden change in temperature is due to the influence of geographical characteristics and the masses of continental tropical area.

Fig. 05: the mean monthly temperatures variation (ONM Timimoun 1988- 2015)



The annual temperatures variation:

Figure 06 and Table 04 below shows the distribution of annual temperatures for a series of 20 years of observation from 1995to 2015.

year	T (°C) max	(T °C) Min	T (°C) mean	year	T (°C) max	(T °C) Min	T (°C) mean
1995-1996	33,41	17,48	25,45	2005-2006	33,06	17,72	25,39
1996-1997	33,16	17,37	25,27	2006-2007	34,21	17,18	25,70
1997-1998	33,6	17,38	25,49	2007-2008	33,7	17,59	25,65
1998-1999	33,72	18,13	25,93	2008-2009	33,63	17,53	25,58
1999-2000	33,58	16,84	25,21	2009-2010	35,28	18,81	27,05
2000-2001	34,89	17,61	26,25	2010-2011	33,4	17,7	25,55
2001-2002	34,28	17,73	26,01	2011-2012	33,4	17,3	25,35
2002-2003	33,88	17,6	25,74	2012-2013	33,7	17,4	25,55
2003-2004	33,41	16,97	25,19	2013-2014	34,4	18,2	26,30
2004-2005	34,53	17,93	26,23	2014-2015	34,5	18	26,25

Table 04: Annual temperatures variation (1995-2015)

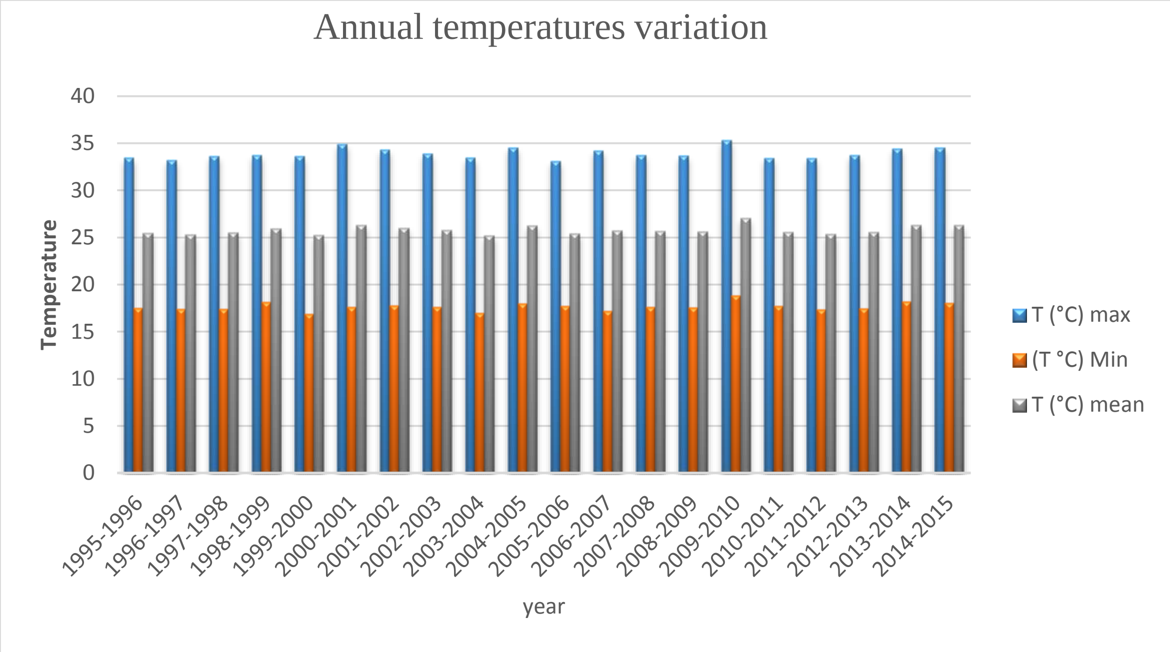


Fig 06: Annual temperatures variation

Data analysis of the annual average temperature shows that the year warmer is 2010 with an annual average temperature of 27.37 ° C and the coldest year was 2000 with an average annual temperature of 25.61 ° C, the interannual average temperature is 24,42 ° C.

4.10.1 The wind:

Percentages or frequencies winds: In Gourara region, the wind frequency very large and it all year. Six percent of winds speeds below 0.001m / s (Quiet), this frequency is calculated according to the eight directions that are shown in Table 04.

Table 05: Mean frequency of winds by the eight directions (2000-2011).

Direction	North	North -East	East	South-East	South	South -West	West	North -West
Frequency%	17	25	14	7	11	8	7	5

Source: Weather Station TIMIMOUN

Figure :(Fig 07) below show Compass of the wind direction:

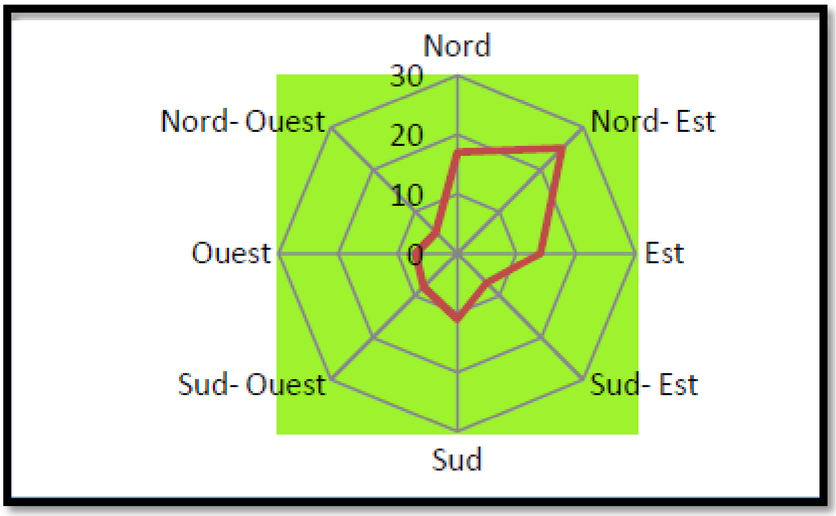


Fig 07: wind Compass Source: Weather Station TIMIMOUN (OMN 2000-2011)

From the Figure (07) North-Easterly winds are generally the most dominant with a frequency equivalent to 25%; the frequency of the East direction is 14% and the frequency of South direction is 11%.

Wind Speed: Wind is one of the most important factors characterizing the climate in the region because it has a direct influence on temperatures, humidity and increases evaporation.

Table 06: The average monthly wind speed for the period (1988-2015).

MONTH	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
S (km/h)	22,4	23,3	25	25,1	25,3	23,6	24,9	24	22,7	21,7	20	20,6

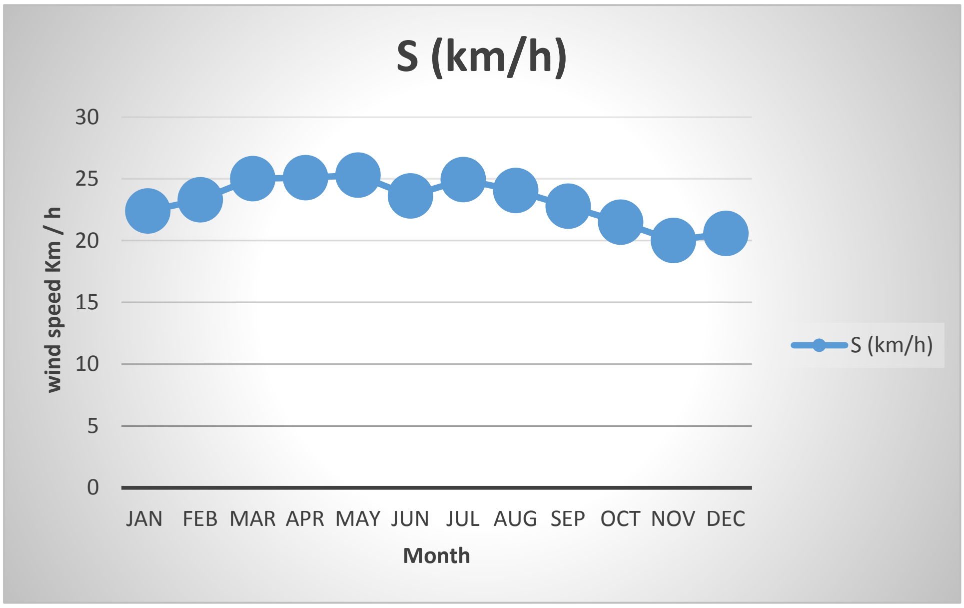


Fig.08: variation of monthly average wind (ONM Timimoun, 1988-2015)

The prevailing wind in Gourara is characterized by medium speed variation between 20 Km / h and 25.30 km / h, according to the (fig.08) we notice that the spring (March, April, May) is characterized by a high-speed wind.

4.10.2 **Precipitation:**

By definition, it is the amount of water collected in a rain gauge for 24 hours whatever the nature of that water (rain, snow).

Gourara region or in general Adrar region is characterized by scarce rainfall, making the soils of the region without cohesion, with poor consistency and without vegetation cover. There are years when it rains for several days, for sometimes against several years without rain.

Table 07: Average monthly rainfall (ONM Timimoun, 1998-2015).

MONTH	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
P (mm)	4,98	1,22	4,03	3,65	1,55	1,02	0,55	2,9	2,4	3,9	2,08	0,85

From the values of the table, we see that the region of Gourara characterized by very low precipitation, which varies between 0.55 mm and 4.98 mm in July and January, this amount of water, is insufficient to meet the needs of plant and Compensate for underground water shortage.

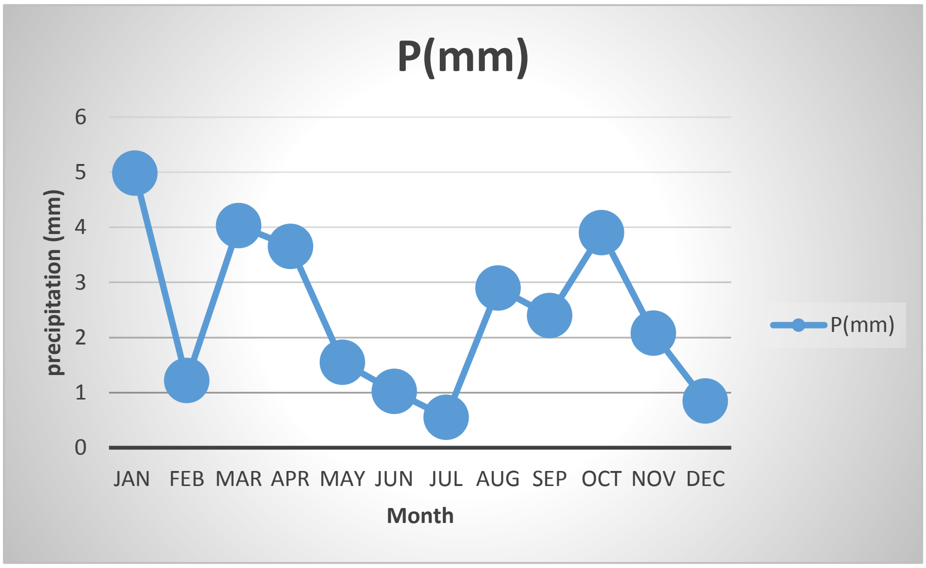


Fig.09: Change in average monthly precipitation (ONM Timimoun, 1988-2015)

According to figure 09, we can see that the study area is characterized by two distinct periods. The shortest period that is relatively rainy, including the rainiest month is January (4.98mm), while the longest period (Dry season) is spread over the rest of the year, the driest month is July (0.55mm).

The Average Interannual Rainfall

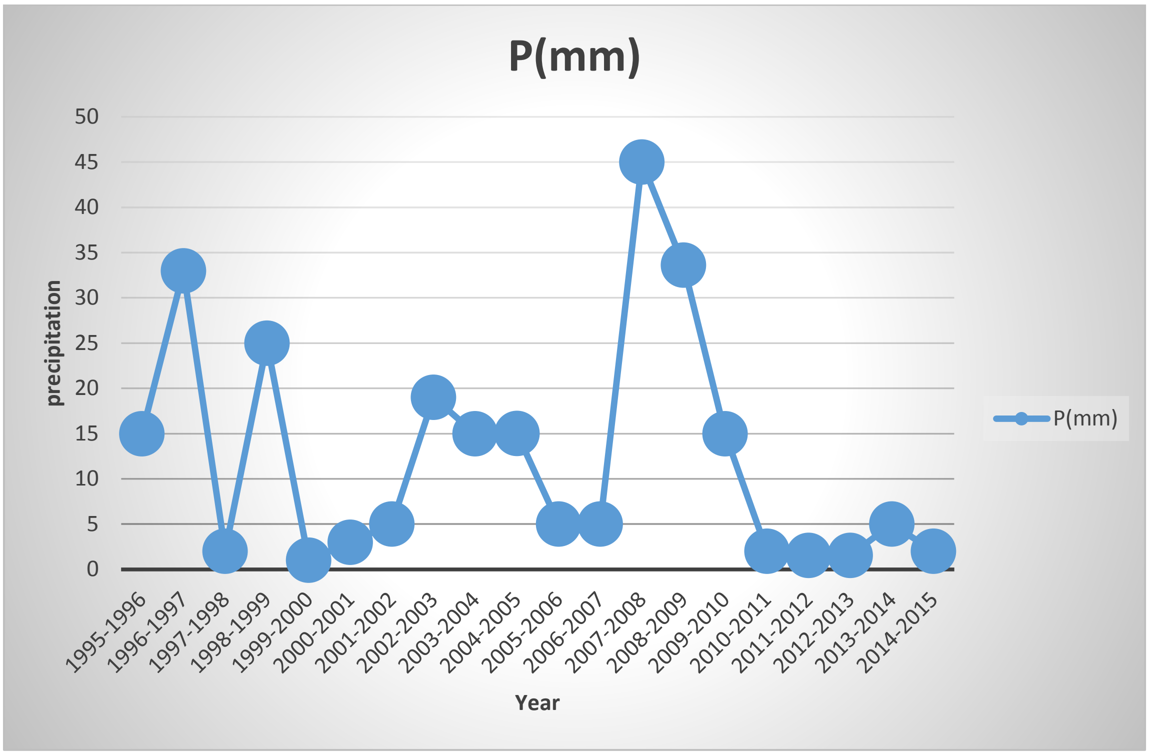


Fig. 10: The average interannual rainfall

The curve analysis of interannual variations of precipitation over a period 20 years (1996-2015) shows that 2008 was the wettest with average rainfall is around 45 mm / year moreover 1998 is the driest with average rainfall is around 1.02 mm / year.

Rainfall is very irregular from one year to another. This situation be explained by the distance from the sea region and a tropical air mass.

4.10.3 **Evaporation:**

The amount of water that goes back into the atmosphere depends only on physical parameters such as the temperature of the air, humidity and wind speed.

Relative humidity:

The rate of steam that exists actually in the air and the steam of extreme intensity that air can carry.

Table 08: The average air humidity. (NOM Timimoun, 1988-2016):

MONTH	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
H (%)	38,1	31, 4	25,9	21,37	19,77	16,4	14,6	16,8	21,9	36,4	36,4	43,9

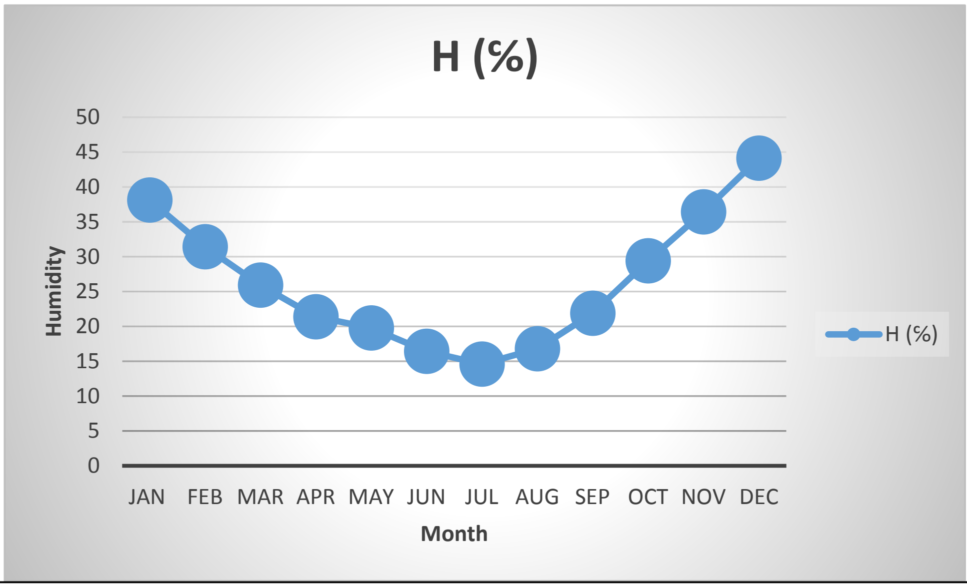


Fig.11: Average monthly air humidity (ONM Timimoun, 1995-2015).

From Figure 11 and the results recorded in the table 08, we find that the maximum humidity is the winter that reached 43. 9 % during the month of December, however, it reaches its minimum in summer with 14 .4% during the month of July. Therefore, there is a lower moisture content to 50 % all year. Therefore, we conclude there is a lower moisture less than 50 % all year that signals that we are on the extreme aridity of the atmosphere, which increases evapotranspiration thus a need for water plants.

4.10.4 **Climate indices:**

Temperatures and rainfall are the major elements regulating the climate of a region.

Emberger Index:

This index is used to determine the bioclimatic stage of the study area, two parameters are considered:

Average annual rainfall (P);

Temperature: the average maximum temperature of the warmest month (M) and the average minimum the coldest month (m) in kelvin degree.

Emberger formula is $Q = 2.000\ P / (M^2 - m^2)$.

$$Q = 2.000*12.44/ (320.852-300.852)$$

$$Q = 2.000*12.44/12434$$

$$Q = 2.0009$$

According to the Figure 12 and the Emberger equation the coefficient equal to 2.009 indicate that the Gourara region in bioclimatic Sahara with cold winter.

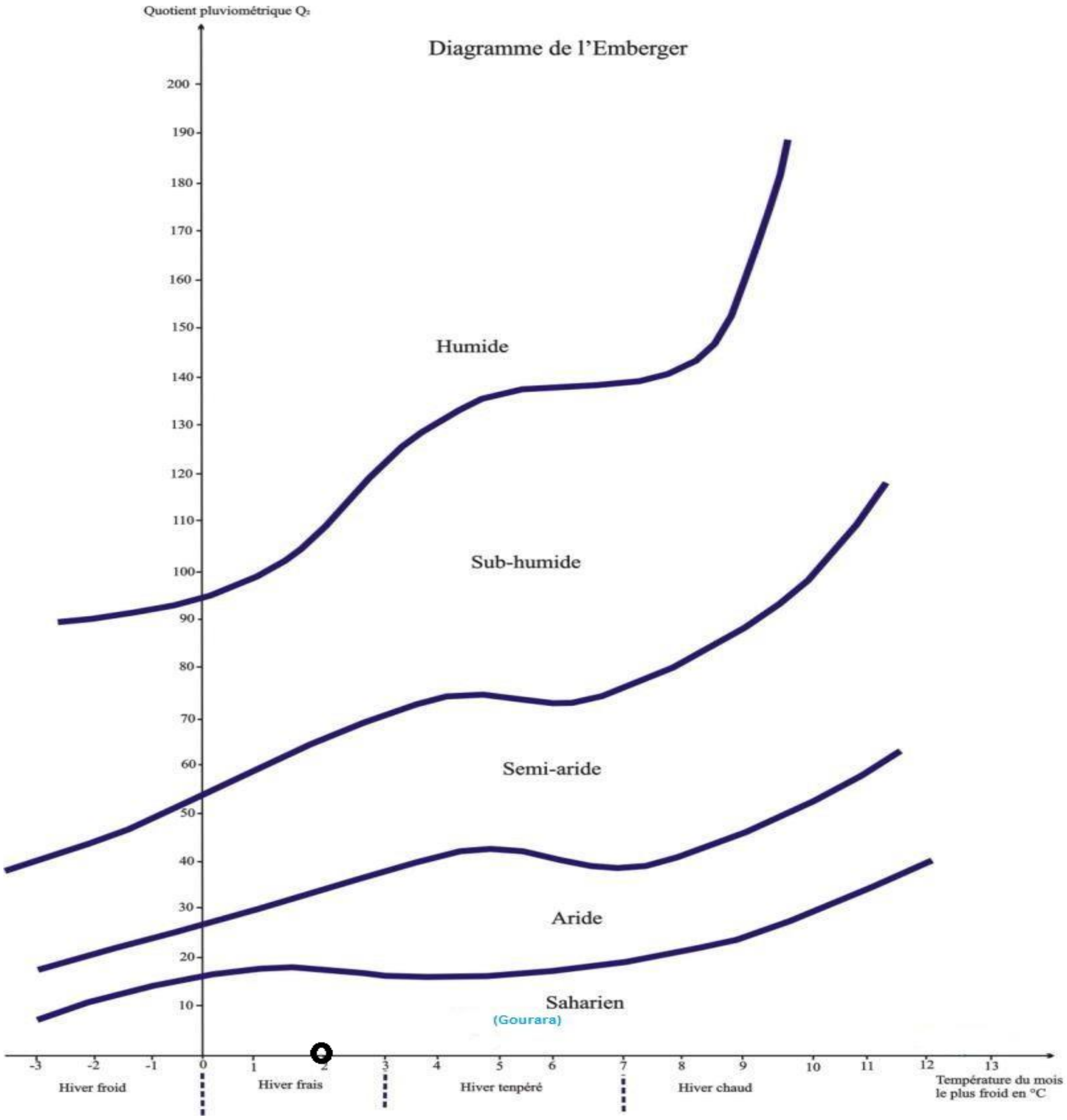


Fig12: Position of Gourara region in the diagram Emberger (1988-2015).

4.11 Hydrogeological study.

This study is intended to guide rational and economical exploitation water resources in our area of study, water table study, interpretation of pumping tests and determination of the hydrodynamic characteristics of the aquifer of the Continental Intercalary.

We briefly based on existing data at the A.N.R.H ; work of the OSS 2003 (the Sahara Sahel Observatory) and UNESCO (1972) and particularly on the synthesis of different lithostratigraphic logs of boreholes, moreover we have used the geological map of the Mesozoic basin of Algerian-Tunisian Sahara and its scale 1/2 000 000 (1967) prepared by BUSSON to show extension side of the aquifer and its substratum.

4.11.1 Northern Sahara Aquifer System:

The North Western Sahara Aquifer System (fig.13), is divided between Algeria, Libya and Tunisia, it covers an area of about one million km2 of which 60% is in Algeria(700 000 km2), Libya 30% (250 000 km2) and 10% in Tunisia(80 000 km2) and extends from north to south, from the Saharan Atlas until the outcrop Tidikelt and the southern edge of Tinrhert and from west to east from Guir-Saoura Valley to Graben Hun in Libya.(ZAGHTOU, 2011).

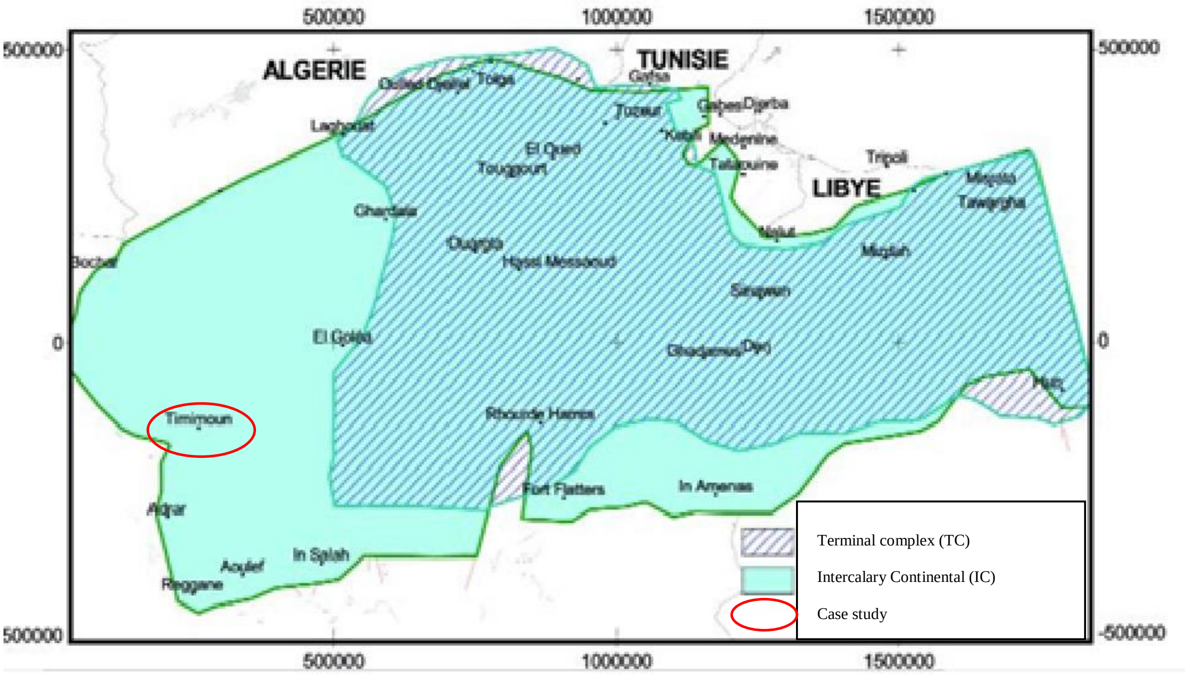


Fig13: The North Western Sahara Aquifer System source: SASS (UNESCO, 2003)

4.11.2 **Characteristics of the North Western Sahara Aquifer System:**

This basin (SASS) contains a series of aquifers that have been grouped into two tanks called the Terminal Complex (TC) and the Intercalary Continental (IC).

The table 09 show the characteristics of the North Western Sahara aquifer system:

Table 09: The characteristics of the North Western Sahara aquifer system

SASS	**Area**	**1, 000,000 km^2**
	theoretical reserves	60.000 Billion m^3
	theoretical recharge	1 billion m^3 / year
	Terminal complex	Recharge: 600 M m^3 / year Roof: 100 to 400 m Salinity: 2 to 5 g / L
	Intercalary Continental	Recharge: 300 m m3 / year Roof: 50-2300 m> 800 m on 60% of the tank. The thickness: 50-1000m Salinity: 1 to 4.5 g / L. Temperature: 25 ° C to 70 ° C.

Source (OSS, 2003)

Hydrogeological study Intercalary Continental (CI): (Fig 14)

It is the most extensive hydrogeological permeable formation, with flexible materials (Sand, sandstone, and sandy-clay) of age Lower Cretaceous. It can include more series of old Jurassic and Triassic.

The substratum of the Intercalary Continental consists of sedimentary formations (Clay, sandy-clay or carbonate). We distinguish in the South and Southwest unconformity a discrepancy on the grounds of the Devonian, but notice to replace the Paleozoic (Devonian) by the Lower Cretaceous (Neocomian) or the Upper Jurassic (Malm) north - east of the dorsal M'Zab. The Jurassic constitutes the sheet of wall across the central part of Hassi Messaoud to large Chotts.

The roof of the Intercalary Continental consists of clay formations of the Upper Cretaceous (Cenomanian) and the sands of the ergs. Northwest toward Wadi Saura, the Cenomanian is completely eroded. In the west and south, Intercalary Continental widely exposed in the Tuat, and Gourara Tidikelt.

The water table of Intercalary Continental extends from North to South, from the Saharan Atlas to the north of the Hoggar and Tassili from east to west from the Saoura to the Hamada El Hamra (Libyan desert), this reservoir has a considerable volume due to its extension on the Northern Sahara (600,000 km^2).

The dorsal of the M’zab divided the Intercalary Continental into two basins, East and West. The Gourara region is located in the western basin.
The lithology of the land constituting and constituting from tank has uniform thickness, its total thickness exceed 250 m in most of Northern Sahara Aquifer System (SASS). They reach 1000 m to the northwest (West Ghardaia) and Centre (West primary dorsale ofAmguid), and eroded into Gourara depression.

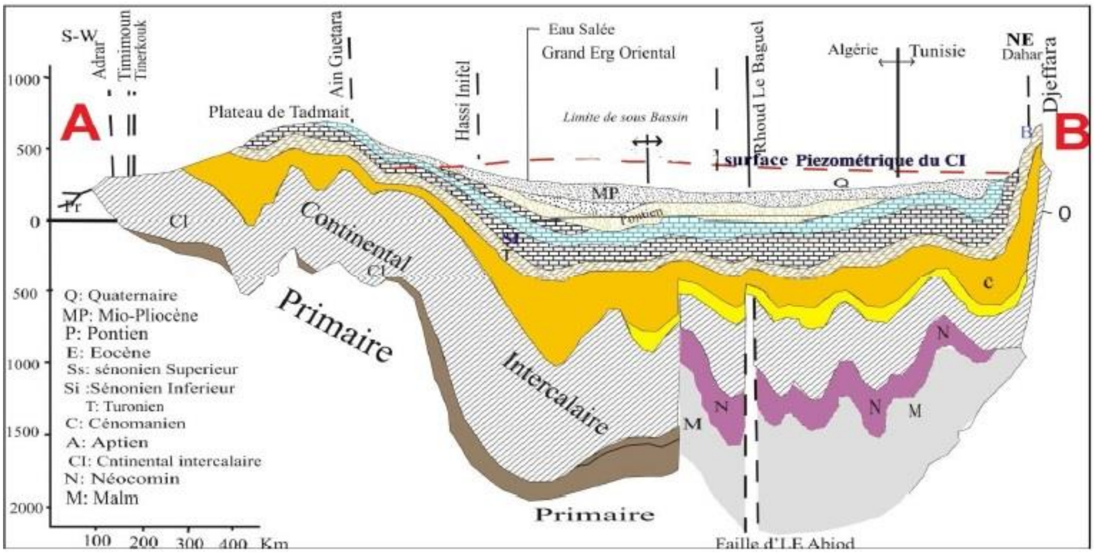


Fig.14: Hydrogeological across the Sahara (UNESCO, 1970).

The Intercalary Continental "IC" aquifer is unconfined aquifer on the outcrop area; confind non gushing under the Great Western Erg, the M'Zab, the Tademaït the Great Tunisian South and the Hamada El Hamra, strongly gushing artesian (at high temperatures) over the domain Oued Rhir, Souf, Djerid, the Grand Erg Oriental and Chott Fedjaj.

The sub surface water individualized in its Northern part:

At the north by the unconfined aquifer of the great Erg Occidental, bounded on the west by the Saoura river flows from the Saharan Atlas. At the West, they go in the Tertiary formations constituting the terraces of the Saoura.

At the South, in the region Gourara they gradually gush into the aquifer of Intercalary Continental.(Fig:15)

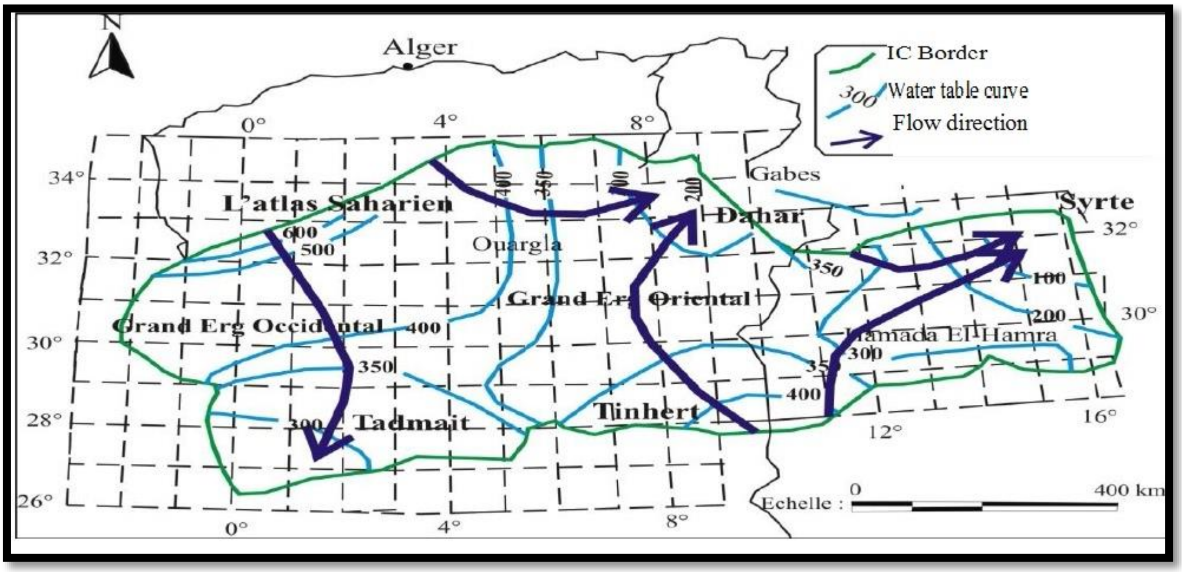


Fig.15: Water table map of a reference (CROSS, 2003).

4.11.3 **Exploitation of Intercalary Continental "CI":**

The exploitation of Intercalary Continental "CI" has done for a long time by the traditional system of irrigation (Foggaras) introduced on the western and southern bord of Tademaït from the Twentieth century. In this century with several boreholes loctaed in all the Intercalary Continental "CI".

Intercalary Continental "CI" in Gourara region:

Deep aquifers with complex geological and geometrical configurations, often including several aquifers, in this case the term is used "Aquifer system". So aquifer Intercalary continental part of the system aquifer of the northern Sahara. It requests the main aquifer in the region.

Our study area is located on the downstream part (IC formations outcrop) where the aquifer is unconfined, while the upstream portion is confined, which induces different hydrodynamic and geochemical behavior. This group mainly includes continental formations gréso clay-Lower Cretaceous outcrop extensively in Gourara region, which the study of drilling sections allowed to associate sea or lagoon sediments, post-Paleozoic and interspersed within antécénomaniens CI. It is based directly on the Paleozoic marine formations. (OSS, 2003).

The examination of lithological section and drilling logs from several boreholes in our region also shows that:

- Continental Intercalary is not formed only from sand and sandstone, but found there also clayey sands, sandy clay.
- The structure of Intercalary Continental (IC) in the SASS basin has alternating layers permeable, semi-permeable or impermeable.

4.11.4 **The outlets:**

The natural outlets of the Intercalary Continental (CI) in Gourara region called Sebkhas, which occupy the bottoms of depressions (topographically low points). While the artificial outlets are Foggaras, wells and boreholes.

. Geometry of Intercalary Continental (CI):

4.11.5 **The substratum**

A contour map of the Continental intercalary in the study area shows that the extension of substratum of the useful reservoir is South-North direction, while the depth is increasing relative to the west and south, the maximum depth of the roof is located to the Southwest reaching 320-410 m depth contrariwise the minimum depths range from 80 to 100 m. (Fig.16).

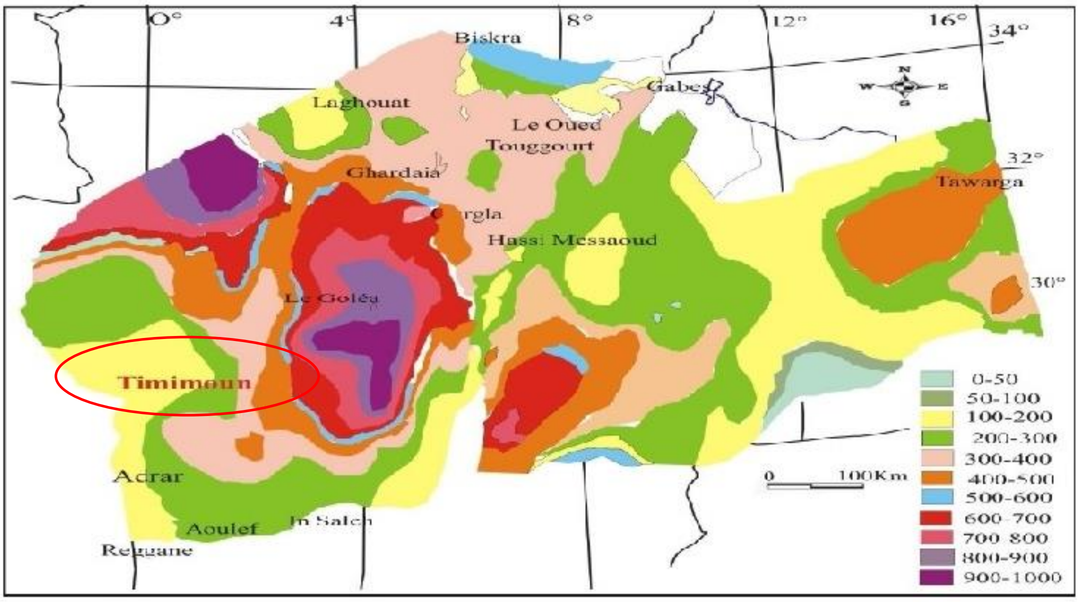


Fig: 16: Thicknesses map of Continental Intercalary OSS 2003b

The case study

Thicknesses map of Continental Intercalary (C.I) (OSS, 2003b):

The thicknesses map of the continental limestone developed under the project of SASS (2003b) shows that the thickness of the Continental Intercalary in the study area varies between 100m and 300m. (Fig: 17)

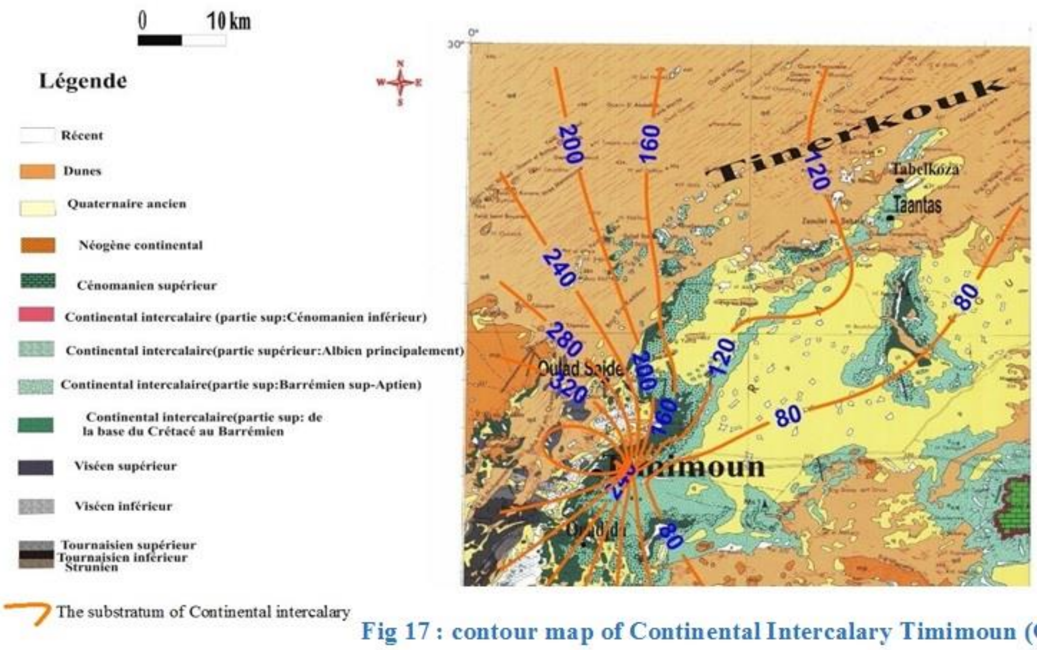


Fig 17 : contour map of Continental Intercalary Timimoun (OSS,2003b)

4.11.6 **Recharge of Continental Intercalary (C.I) (OSS, 2003b):**

The channelled flows have maximum intensity at the upper Villafranchian, which is the largest Algerian Sahara river system, and fluvial endoreic networks that were individualized to the Plio-Villafranchian have the largest geographical extension.
The return to sub-arid climatic conditions, for long periods, allowed the reorganization of the former river system and deposition of fluvial and lacustrine sediments, which are generally smaller and more tightly localized in the valleys than in the past.

The Intercalary Continental was charge during storm periods. Currently, it receives a low recharge, particularly from the piedmont of the Saharan Atlas the amount of water falling annually of the lower Cretaceous is estimated at 2.5 billion m3 / year. (HADJ FATEH L. and ROUAS D., 2013).
The estimation of recharging of Intercalary Continental was the subject of several studies; the main ones are summarized in the flowing Table (Table 10). These estimates are overstated in ancient works but they were corrected later in the work of the OSS (2003) that are closest to the reality.

Table 10: Estimated recharge IC (Western Basin) Source (OSS, 2005)

<table>
<tr><th>Study</th><th colspan="3">Estimated recharge</th></tr>
<tr><td>CORNET (1961)</td><td colspan="3">23m3/s</td></tr>
<tr><td rowspan="3">BURGEAP (1963)</td><td>Saharan Atlas</td><td>4 m3/s</td><td rowspan="3">12.5 m3/s</td></tr>
<tr><td>Hamada south Oranais and the Grand Erg Occidental</td><td>8 m/s</td></tr>
<tr><td>the Tademaït</td><td>0,5 m3/s</td></tr>
<tr><td rowspan="3">GEOPETROLE(1964)</td><td>Saharan Atlas</td><td>4.5 m3/s</td><td rowspan="3">14 m3/s</td></tr>
<tr><td>Hamada south Oranais and the Grand Erg Occidental</td><td>8.9 m3/s</td></tr>
<tr><td>the Tademaït</td><td>0.3 m3/s</td></tr>
<tr><td rowspan="2">ERESS (1972)</td><td>Saharan Atlas</td><td>2.03 m3/s</td><td rowspan="2">5.58 m3/s</td></tr>
<tr><td>Grand Erg Occidental</td><td>3.55 m3/s</td></tr>
<tr><td>OSS (2003) calage du Modèle SASS</td><td colspan="3">7.54 m3/s</td></tr>
</table>

4.12 Hydrochemical analysis:

The hydrochemical analysis of water is an essential supplement to study the hydrogeological parameters of aquifer and water resource management. It helps to bring much information about the environment in which groundwater flow and the portability of water.

Drinking water is water that you can drink without risk to health. It must also be a pleasant water to drink, it must be clear, have a good taste, it must not corrode the pipes and it must contain a minimum of dissolved mineral salts from 0.1 to 0.5 grams per litter.

The standards are only set at one time, an acceptable level of risk for a given population. They depend also of scientific knowledge and available technology, particularly in the areas of health hazards and chemical analysis. They can be changed at any time depending on progress. All countries of the world do not follow the same standards. Some enact their own standards. Others take those recommended by the European community. The tables 11 and 12 below show the Algerian and European water standards.

Table 11. The Algerian standards for qualify of drinking water
Officiel Journal N° 57 DU 14 SEPTEMBRE 1994.

Settings	units	guide level	maximum concentration
pH		6,5- 8,5	
Conductivity	µS/cm à 20°C		**2880**
Dry residue	mg/L après séchage à 180 °C	-	**2000**
Total hardness	mg/L de CaCO3	100	**500**
Calcium	mg/L	75	**200**
Magnesium	mg/L	-	**150**
sodium	mg/L	-	**200**
potassium	mg/L	-	**20**
Sulfates	mg/L	200	**400**
chlorides	mg/L	200	**500**
nitrates	mg/L	-	**50**
nitrites	mg/L	-	**0,1**
ammonium	mg/L	0,05	**0,5**
Phosphate	mg/L	-	**0,5**
Dissolved oxygen	mg/L	5	**8**

Table 12. The European standards for qualify of drinking water (D'G Castany after 1980).

Parameter /substance	Contents		
	Guide (Mg / l)	Max (Mg / l)	Min (Mg / l)
pH	6.5 à 8.5	9.5	6
conductivity (µs/ cm)	400	1250	
dry residue		1500	
hardness	35		10
Calcium Ca2 +	100		10
Magnesium Mg 2+	30	50	05
Sodium Na +	< 20	100	
Potassium K +	< 10	12	
Sulphate SO42-	05	250	
Chloride Cl-	05	200	
Nitrate NO3-		50	
Nitrite NO2-		0.1	
Ammonia NH4+	0.05	0.5	
Fluor F	0.7	1.5	

To precisely define a drinking water (potable), standards have been established by communities to qualify a drinking water. They set content limits not to be exceeded by a number of harmful substances that may be present in the water. The fact that water complies with standards, that is to say drinking, so does not mean it is free of pollutants. However, their concentrations are considered low enough not to endanger the health of the consumer.

In our case study, the chemistry of water can be influenced by the effect of the dissolution of geological, industrial discharges and agricultural activities.

This study aims at highlighting the current state of water through an analysis of its chemical state due to natural and anthropogenic parameters within the environment

Data obtained through analysis of physicochemical parameters done at ANRH Adrar laboratory.

This study covers 16 boreholes and 2 Foggaras that capture the tablecloth IC Gourara in the region. Analytical results of physico-chemical parameters are listed in Table 13:

Table 13: Results of physicochemical analysis of water.

	Longitude	Latitude	PH	Cd in µs/cm	Ca	Mg	Na	K	Cl	SO4	NO3	HCO3
TINERKOUK	00°14'30"E	29°10'17"N	6,94	4170	243	51	480	28	730	860	55	122
TINERKOUK	00°15'12"E	29°14'34"N	7,3	2220	102	72	230	19	350	465	40	119
TINERKOUK	00°17'28"E	29°15'34"N	7,19	2440	110	56	300	17	410	448	44	119
TINERKOUK	00°44'21"E	29°47'03"N	7,51	840	43	61	35	4	125	120	19	110
TIMIMOUN	00°15'20"E	29°13'45"N	7,28	1830	94	59	180	19	250	402	36	110
TIMIMOUN	01°34'02"E	29°31'57"N	7,03	1350	98	35	130	8	210	260	30	73
TIMIMOUN	01°33'39"E	29°31'14"N	7,01	1250	89	43	100	8	185	240	27,5	73
TIMIMOUN	01°33'26"E	29°30'43"N	7,02	2550	123	101	195	12	324	615	51	73
OULED AISSA	00°03'26"E	29°11'34"N	7,16	2200	64	72	250	34	380	260	39	198
CHAROUINE	00°15'19"W	29°03'38"N	7	4430	140	152	500	78	750	800	95	125
CHAROUINE	00°15'20"W	29°03'49"N	7,06	3010	98	51	500	50	495	663	68	146
CHAROUINE	00°01'49"W	29°31'22"N	7,42	1600	85	53	172	15	280	206	44	153
CHAROUINE	00°15'48"W	29°11'17"N	6,99	2590	81	101	280	37	455	415	24	149
TINERKOUK	00°41'20"W	29°47'09"N	7,12	660	47	24	35	4	66	94	36,2	104
TINERKOUK	00°41'29"W	29°47'01"N	7,2	710	58	23	40	7	62	100	131	22
TINERKOUK	00°05'42"E	29°23'59"N	7,44	1320	60	51	89	20	170	125	27,5	168
Foggara of M'ghair	00°13'09" E	29°15'34"N	7.6	1800	161	3	200	20	240	423	49	137
Foggara of Ali welhaj	00°13'09" E	29°15'34"N	7.63	3800	126	32	220	27	293	431	49	137

4.12.1 **Methods and Strategy:**

4.12.1.1 Sampling:

It is a very important and sensitive process; the water should not be mix with any external factors. The container must be washed bay the same water that want to be analysed before fill it to avoid contamination.

4.12.1.2 In situ measurements:

Three parameters are measured in situ (T, pH, and conductivity) immediately after collection of the sample .These parameters used to define the basic characteristics of water. Statistical analysis of physical and chemical data:

The method of multidimensional statistical analysis in main components is to express a variable set into a set of linear combinations of uncorrelated factors together (ZAGHTOU, 2011).

The statistical interpretation of results of chemical analyzes of water using parameters sample characteristics, such as mean and standard deviation may be insufficient if the number of samples becomes important. The method of multidimensional statistical analysis are intended simultaneous description of data, providing information and elements.

Among these interpretations methods, analysis was used principal component (minimum, maximum, average, standard deviation) that allows an analysis of relationships among many variables giving information on the changing chemistry of the waters and determination of dominant characters in our statistic study of 18 samples(Table14) the data obtained was analysied using EXCEL stat version 8.

Table 14: The result of statistical analysis.

Elements	minimum	maximum	average	standard deviation
Mineralization	637 .177	1998.7	1317.9385	962.74
Ph	6.94	7.63	7.285	0.49
Ca^{2}+ (mg/L)	43	143	93	70,71
Mg^{2}+ (mg/L)	3	77,5	40.25	52.68
Na+ +k+ (mg/L)	39	308.5	173.75	190.57
HCO3- (mg/L)	22	110	66	62.23
Cl- (mg/L)	62	406	234	243.24
$SO4^{2}$- (mg/L)	94	477	285.5	270.82
NO3-(mg/L)	19	131	75	79.20

From Table 14, we see that the Sulfates, Chlorides, Sodiums and Mineralization present important values of the standard deviation; this confirms the wide dispersion between the values for these elements.

4.12.2 **Analysis of Chemical Elements:**

4.12.2.1 Organoleptic Parameters:

The organoleptic characteristics are parameters that must be assessed at the time of sampling: certain odors can, for example, disappear in transit or the appearance of the sample changes during transport and storage (color development, precipitate).

During our training the organoleptic parameters of our samples were:

Color: all water withdrawn and analyzed are colorless.

Odour: organic matter tests, ammonium, phosphates, nitrates and nitrites gave no remarkable result in the waters.

Taste: in general, it is difficult to pass judgment on the quality of water by the single evaluation of the flavour.

Study of physico-chemical parameters:

4.12.3 **Physical Parameters:**

4.12.3.1 Temperature:

It plays an important role in increasing the chemical activity, bacterial and evaporation of water. It varies depending on the outside temperature (air), the geological nature and the depth of the water level relative to the surface.

According to the data from ANRH, average water temperatures vary between 21to 24°C.

4.12.3.2 Potenz Hydrogen (pH):

The pH depends on the origin of water, the geological nature of the formations crossed (Dussar, 1966 Bermond and Vuichard, 1973). This setting affects many physico-chemical equilibrium between water, the dissolved carbon dioxide, carbonates and bicarbonates, which are, buffered solutions giving an aquatic life favorable development. In most natural waters, the pH is usually between 6 and 8.5 (HCEFLCD, 2007).

The table 15 below show the variation of pH:

Table 15: The variation of pH.

pH	Maximum	Minimum	Mean
Values	7.51	6.94	7.16

The pH values are in accordance with the Algerian and European standard of potability of waters (drinking).

Electrical conductivity:

The electrical conductivity of water is the conductance of a water column comprised between two metallic electrodes (platinum) surface of 1to 2 cm and separate from each other from 1 cm. it is the inverse of the electrical resistivity.

The unit of conductivity is the siemens per meter (S / m):

1 S / m =104 µs / cm = 103 S / m. (HCEFLCD 2006).

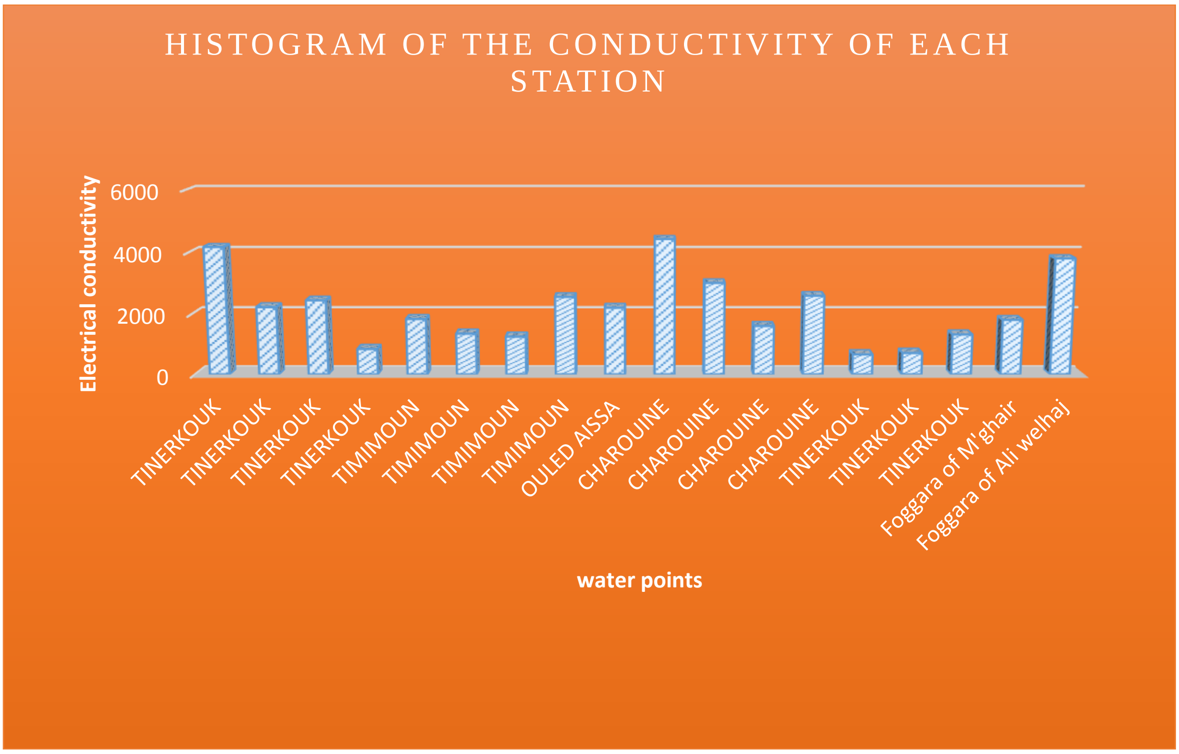
The table 16 below summarizes us the water quality as a function of conductivity (FRANC-N.KEMMER, 1983)

Table 16: Water quality in function of the electrical conductivity (Manuel of water Nalco1983):

Conductivité électrique (exprimée en µs/cm)	Water quality
50 à 400	Excellent
400 à 750	good quality
750 à 1500	poor but usable water
> 1500	Mineralization excessive

The measuring of conductivity (Fig:18) allows a measure of the amount of salts dissolved in water and then give an idea about the total mineralization of water. The measured values were corrected in relation to a standard temperature of 25 ° C.

Fig 18: Histogram of the conductivity of water samples.



The waters of region studied have very high conductivities, sometimes exceeding widely drinking water standards, they are superior to 1500 µs / cm, and they reach the 4430 µs / cm.

The maximum values are related to the presence of Gypso-salt formations occupy depression areas of the region (and former sebkhas wadi beds).

4.12.4 **Mineralization:**

The mineralization of water can be determined either by the electric conductivity (Farst method) or by the dissolved ion content obtained by summation of the concentrations of anions and cations since they are highly correlated in all aquifer (in first approximation can be bound ionic strength to the ionic concentration).

Overall mineralization Determination: in the table below (Table: 17) the determination of mineralization from conductivity.

Table 17: The mineralization from conductivity.

Conductivity (µs / cm)	Mineralization (mg / L)
CE < 100	Very weak
100 <CE < 200	weak
200 < CE < 666	Average
666 < CE < 1000	Important
CE >1000	High

Source: (Manuel of water Nalco1983)

The deferent formulate of calculation of mineralization show in the Table: 18 below

Table: 18: The deferent formulate of mineralization calculations

Conductivity (µs / cm)	Mineralization (mg / L)
CE < 50	M = CE x 1.365079
50 < CE < 166	M = CE x 0,947658
166 < CE < 333	M = CE x 0,769574
833 < CE < 10 000	M = CE x 0,758544
CE <10 000	M = CE x 0,850432

Source: (Manuel of water Nalco1983)

Water classification in function of the conductivity:

Calculation of Mineralization:

Using the data we have and the deferent formulate of the Table 18; we present the Table below (Table: 19); the Table 19 show the mineralization of water and its quality.

Table19 :The mineralization and quality of water

water sample	Mineralization (mg / l)	Mineralization of water
Tinerkouk	3163,12848	High
Tinerkouk	1683,96768	High
Tinerkouk	1850,84736	High
Tinerkouk	637,17696	Important
Timimoun	1388,13552	High
Timimoun	1024,0344	High
Timimoun	948,18	Important

Timimoun	1934,2872	High
Ouled Aissa	1668,7968	High
Charouine	3360,34992	High
Charouine	2283,21744	High
Charouine	1213,6704	High
Charouine	1964,62896	High
Tinerkouk	507,91884	Average
Tinerkouk	546,39754	Average
Tinerkouk	1001,27808	High
Foggara of M'ghair	1365,3792	High
Foggara of Ali welhaj	2882,4672	High

The water quality of our case study from the Table: 19 has high mineralization, it present 77% of the water, samples and 22% vary between average and important.

4.12.5 Dry Residue:

The dry residue is the total mineralization of water, Means the total dissolved salts and organic matter contained in water. (Hassani & Djoualil 2014)

For taste reasons, the O.M.S. recommends a limit of 1000 mg / l in water intended for human consumption. In countries with arid and semi arid climate this is often far exceeded.

The Table: 20 below show the Dry Residue (DR) analysis of the area of case study.

Table 20: The Dry Residue analysis.

water sample	**DR mg/l**
Tinerkouk	2620
Tinerkouk	1470
Tinerkouk	1700
Tinerkouk	520
Timimoun	1190
Timimoun	880
Timimoun	830
Timimoun	1770
Ouled Aissa	1370
Charouine	2700
Charouine	1850
Charouine	1060
Charouine	1710
Tinerkouk	470
Tinerkouk	446
Tinerkouk	830
Foggara of M'ghair	1216
Foggara of Ali welhaj	1245

From the Table: 20 the minimum value of dry residue is found (446 mg / l) to a maximum dry residue (2700mg / l) with an average of 1326.5mg / l. This is due to the solubility of elements of Terrain traversed, with the highest temperatures in summer, it promotes evapotranspiration of water and Sebkhas formation. Among the factors controlling the chemical composition of groundwater, lithology, as it plays a key role, either directly as a source of minerals dissolved in the water, or indirectly by promoting or limiting, depending on the permeability and flows.

4.13 Study of major chemical parameters:

4.13.1 Study of Cations:

Calcium Ca^{2+}

Calcium is an alkaline earth metal extremely widespread in nature and especially in limestone in the form of carbonates, it is a major component of the water hardness; it is usually the dominant element. Drinking water of good quality contains 100 to 400 mg / l calcium. (RODIER, J.1984)

Calcium values are between 43 mg / l and 243 mg / l with an average of 101.1 mg / l. Most water have concentrations comply with drinking water standards (100mg / l).

The presence of Ca^{2+} ions in groundwater is related to geology; the dissolution of carbonate formations $CaCO_3$ belonging to the Turonian and Senonian, and gypsum $CaSO_4$ formations belonging to the lower Senonian.

Magnesium Mg^{2+}

Magnesium is one of the most abundant elements in the nature. It gives a bad taste to the water. The evolution of magnesium contents is identical to that of calcium. (anonymous).

The contents are between 03 and 152 mg / l with an average of 57.8 mg / l. The majority of concentrations are in accordance with the Algerian and European potability standard (50mg / l <Mg <05mg / l), the origin of magnesium in groundwater is related to the dissolution of carbonate formations with high magnesium content (magnesite and dolomite), and in our case we can say they are probably from the Cenomanian.

Sodium Na^+

Sodium is an element whose concentration in water varies from region to region. The origin of sodium in water is mainly due to leaching of deposits evaporite and these phenomena by leaching, evaporation and by Base Exchange. The dissolution of salt-bearing minerals is done according to the following relationship:

$$NaCl \longrightarrow Na^+ + Cl^- \quad \text{(RODIER, J.2009)}$$

The content of sodium ion is higher than the standards for drinking water is reche (100 mg / l) the maximum value is reached (500 mg / l), the minimum level (35 mg / l), so the average is 218.83 mg / l.

This increase is mainly due to leaching and dissolution of formations evaporite salt Gypso-level depression areas.

Potassium K^+

Potassium is the element less common in groundwater. Values observed show that potassium concentrations between 4 and 78 mg / l, with average of 23.61 mg / l, the majority of water points have concentrations above the potability limit (<10 mg / l).

High concentrations observed are related more to the rich clay formations in potassium and much less the use of chemical fertilizers.

4.13.2 **Study of Anions**

Chloride Cl^-

Chlorides exist in all the water in varying concentrations. Chloride ion has different characteristics from those of other elements, it is not adsorbed by geological formations, are not easily combined with chemical elements and rest very mobile. Chlorides encountered in large quantities in groundwater come from the dissolution and leaching of saliferous formation. (RODIER, J.2009)

The levels recorded in our study area show significant values range from 62 mg / l and 750 mg / l. The origin of chlorine in water is mainly due to the dissolution of fertilizers and pesticides used in agriculture as well as the discharge of wastewater.

Bicarbonates HCO3-

The presence of bicarbonate in water is due to the dissolution carbonate formations and water loaded with carbon dioxide. The sum of the equations dissolution is given as follows: (RODIER, J.2009)

$$CaCO_3 + H_2O + CO_2 \longrightarrow 2HCO_3 + Ca^{+}$$

Registered contents show values which vary between 22mg / l and 198 mg / l with an average of 111 mg / l. they are below the potability standards of the European community to qualify a water drinking fixed at 250 mg / l. The presence of bicarbonate is related to land leaching and the dissolution of carbonate formations of Turonian and Senonian formations interspersed throughout the IC.

Nitrates NO3-

A part of the natural nitrates in the soil resulting from the fixation of atmospheric nitrogen by soil bacteria, for example in the bulbs of legume roots, Another part enters with precipitation by leaching anthropogenic impurities in the air or during storms. (RODIER, J.2009)

Observed concentrations ranging from 19mg / l and 131 mg / l with an average of 45.3 mg / l, the average of concentrations are within the drinking water standard (50mg / l).The high values are due to agricultural activities in the area and wastewater discharges. On the other hand, by anthropogenic pollution, contamination from the sewerage and septic systems on the one hand, and by the use of other fertilizers on the other hand.

Sulphates SO_4^{2-}

sulphates may have a meteoric origin; as they may also come from natural agricultural or biological activity, or for domestic use (Detergents), or the presence of evaporites (gypsum). (RODIER, J.2009)

The sulphate concentration varies between 94 mg / and 860 mg / l with an average of 393mg / l. The water sample have concentrations greater than the potability standard (250mg / l).

The total hardness or TH (total hardness):

The total water hardness or hydrotimétrie is a global parameter in the concentration of calcium and magnesium salts dissolved in water.

Water from which hardness values are high is called "hard" in the opposite case it is a soft water. Moreover, the hardness of water is a natural character due to leaching terrain to be traversed.

The temporary hardness is directly related to the carbonate alkalinity while the permanent hardness is predominated by the presence of sulphates and chlorides of calcium and magnesium.

It is expressed either in meq / 1 either in mg / 1 CaCO3 in ° F:

1 meq /l = 5 ° F = 50 mg / 1 CaCO3.

TH= (rCa++ + rMg++) meq/l.

Or:

TH = (rCa++ + rMg++) × 5 in French degrees (F °).

The values of Total Hardness of water determining its quality are given in the Table 21 below:

Table 21: Water quality based on TH.

TH (°F)	**0-7**	**7-22**	**22-32**	**32-54**	**>54**
Water quality	fresh	In moderation fresh	Enough fresh	Hard	Very Hard

The results of our study area show that the hardness of the water between 55 and 88 F ° are in very hard water, this high hardness mainly from circulation of water in the carbonate formation. The Algerian standards indicate as good quality water with a hardness between 20 ° F and 50 ° F. (NA752 Seminar on Water Quality, 1996).

4.14 The tradional system of collection and water distribution (Foggaras) in the south of Algeria case study Foggaras of Timimoune

For several centuries, the desert population adapt to the desert environment, the arid environment, and contribute to the creation and development of an agricultural ecosystem despite the extremely hostile conditions for life imposed by nature (stifling temperature, weak meteoric flows and intense wind) with technical engineering oasis societies extraction of groundwater called Foggaras.

4.14.1 Overview historical on the system Foggara:

The system of drainage galleries is known worldwide under several names. This is the Foggaras in Algeria, the Qanat in Iran, falj the Sultanate of Oman, kariz in Afghanistan and Pakistan, Khettara Morocco, the Qanat Romany Jordan and Syria, Kanerjing China and Kriga in Tunisia. These are names for the same principle operating, based on the drainage galleries. They are in over 30 countries worldwide (BOUSTANI,2008). This is the channel, which is the oldest technical; it was performed foe over 3000 years and is the Northwestern Iranian Plateau is considered the original home of these galleries (CRISTINI and Langlais, 2004; GOBLOT, 1979; WESSELS, 2005).

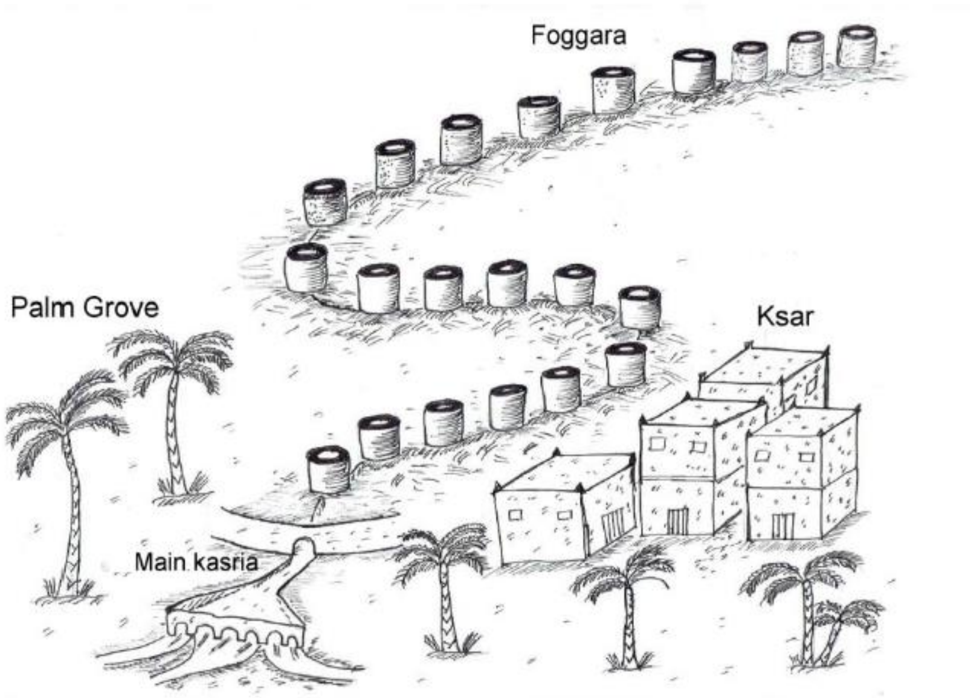
Over 50.000 channel were operating in Iran (GHORBANI, 2007). Today, there are only 22.000 channel functional, with a total length of drains is around 250.000 km (Wulf, 1968). The longest channel has a gallery of 50 km in length and is located in the Kerman region. The Falj locates in the north of Oman. The Aflajs were developed there over 2000 years (ZAHER BIN KHALID et al., 2007). Currently, there are only 3017 functional Faljs a total of 4112, which drain a flow of 680 million m3 par year for a length of 2900 km (AL GHARFI and al.2000). Unlike channels who draw water from underground sources, there are three types of Faljs:
The Falj Ghaili that captures the waters of the streams. It represents 49% of Flajs of Oman.

The Aini Falja that captures the sustainable natural sources. It represents 28% of total Flajs. The Falj Daoudi that draws water aquifers near the mountains. It represents 21% of total Flajs.

Tafilalet in southern Morocco, khettaras numbered 300 at the beginning of the twentieth century, to about 450 km of galleries. They focus on the right bank of the river, about 450 km of galleries. They focus on the right bank of the Ghriss river in northeast of Tafilalet. In 2000, there were only 150 khettaras, which works (BEN BRAHIM, 2003).

Whether the Qanat, the Khettara the falj or Foggaras, all these techniques have the same operating principle; it is water collection using the drainage galleries provided with ventilation wells. However, the sensed water source differs from one method to another.
In Algeria, when we talk about Foggara, we automatically talk Foggara Tuat, Gourara and Tidikelt that capture the waters of the Albian. The largest Foggaras in Timimoun region is that of El Meghier. It was was developed by Sid Marabot Othmane and his son, who lived in the ninth century of Elhejry (REMINI and ACHOUR, 2008).

The Figure 19 below show the overview of the Foggara:

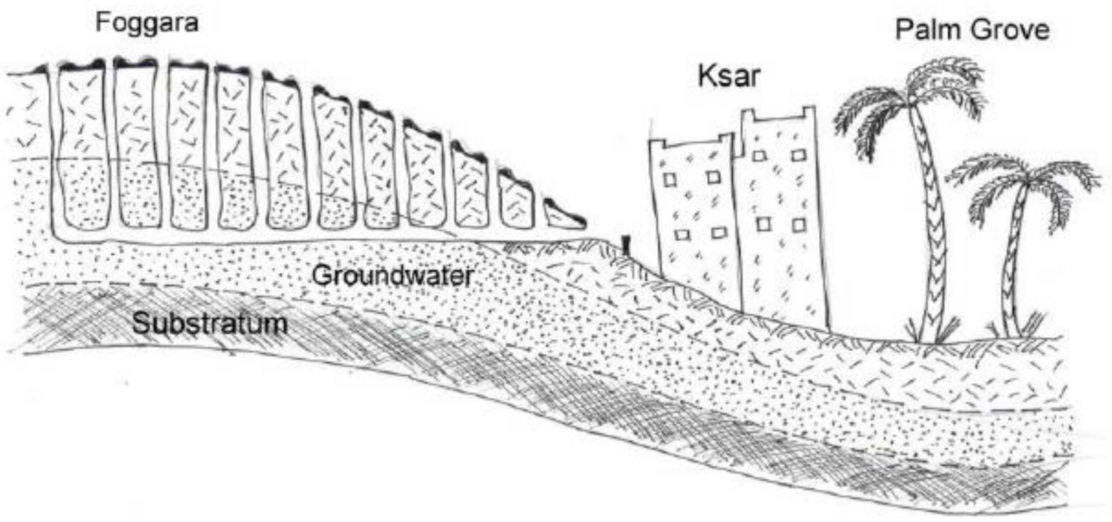


a) An overview of the foggara

Fig: 19: Overview of the Foggara.

4.14.2 Definition of Foggara: (Fig:20)

The Foggaras means in Arabic Fakara (creuser). Is an inclined underground tunnel , which drains water from the aquifer upstream to the drier lands downstream, towards the palm. This process uses a gently sloping tunnel system hydraulic head gravity flow with a length of up to 20 km, equipped with a series of vent wells spaced from 5 to 22 m, the depth may reach 20 m (Figure 00). The minimum distance between Foggaras is 80 m (CHEYLAN 1990). The Foggaras is a technique related to a social system of collective work, conducted by a committee of wise men, called Djemaa, whose role is to lead and oversee the maintenance of the Foggaras and distribution of its water.



b) A logitudinal cup of the foggara

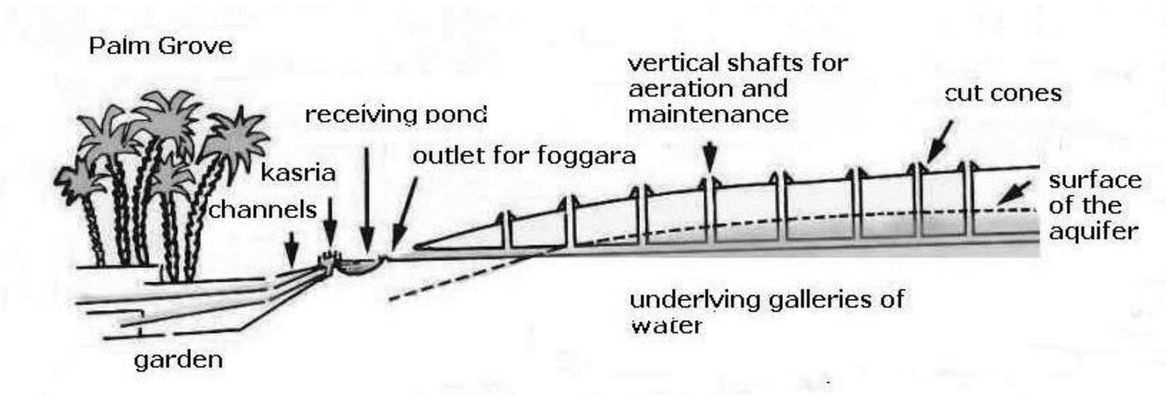


Fig:20: Longitudinal cup of the Foggara

Several authors define Foggaras of the Algerian Sahara as an underground gallery capturing the waters of the Continental Intercalary aquifer, but following several studies in various regions, we identify seven types of Foggaras:

- ✓ Foggara of the Albian:

Foggara of the Albian, called "classic foggaras", this type of foggaras localizes to the southwest of the Grand Erg Occidental, in areas of the Tuat, Gourara and Tidikelt, where the plateau Tadmait is a real water tower. Indeed, the Albian aquifer deep, is closer to the surface in the periphery of the plateau due to drilling the underground galleries of the Foggaras; these galleries penetrate in the upper part of sandstone of the Continental Intercalary aquifer, at the periphery of Plateau Tadmait. These galleries provide gravity flow towards the low depressions where palm groves and gardens to locate. There are in areas of the Tuat, of Gourara and Tidikelt, about 820 Foggara currently in service, the rate is around 2.8m3/s, and a total length of 2000 km. The oases of Tuat count 531 Foggaras including 358 in operation (DUBOST and Moguedet 1998).

Irrigated areas by this technique vary from 7 000 ha and 3000 ha, of which agricultural production is very varied: Dates, cereals, Pulses, Vegetable and Fruit crops (KESSAH 1998). For this type of Foggara the flow is continuous throughout the year. There is an interruption of the flow in the case of a collapse of a portion of the gallery or rapid drawdown caused by the installation of a drilling near the Foggara.

- ✓ The Foggara of Erg:

The foggara of Erg collects water from groundwater that form below the Grand Erg Occidental, through water that flows slowly under the Erg in ancient rivers from the Saharan Atlas, Unlike Foggara of Albian, the flow of the Foggara of Erg remains stationary throughout the year; the water is less salty and good quality. This type of Foggaras localizes in the oasis of Ouled Said (Timimoun). Currently, there are a hundred Foggaras of this type, of which less than 80 are functional. It is very difficult to know the exact length of this type of Foggaras; galleries and wells are lost in the dunes of the Grand Erg Occidental.

The Foggara of Erg has its own characteristics, namely:

• The length and the number of wells are difficult to identify.

• It is difficult to find the mother of the well Foggaras view the inability to access the Erg.

• Its water has good quality.

• It flow rate affected by sand.

- ✓ The Foggara of Garden

Is a characteristic of the Algerian Sahara. We identified seven Foggaras of this type in the Timimoun region, whose length does not exceed 1 km and the wells do not exceed the number of 20. For example Foggaras of Agalou (20 wells), Zahzaa (15 wells) Akraf, Ksar el Kadim1, Ksar el kadim2, Oukala (abandoned) and Bouchouk (Abandoned).

It is a small Foggaras the length of the gallery does not exceed 1.5 km. It belongs to a single family located downstream of one or several large Foggaras Albian (or conventional) to capture water drainage, infiltration and irrigation from the irrigation waters of the park and gardens. Even seepage from the seguias and madjens, classical Foggaras are recovered by this Foggaras. This shows that there is no loss of water, the whole resource is used. As for the distribution and sharing of water from this type of Foggaras, it is simple and requires no measurement or calculation.

The Foggaras is not even equipped with a kasria (comb), water from the gallery directly from the reservoir (the madjen). Such Foggaras is equipped with a small kasria, an orifice becomes clogged with a pebble covered with a fabric and clay to minimize leakage (a kind of valve). To make a good irrigation operation, closes the hole in the rock until filling madjens in an acceptable time.

- ✓ The Foggaras of source or Foggaras Al Ain (source in Arabic)/

Unlike classical Foggara the Foggara of El Ain collects water from natural sources. There were 15 Foggaras called Aayounes (plural of "Ain"), which are distributed between the oasis of Moghrar (Naama), Beni Abbes (Bechar), Adrar, Beni Unif (Bechar) and Boussemghoune.

This type of foggaras resembles that of falj Aini of Oman that drains also the source of water; this is why it is called Aini (source).

- ✓ The Foggara of mountain :

This type of Foggara is no longer in service in the Algerian Sahara. The few Foggara we identified are located in the region of Bechar. The foggara of mountain draws its water from an aquifer that is recharged from runoff from peripheral mountains, This type of Foggara has much similarity with the Moroccan khettara the Iranian qanat and kariz Afghanistan. The main characteristic of the Foggara Al Ain is the change in its flow during the year. Indeed, it is during the rainy season that the flow records the highest values, due to the recharge of groundwater.

The draining of foggaras occurs in warm periods, following various periods of drought for several years and lack of maintenance, the Foggara of mountain the oasis of Taghit are currently abandoned. This type of Foggara locates at the foot of mountain Marhoma in Beni Abbes. It is characterized by a length of the gallery that does not exceed 1000 m. It is large compared to the Albian Foggara.

- ✓ Foggara of stream:

This type of Foggara collects water of stream, as falj the Sultanate of Oman. The length of this Foggara dug in the sand coarse alluvium of the stream, can reach 1500 m. This is a temporary Foggara works in the wet season by capturing the waters of the slick inféroflux. For this type of Foggara, the mother well and the ventilation well are located in the bed of the stream, where soil types encountered are generally silty clay and sometimes rocky. They are vulnerable to flooding and silting, the ventilation well being covered by alluvium of the river during floods; no Foggara of this type currently operating, they are abandoned after their collapse and drying flood This type of Foggara is localized in the regions of Becher and Tamanrasset, in the oasis of Lahmar.

- ✓ The Foggara of flood:

It is a special foggara, unique in Algeria and located in the valley Mzab in the oasis of Ghardaia. This Foggara is intended to recover the flood waters; once collected at the retaining called Bouchene, water is channelled Four galleries with a length of about 200 m, which are equipped with ten ventilation well The water goes directly into the gardens and the surplus of the flood is recovered downstream.

Sharing and water distribution of Foggara.

Once the water reaches the level of the gardens, sharing is based on two methods: volume and schedule.

- The volumetric method

This type of sharing is most common in Algeria. In all oases Foggara Albian, water sharing is by volumetric method. Each owner is the recipient of a volume of water determined according to its contribution to the upkeep and maintenance of the Foggaras. This distribution is provided by kasriate (plural of kasria).

The distribution network has a number of kasriate which is proportional to the number of subscribers. kasriates are arranged in a pyramid. From the kasria Lakbira (main) (Figure 00), a sort of triangular pool with a diverter (comb) receives all the water from the Foggara and distributes the flow into three, four and even five channels (seguias). From the main kasria the seguias will distribute in all directions. At the end its seguias, other side secondary kasriates distribute the water and other and so on up guemouns (gardens).

- The method of schedule

This method of sharing water, characteristic of sources Foggara, mountains and stream, is based on the unit time. The sharing of water is by the schedule process called Nuba, that is to say in turn. It defined as the duration of time sufficient to completely irrigate the garden. Water sharing khettaras Tafilalet (Morocco) and qanats (Iran) is made in the manner of the shindig. In Algeria, the sharing of water per unit time currently takes for water to two Foggara Moghrar (Naama); it works the same way as Moroccan khettaras.

The distribution of water among owners takes place in turn. In the region of Adrar, the watershed of the Foggara of Hanou, a schedule Foggara, is performed alternately no kasriates as in other neighboring Foggara. Relatively large seguias directly leave a large madjen (tank). The foggaras is obstructed once or twice per day to allow to restore the required level, then the water is released for a given time, proportional to the financial contribution paid by the beneficiary (Oleil 1994).

Foggara distribution in Algerian sahara:

Today, no one is able to determine the exact number of functional Foggara in Algeria. However, their numbers to about 930; they are classified according to seven types which are located around the Grand Erg Occidental; Foggara are abandoned each year, others

rehabilitated, either by farmers or by local services. For Foggara of Erg, it is impossible to give an exact figure, as many Foggara are under the sand of the Grand Erg Occidental. You will find traces of Foggara in some areas, but it difficult to estimate their number.
In 1988, the National Agency for Water Resources revealed the existence of 903 Foggara "perennial", a gallery of total length of 2300 km equipped with ventilation shafts 187.500. In 2014, this number was revised downward highlighted the existence of 679 active Foggara, 28 other active but the low rate so do not achieve the palm plantations, in addition to 758 Foggara whose waters have dried up and 369 Foggara "permanently lost." The satellite channel shows 154.360 wells on the route foggaras systems, from Tsabit area north of the province, to those of Zaouiet Kunta-South.

4.14.3 **Elements of Foggara:**

The system of Foggar is divided into two parts the collection and distribution:

- Capture:

The capture of groundwater is ensured by a gallery of several kilometers of low slope, which drains water from the unconfined aquifer to the free surface. This gallery is equipped with several vertical wells that serve to maintain and ventilate the Foggara.

- The gallery

The gallery is the motor element of Foggara. It consists of two parts:

- ✓ The first part is the seat of a flowing load.
- ✓ The second part is the location of a free surface flow.

The system consists of a variable section gallery width ranging from 50cm to 80cm and the height from 90 cm to 150 cm. The length of the gallery can vary from 1 km to 15 km (figure00), while the range of the flow rate is 1 L / s to 50 L / s (Remini.et, Achour, 2008).

The Foggara are aligned from east to west and are carefully arranged to avoid any drainage that could damage ancient neighboring Foggara. The distance allowed between two galleries must be greater than 100 "Khamas". The Khamas corresponds to the length of two open arms 2 meters.

The gallery is composed of several "Enfad" term for the tunnel between the two wells. Generally, the average distance between two "Enfad" around 13 meters. The gallery ends with Aghissrou representing the portion between the first well, counted from the exit, and Majra. This part may be covered by flat stones. (ABIDI.N)

The study of the alignment of Foggarashows that the galleries of most foggaras are branched, the upstream part of the Foggara take shape at the end of the sign 'Y'
The wells (Fouaha) are the visible part of the Foggara, inside the cities they are considered an aesthetic object.

The gallery of the Foggara is a series of vertical wells, the distance between them, it changes from one region to another depending or the type of terrain crossed, the length varies between 07 and 40 m.

Well depth varies according to the static water table and topography of the area. At the beginning of the realization of the Foggara, wells serve to remove cuttings or bringing embankments. Once in operation, these wells are used as access for maintenance and for aeration of the gallery. Their depth ranges from 1 to 40m and diameter of 0.5m to 1m.

The wells are aligned parallel to the flow direction of the web with a NE-SW direction, to increase flow from the Foggara, wells are added to left and right of the main alignment, wells for the second gallery.

- Main channel "Majra"

It is a rectangular channel which serves to conduct the water towards the dispatcher "Ksaria", has a length of several meters to several kilometres , it is built by clays, these channels are currently in cement and even PVC to minimize seepage losses.

- The distribution network of Foggara : (Fig: 24)

On the exit of Foggar, water is distributed by a comb called "kasria" or "Qasri" designed stone flat triangular or rectangular shape constructed by clays present in cement to store water before being distributed among the owners. The basin has a stilling to cushion the speed before passing through the machte "brush" where each part water will be channeled through a Seguia to the farthest in the palm garden.

The comb has several varying sizes of openings. Several types of kasria can be observed in the palm:

- ✓ The kasria Lakbira or main kasria :

Is a triangular basin; It not only helps to cushion and calm flow before its distribution but also the flow measurement. The kasria Lakbira receives the full flow from Foggara which is then divided into 3, 4 cannels (seguias).

- ✓ The kasria Secondary (Fig: 21)

Is a triangular basin placed after the kasria Lakbira. It is used for family sharing every tribe or group of persons involved in the realization of Foggara.

Fig: 21: The Kasria Secondary.

- ✓ Multiple kasria:

Are small seguias that come after secondary kasria, along the route of seguias that carry the water to the Majene.

- ✓ Channel "Seguia" (Fig: 22)

It is an open channel of rectangular or circular section is constructed typically planted. An appreciable quantity of water is lost by seepage and evaporation. This encourages oasis to build cement seguias and even PVC to reduce infiltration, but this solution has caused the drying of some palm trees located near these seguias. The channels drain water from kasria Lakbira until Madjene and the Madjene to Gamoun. The seguias branch in all direction of the palm.

Fig: 22: Channel "Seguia"

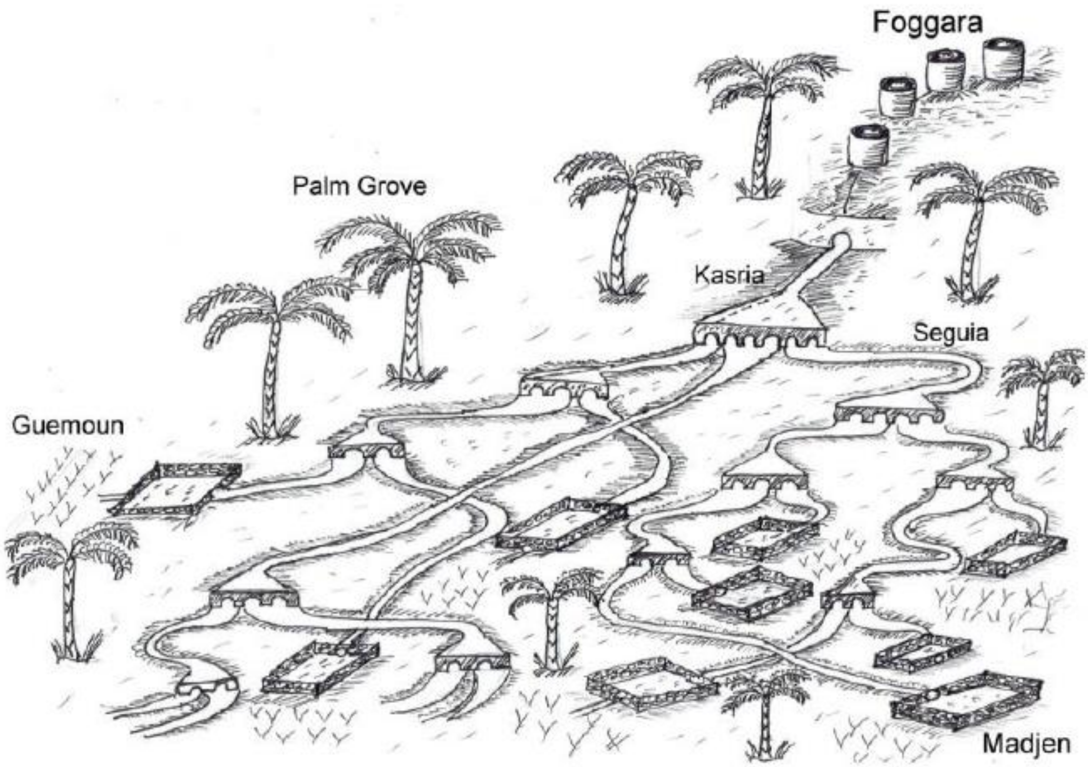
- ✓ Bassin "The Madjen" (Fig: 23)

It is a recovery and regularization basin that receives water from multiple Kasriates. On a rectangular or square relatively shallow section, it acts as a water tower. It is at the higher side of the garden to allow water to flow by gravity into seguias and irrigate the entire garden. The Madjene is constructed to fill in 24 hours.

The bottom of the basin is covered with a layer of clay to prevent seepage. The most recent basin is designed by cement. Irrigation is generally carried out in good time, whether in summer or winter. The basin in the palm create a fresh summer with moisture they release during the day.

Fig: 23: Bassin "The Madjen"

Fig : 24 : The distribuation network of Foogara



c) A distribution network of the foggara

4.14.4 Foggara Evolution:

The review of the topographic map of the Adrar region shows that all Foggara are in the periphery of the Tademait plateau. Use of this system Drainage is in favor of the existence of topographical conditions and especially hydrogeological that are:

- The presence of a shallow aquifer.
- The existence of a natural depression.

According to reports of the work of hydrologists and hydrogeologists interested in this drainage system, birth foggaras developed from downstream to upstream It has its origin in a source, it has dried up over time.

The farmers wanted to increase its flow rate, they dug a slice into the aquifer and within the direction of flow, starting from downstream to upstream, but the progressive deepening of slice; the difficulty of evacuation of water and the ability to construct galleries in sandstone layers of the Albian, led to the appearance of the first well.The driller is then transported the soil to the surface, he digs up the water then it connects the different wells by an underground gallery and this is how the Foggara was born.

Over time, the water needs have increased because of the expansion of irrigated areas; at that time, the farmers have made to increase the number of wells along a straight path as they dig into the sandstone of the aquifer.

On other hand they can not expand the system laterally, because of the internal regulation that sets the minimum interval that should separate two Foggara.
Unfortunately this gradual extension of Foggara into the upstream is limited by the cliff of the plateau, Add to that the difficulty caused by the growth of the depth of well whenever Foggara advancing upstream.

To increase the flow of Foggara, The farmers proceed to add a branching called " DARA " (arms) or " KRAA " (foot), but the continuing decline of the groundwater level of the aquifer complicates the situation and consequently farmers are always at the same starting point.

Operation of Foggara:

The Foggara generally constitutes 02 different parts:
- An upstream portion which enters the water, it is an active part (draining).
-Downstream allow the flow of water to the gardens through its slope is an inactive portion.

The direction of the Foggara is not related to the depth of the layers but the topography of the region.

Foggaras generally parallel to the flow of the aquifer. The permanent drainage performed by the active part causes a continuous lowering of the water table and consequently a reduction of the flow and changing the inactive portion upstream. Improving the flow by digging new wells will allow the migration of the inactive portion upstream and resulting in increased loss rate of drainage water in the downstream part by infiltration especially if there is an obstacle that hinders the free flow of water. The fraction of lost flow by infiltration is estimated 10 to 20% of the total flow drained.

The factors affecting on the operation of Foggara:

- Slope :

Regular slope usually a good compromise:

Too low: It promotes sedimentation and increases the frequency of dissections.
Too strong: It exacerbates linear erosion.
In general, the slope of the Foggara, is an average value of about 2 to 6 mm / m with a wide gap around this average. This small slope is insufficient (given the irregularity of the bottom of the gallery and walls) to ensure rapid flow of enough water; removing of all foreign material and avoid silting. Otherwise, it is difficult to increase the drawdown, therefore the yield of Foggara.

- The form of the gallery:

The form of the gallery plays an essential role in the operation of a Foggara. There are:

- ❖ Very narrow areas of the order of 0.4 to 0.5 m in width, to increase the speed flow and promote self-cleaning.
- ❖ Very large areas > 0.5 m and deeper until 1.2m, can increase the volume of water to trap sediments from the narrow area and facilitate their removal.

- The drawdown:

The drawdown is given by the difference in the level of water in the foggaras and the water table of the aquifer.

Technical and organization of the water measurement in Foggara:
As water is a scarce material, it takes the first importance in the arid region. An absolute necessity is essential for the following distribution rules suitable for such low rates, It is authorized anyone to measure a kasria whether primary or secondary without warning well in advance all owners.

The date of the transaction is fixed connection between the Chahed, the kial and the owner who wishes to transfer Habba sghira an irrigation channel to another, withdrawal or check if it feels a lesion.

The presence of all owners is not mandatory. If for one reason or another Kial el-ma is absent, the measure is simply canceled and postponed to a later date. A record of each meeting, written by chahed must appear in the register of Foggara.

4.14.5 **Measuring tools:**

The flow of a Foggara is measured in Habba kbira. Before distribution, that is to a primary or secondary kasria, kial el-ma must first know the number of Habbas kbira provided by Foggara.
This is done by a traditional manufacturing tool called "Louh" in Gourara region "Chegfa Halafa or" in the region Tidikelt and "Kiel Asfar or Chegfa" in the Tuat. This is a copper plate manufacturing of various shapes and diameters, the name " chegfa " comes from the Arabic word "chakafa" (the shard) a piece of a pot or a clay container. This device is a cylindrical top 15cm and about 25 to 30cm in diameter. It is open on each side. Or rectangular 15cm to 25cm in width and 50cm, 30cm in length. The tool is pierced by a row of holes of different diameters which correspond to multiples and sub multiple of the unit of measurement.

4.14.6 **Unit of measure:**

The unit of measurement of speed "Habba" "Habba zrig" "Habba Maaboud" changes name in each region, it is called kherga in Tidikelt, tmen, Majen, Sba, Aud, Kherga in Gourara and Sbaa, Majen , Habba in the Tuat.

The unit of measurement is not the same throughout the region, it differs from one region to another and even from Foggara to another in the same Ksar, from which the various tools used for flow measurement for each Foggara.

4.14.7 Methods for measuring the amount of water in the Foggara system: (Fig: 25)

First make a well leveled platform between kasria and after Majras removed enough of the beds of all souagui starting from this kasria. The Chegfa be set and maintained by help of clay in the axis of kasria and 80cm to allow calm flow.

During the measurement, no one take water from the Foggara, at least 100m far from the kasria. In order not to interfere the constant flow of water.
The Kial (measurer) (Figure 00) starts the measurement by the rightmost opening kasria. During the measurement thereof, water flows freely in other openings disorders in seguias. The Kial built with clay, a small, tight channel, so that the total water discharged by opening that measure, flows directly into the Chegfa through the gate. He leaves a number of holes open on the wall. All other holes are blocked by the clay. When the water level in the Chekfa is maintained exactly the level superior of cylinder, the measure is considered fair, so he mark on tablet of clay previously prepared, the number of Habba Zireg obtained, It proceeds as successively to all other openings diverter (the kasria). Once the measurement is done properly under the witnesses of the owners present, El-Hassab (accounting) is the addition following numbers etched into the tablet to give total flow in Habba Zérig. The shaheed announces the number of Habba Maaboud of all owners.
(H. A. El Hadj. 1982).

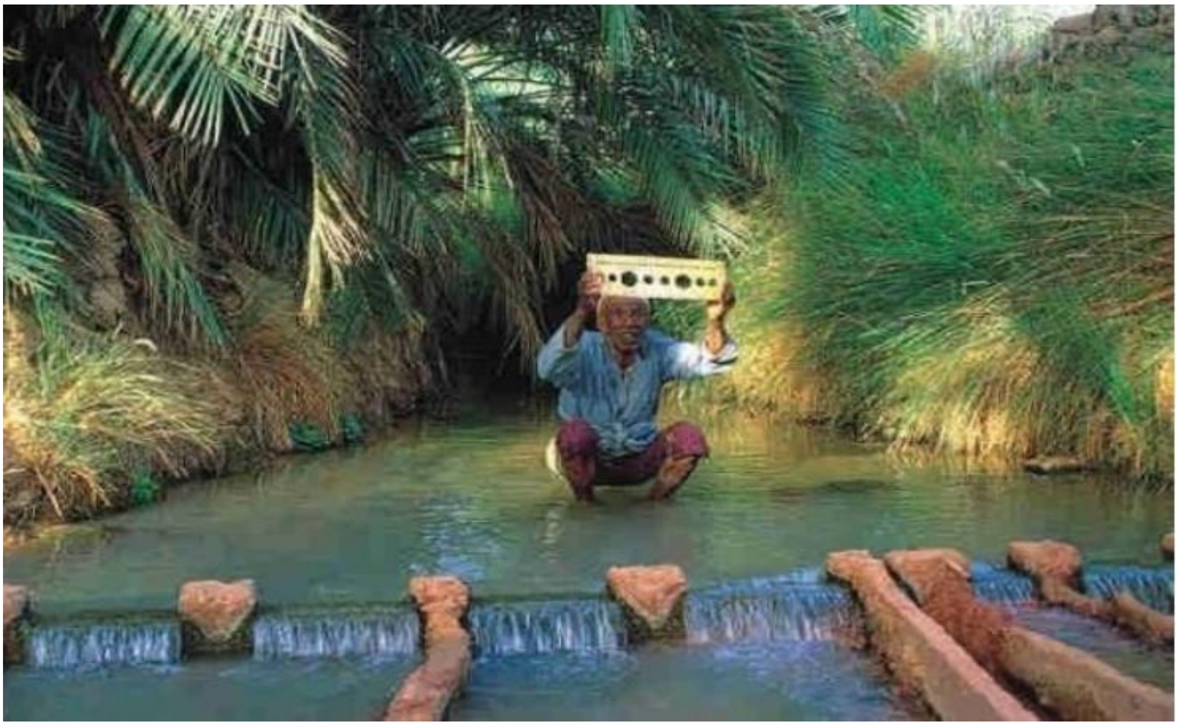


Fig25. Kiel El Ma with his Louh (Boutadara.Y, 2009)

Foggara flow evolution:

Foggaras of Timimoun, are the natural outlet of the Continental intercalary aquifer, according to the results of the last three gauging companions Foggara debits carried out during the years 1988, 2011 and 2016

Factors influencing the flow:

- Natural: drought and silting.
- Humans: lack of maintenance, the impact of drilling of borehols.
- Natural:
  - ❖ Drought:

The aquifer exploited by Foggara, located in the upper layers of the Continental Intercalary is influenced by natural agents: the scarcity of rainfall, especially in recent decades and the remarkable increase of temperature (intense evaporation). These two agents are among the factors contributing to the drop in the water table and therefore the flow of Foggara.

- Sand encroachment:

This is a second factor that seriously threatens Foggara. Timimoun is one of the most ventilated areas where the wind causes a significant formation of Ergs and sand dunes, they are gradually disappearing Foggara under the dunes. To achieve the gardens, they must traverse dune areas, which in some cases exceed 1000 m of width. Farmers protect pipelines by integrating them, but as soon as one of them collapses under the weight of the sand.

The Foggara became unusable. Moreover, the distance between the exit of the Foggara and gardens is increasing. The seguias lengthen constantly and the volume of water that reaches the end of Foggara in the cultivable land is minimal.
In the upstream, this factor is a major problem because the wind carries and throws large quantities of sand in wells, and sometimes made completely blocked.

- Humans:
  - Lack of maintenance:

without working the gardens therefore lack manpower. The appearance of multiple professions related to agronomy. Maintenance greatly affects the performance of Foggara.

- The influence of boreholes:

In general, the appearance of boreholes and excessive exploitation of groundwater has led, over time; lower the static level of the water, Therefore the flow of Foggara.

The infiltration of water by the neighbour boreholes, have a remarkable influence on the Foggara, because it cause a change in water level from the drilling zone of influence (distance of 800m to 100m). In addition mismanagement by unqualified officials, aimed only their personal interests, in recent years several people have built gardens and boreholes near the Foggara.

5 MATERIALS AND METHODS

5.1 Water collection

water was collected from many sation from Timimoun region, the Table 22 below show the location taken by GPS of the wells and the tow Fogarra:

Table 22: Water samples location.

	Longitude	Latitude
TINERKOUK	00°14'30"E	29°10'17"N
TINERKOUK	00°15'12"E	29°14'34"N
TINERKOUK	00°17'28"E	29°15'34"N
TINERKOUK	00°44'21"E	29°47'03"N
TIMIMOUN	00°15'20"E	29°13'45"N
TIMIMOUN	01°34'02"E	29°31'57"N
TIMIMOUN	01°33'39"E	29°31'14"N
TIMIMOUN	01°33'26"E	29°30'43"N
OULED AISSA	00°03'26"E	29°11'34"N
CHAROUINE	00°15'19"W	29°03'38"N
CHAROUINE	00°15'20"W	29°03'49"N
CHAROUINE	00°01'49"W	29°31'22"N
CHAROUINE	00°15'48"W	29°11'17"N
TINERKOUK	00°41'20"W	29°47'09"N
TINERKOUK	00°41'29"W	29°47'01"N
TINERKOUK	00°05'42"E	29°23'59"N
Foggara of M'ghair	00°13'09" E	29°15'34"N
Foggara of Ali welhaj	00°13'09" E	29°15'34"N

5.2 Water level measurement: (Fig26)

The water level was measured for the tow Foggara by the borehole dip Meter Fig 26 and with the help of the tow professor (Bourouba Ibrahim and Dasidy).

Fig 26: Water level measurement

The Table 23 below show the result of the water level measurement of Foggara of El Meghil of length of 9km:

Table 23: Water level measurement

well N	Longitude	Latitude	z	the depth of the well (m)	Water level
1	00°14'09"E	29°15'34"N	283	13	0
2	00°14'25"E	29°15'25"N	290	14,47	0
3	00°14'38"E	29°15'19"N	287	/	0
4	00°14'42"E	29°15'19"N	287	/	0
5	00°14'52"E	29°15'16"N	292	/	0
6	00°15'05"E	29°15'14"N	288	/	0
7	00°15'15"E	29°15'13"N	294	23,67	0
8	00°15'24"E	29°15'11"N	297	24	0
9	00°16'02"E	29°15'02"N	306	/	0
10	00°16'16"E	29°14'59"N	310	31	0
11	00°16'18"E	29°14'59"N	313	36,88	0
12	00°16'42"E	29°14'52"N	312	/	0
13	00°16'53"E	29°14'53"N	313	/	0
14	00°17'37"E	29°14'43"N	315	35,4	0
15	00°18'01"E	29°14'42"N	317	/	0

In this stage we couldn't rich the water level because of the structure of the well they put a slab above the water to eliminate the contamination between the water and the extern morover we did not measure the depth of all the well of the Fogarra moreover we did not take all the well because they were near to each other; so we measure water flow in the end of Foggara the exit of water. Fig 27

Fig 27: Water flow measurement

The second measurement was in the Foggara of Ali Elhaj the result are in the Table: 24

Table 24: Water level measurement

well N	**Longitude**	**Latitude**	**z**	**the depth of the well(m)**	**Water level**
1	00°14'10"E	29°16'21"N	275	9,75	0
2	00°14'15"E	29°16'18"N	271	10,447	0
3	00°14'28"E	29°16'07"N	278	/	0
4	00°14'27"E	29°16'05"N	277	/	0
5	00°14'29"E	29°16'02"N	278	/	0
6	00°14'35"E	29°15'59"N	282	/	0
7	00°14'39"E	29°15'56"N	281	/	0
8	00°14'53"E	29°15'53"N	285	16	0
9	00°14'54"E	29°15'53"N	289	17,85	0
10	00°14'56"E	29°15'53"N	290	/	0
11	00°15'03"E	29°15'03"N	295	/	0
12	00°15'07"E	29°15'50"N	291	20,34	0
13	00°15'42"E	29°15'34"N	296	/	0
14	00°15'49"E	29°15'31"N	297	/	0
15	00°15'38"E	29°15'31"N	299	/	0

6 RESULTS AND DISCUSSION

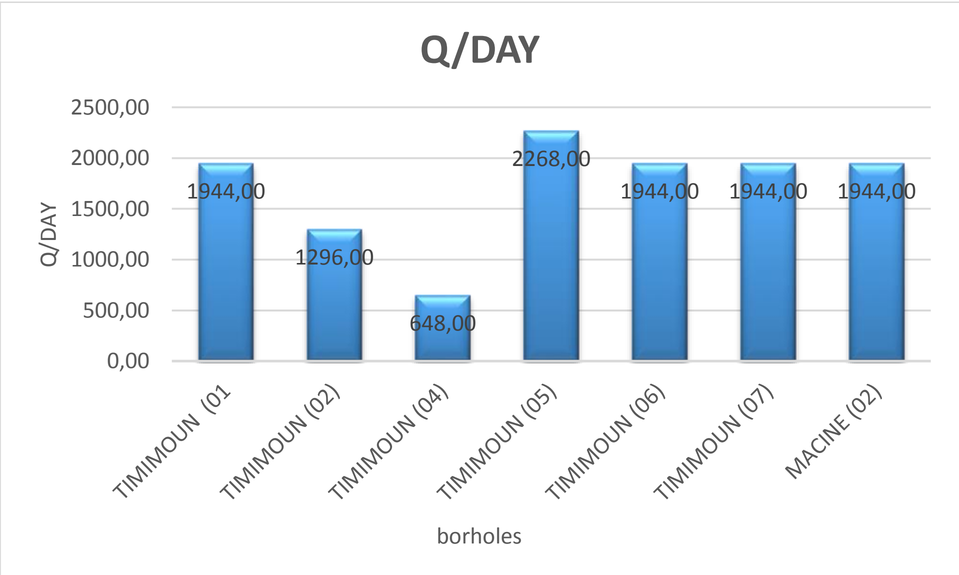
The analysis of the results was done using Microsoft office excel, Google Map; Auto CAD and Diagramme softwere these include:

- The interpretation of data.
- The location of Foggara and boreholes.
- The calculation of water flow.
- The hydrochromic study.

6.1 Results

6.1.1 Using Microsoft office excel to present the water flow of the nearest boreholes to Foggara moreover the water flow of Foggara.

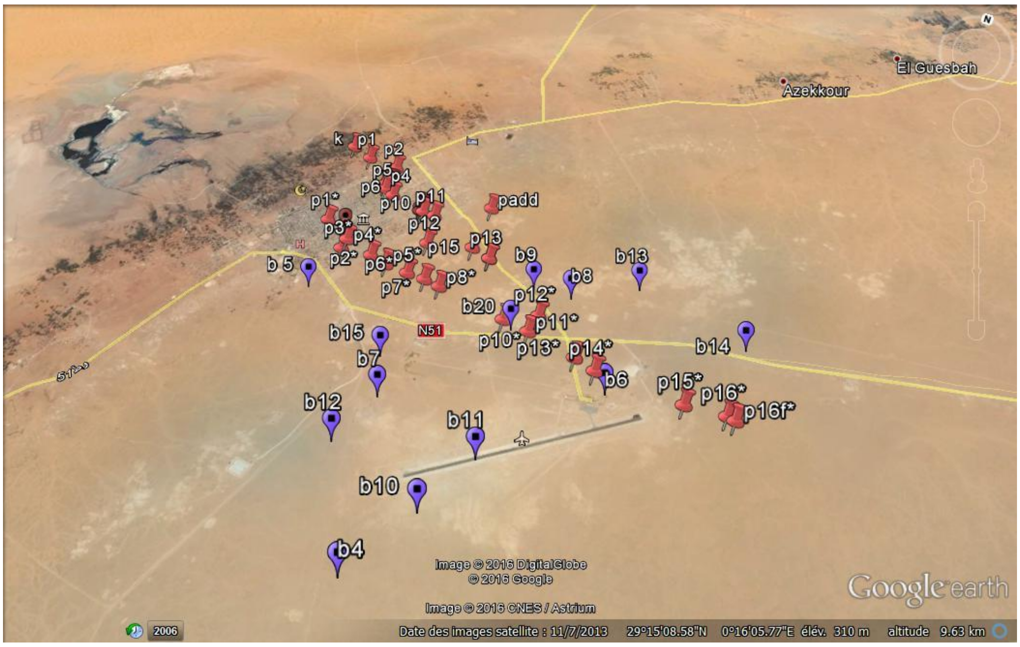
The Graphic columns bellow show the deferent water flow of boreholes:



From the Graphic columns, we can see the water fellow very high than water demand by the capital (150L/day/ca) from the Algerian norm. Moreover, it effect the flow water of Foggara.

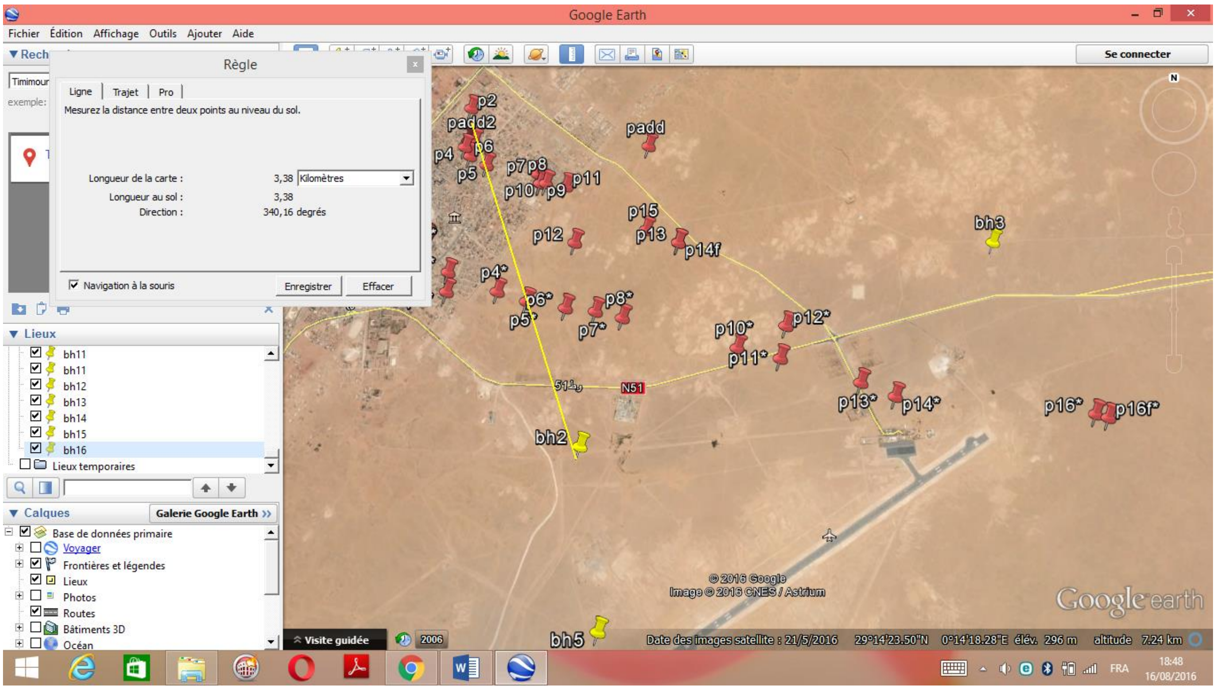
6.1.2 Using Google Map

The figure below show the presentation of data taken bay GPS the location of boreholes and the well of Foggara.

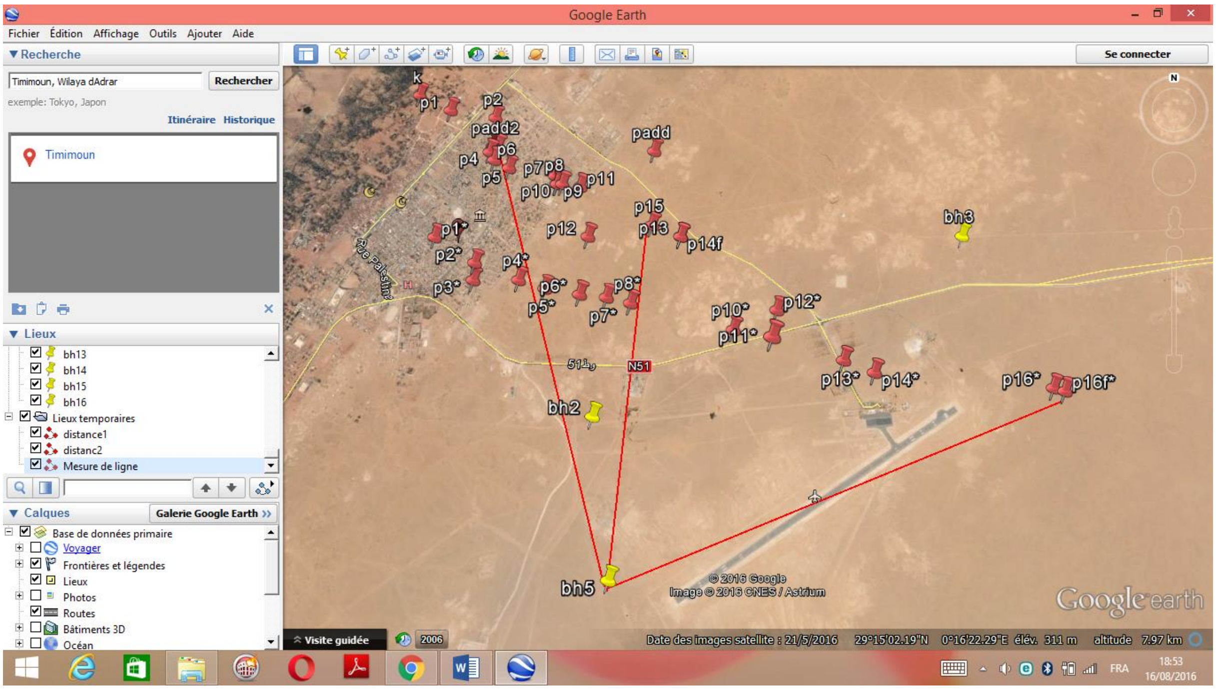


b is mention the boreholes and p the well of Foggara.

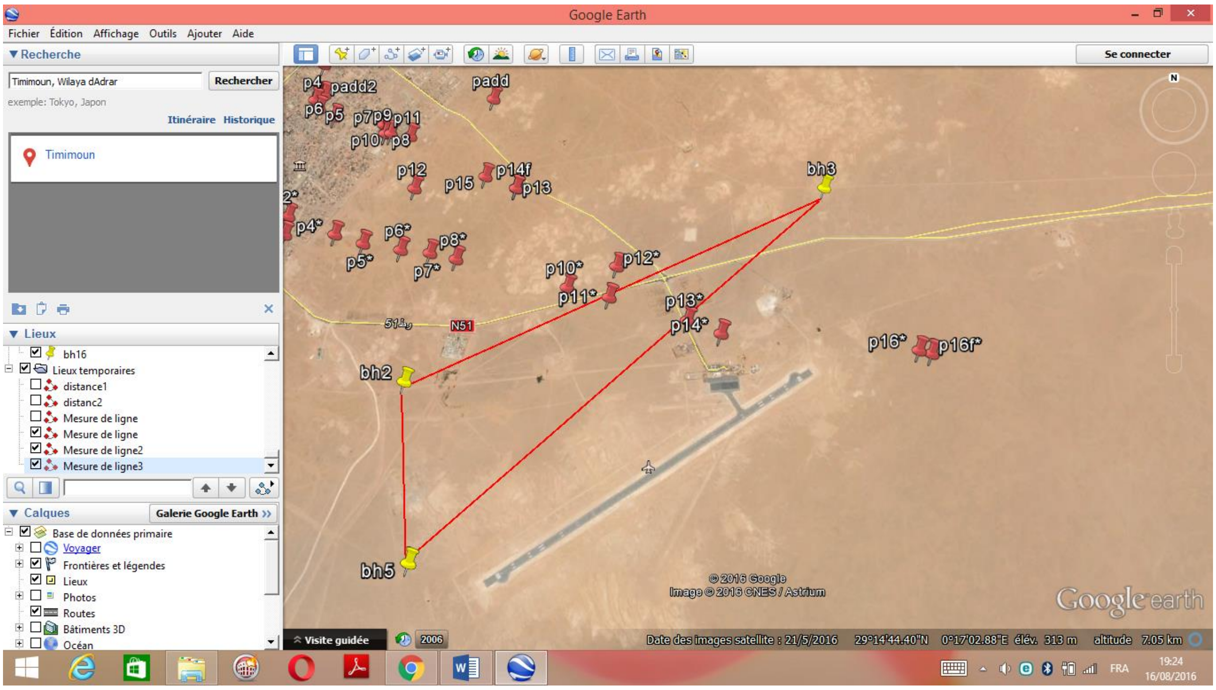
The images show the location of boreholes and the wells of Foggara, The distance to be respected between the boreholes and the well of Foggara is 5 km and that is not respectful, by the use of Google map the distance between the boreholes number 2 and the well p1 is around 3.38 km

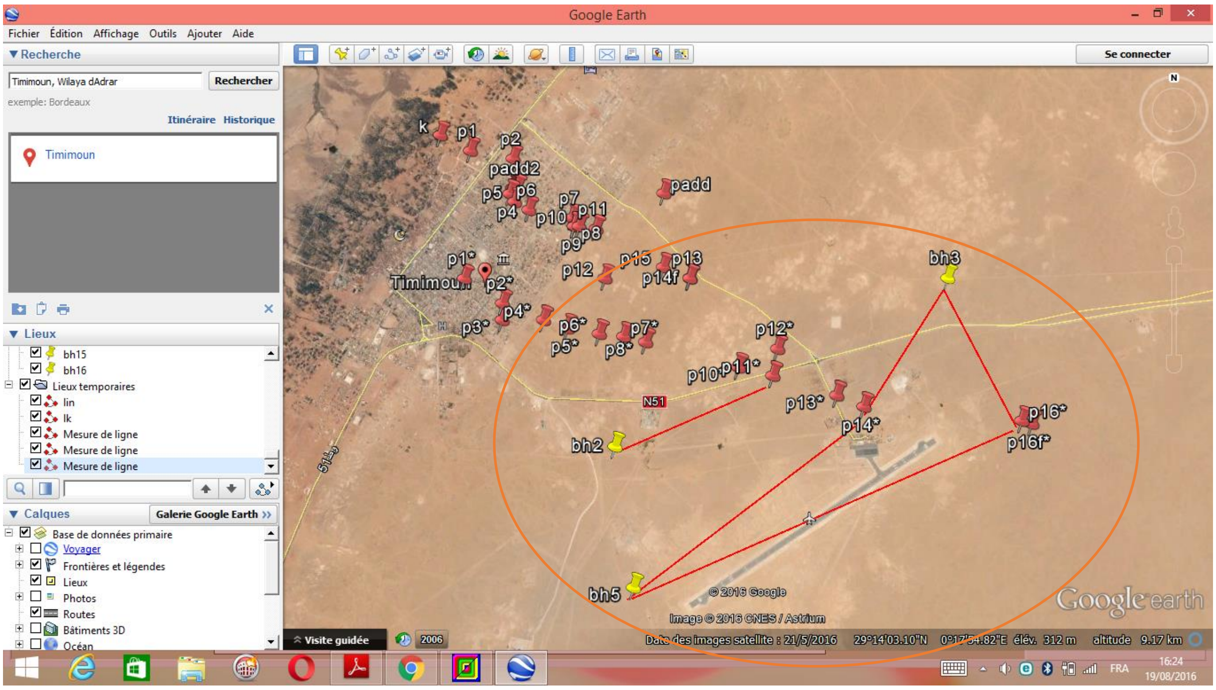


Moreover, between the borehole 5 and wells number p6, p15 and p16f are around 4.64km, 3.25km and 4.86km.



The Standard distance between the boreholes and others is around 10 km and this Standard is not respectful. The distance between the borehole bh2, bh5 is 3.45, between bh2 and bh5 is around 1.49kmand the between bh3 and bh5 is around 4.85 km.





The location of drilling in the outskirts of Foggara has caused interference between the two systems, the influence of the most powerful method of capture "drilling" on the traditional collection method the Foggara. The Foggara only captures first saturated meters of Continental Intercalary aquifer, any fluctuation in the groundwater level directly affects the productivity of the Foggara.

The consultation of Foggara and the position of boreholes in the map shows that all boreholes are located upstream Foggara, this positioning will affect the water flow of Foggara. That creat a water shortage at Foggara. The table bellow show that. Moreover, the problem of maintenance also affected the water flow of Foggara, because the traditional cleaning process is tedious and painful and requires skilled workforce and favorable to undertake this type of work. This lack of maintenance has reduced the number of functional Foggara more 1400 only 900 and that, with a constant flow reduction and drawdown of the water table of the aquifer.

6.1.3 Water shortage in Foggara since 1970 until 2001:

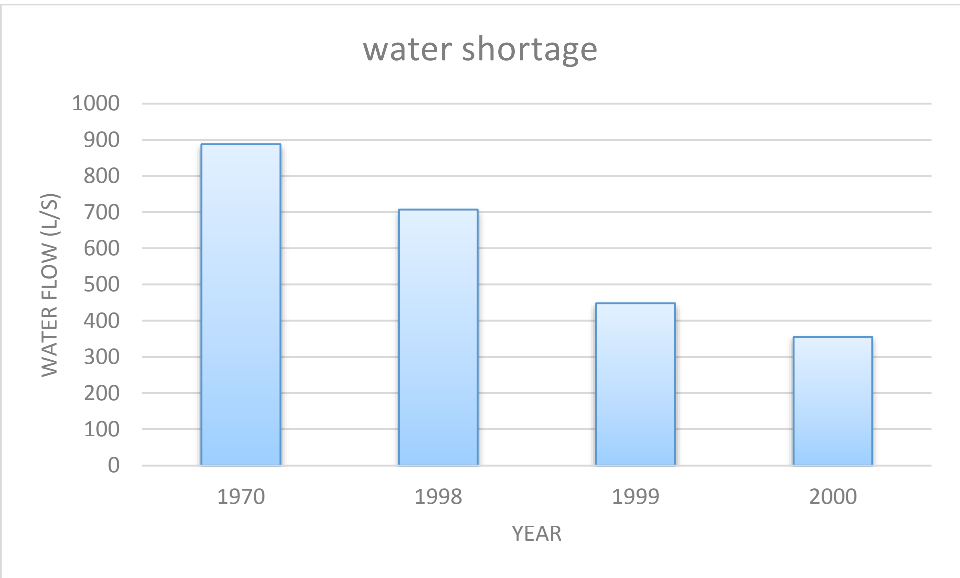
In the table below Table: 25 the water shortage in the Foggara of Timimoun.

Table 25: Water shortage in the Foggara.

Foggara flow in 1970(l(/s)	887
Foggaras flow in 1998(l/s)	707
Foggaras flow in 1999(l/s)	448
Foggaras flow in 2001(l/s)	355.45

Source (OSS, 2003)

The result show in the Graphic columns below:



From the Table25 and the graphic columns, the shortage of water in the Foggara of Timimoun is clear it was 887 l/s to be in 2000 to 355.45l/s

In our case study by the using Auto CAD we clculate the water flow of the tow Foggara (Ali Elhaj et El meghir)

The water flow calculation by the software Auto CAD for Foggara Ali Elhaj is around 0.0017m3/s =1.7L/s.

For the second Foggara we could not measure because the low flow of water.

6.2 Using Diagramme software

6.2.1 The Ionic Balance:

Is calculating the number of milliequivalents per liter for each element from the masses in mg / l;

The physico-chemical analysis of water must contain the elements necessary for the establishment of its ionic balance: is then verified that the sum of cations is equal to that of anions, for its major ions: calcium, magnesium, sodium and potassium to the cations; chlorides, sulfates, nitrates and bicarbonates for anions, It is assumed that difference can exist between the sum of anions and cations that, but it should not exceed 10% (amounts expressed in milli-equivalents per liter).

The formula of Ionic Balance calculation is:

$$IB = [(\Sigma r+ - \Sigma r-) / (\Sigma r+ + \Sigma r-)] \times 100$$

If:

IB< 2% good analysis.

2% < IB< 5% acceptable analysis.

IB > 5% Bad analysis.

By the use of Microsoft office excel and the chemical parameter of water samples, our calculation are:

The formula is:

$IB = [(\Sigma r+ - \Sigma r-) / (\Sigma r+ + \Sigma r-)] \times 100$

$IB = (14.56/691.35) \times 100$

IB=2.10%

From this calculation, our water analysis is acceptable.

Study of the characteristics reports:

-The Study of variation of these reports allows:

Control the chemical evolution of water during their underground path and their contact with the geological environment.

Provide information on the recharge area and water underground circulation.

6.2.2 Study of the characteristics reports:

The Study of variation in these reports can: The main reports are studied: $rCa2 + / rMg+2$;

$rSO4-2 / rCl-$; $r (Na 2 + K +) / rCl-$ to explain the origin of salinity.

The report $rCa2 + / + rMg2$:

The result of the report of calcium and magnesium is equal to one, and that mean to dissolution of formation of Dolomit.

The report $rSO4-2 / rCl-$

We observe that:

Over 78% of the values are greater than one demonstrating that chlorides dominate compared to sulfates. This is related to the dissolution of saliferous formation(evaporite Gypso –salines formation)

More than 22% are less than one indicating that dominate sulfates compared to chlorides. This is related to leaching of land gypsiferous.

The report $r (Na 2 + K +) / rCl-$

This report we found that sodium is predominant in relation to Cl for 61% and this due to the presence of the lands evaporite and Gypso-salt.

More than 39% representing the samples taken in the study areas predominance of chlorides and indicates the presence of licks, clay, and domestic and industrial waste.

6.2.3 The chemical profile of water:

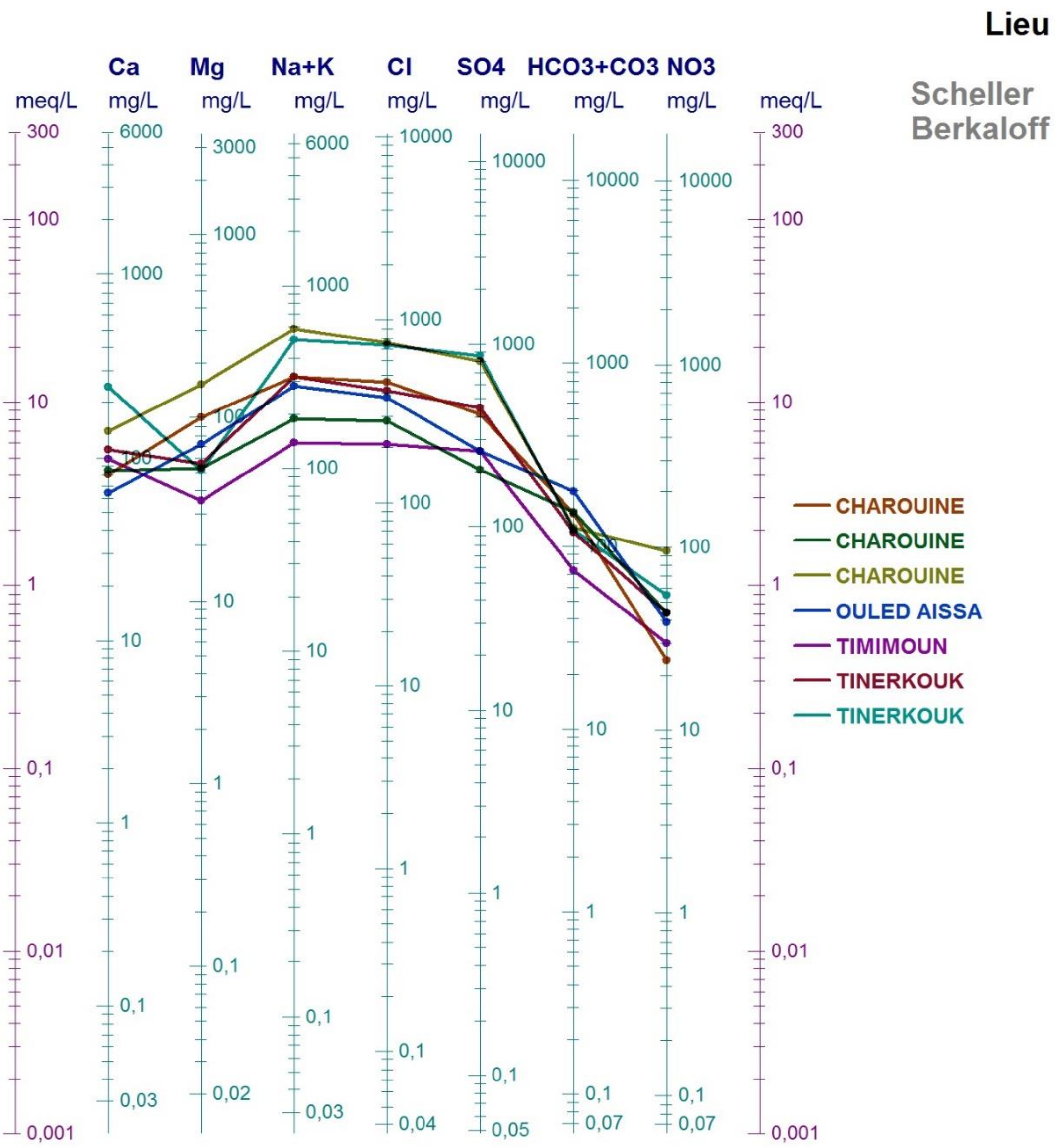
There are several natural water classification methods (SITTIF, SCHELLER, and PIPER), where they are based on the composition Chemical of water.

SCHELLER -BERKALOFF classification:

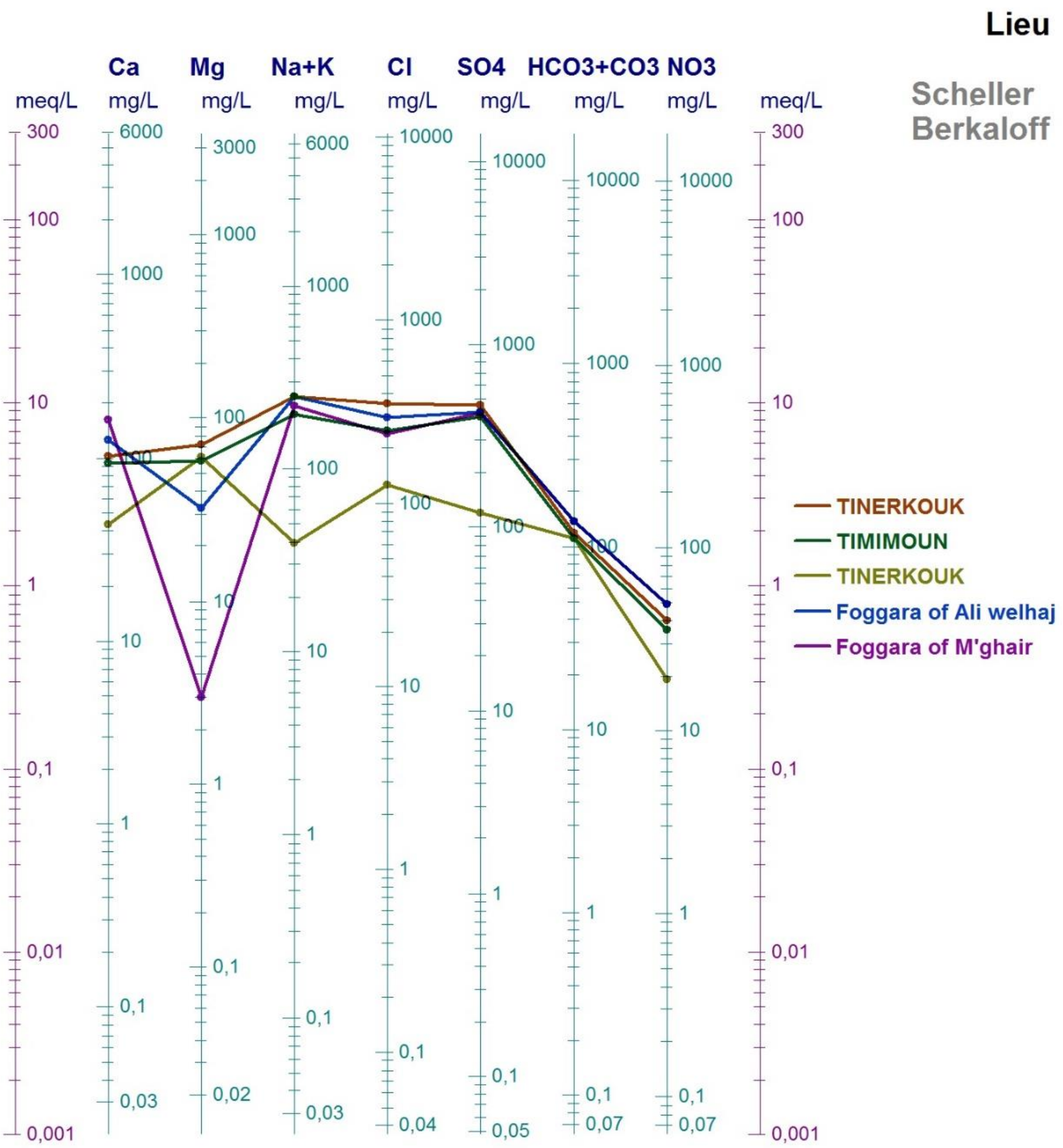
It is a semi-logarithmic graph SCHOELLER BERKALOFF is used to the graphical representation of chemical analyses of water, classification takes into account the importance of the major anions and cations and determines the type of water facies. This type of diagram used to represent several points on the same waters diagram.

According to this chart notes and with the use of Diagrammes software that the quality of the majority of water is passable. We also note that we have:

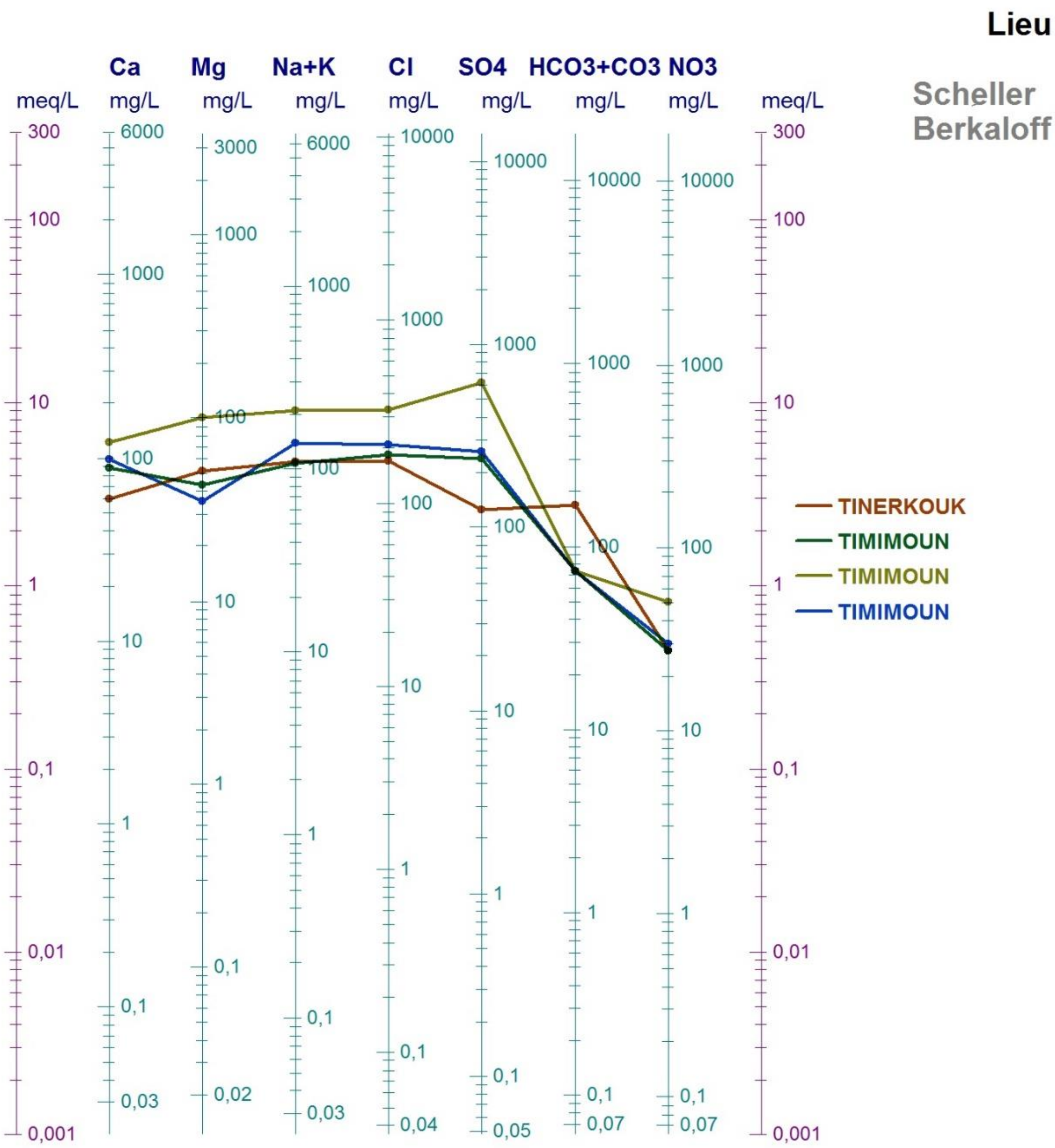
- Sodium chloride facies: it is from evaporite rocks, saline rocks They are often found in alternations of clays often gaudy or gypsiferous, or in the presence of dolomite and dolomitic limestone. It present 38% of water samples. The figure below show the grave of the facies:



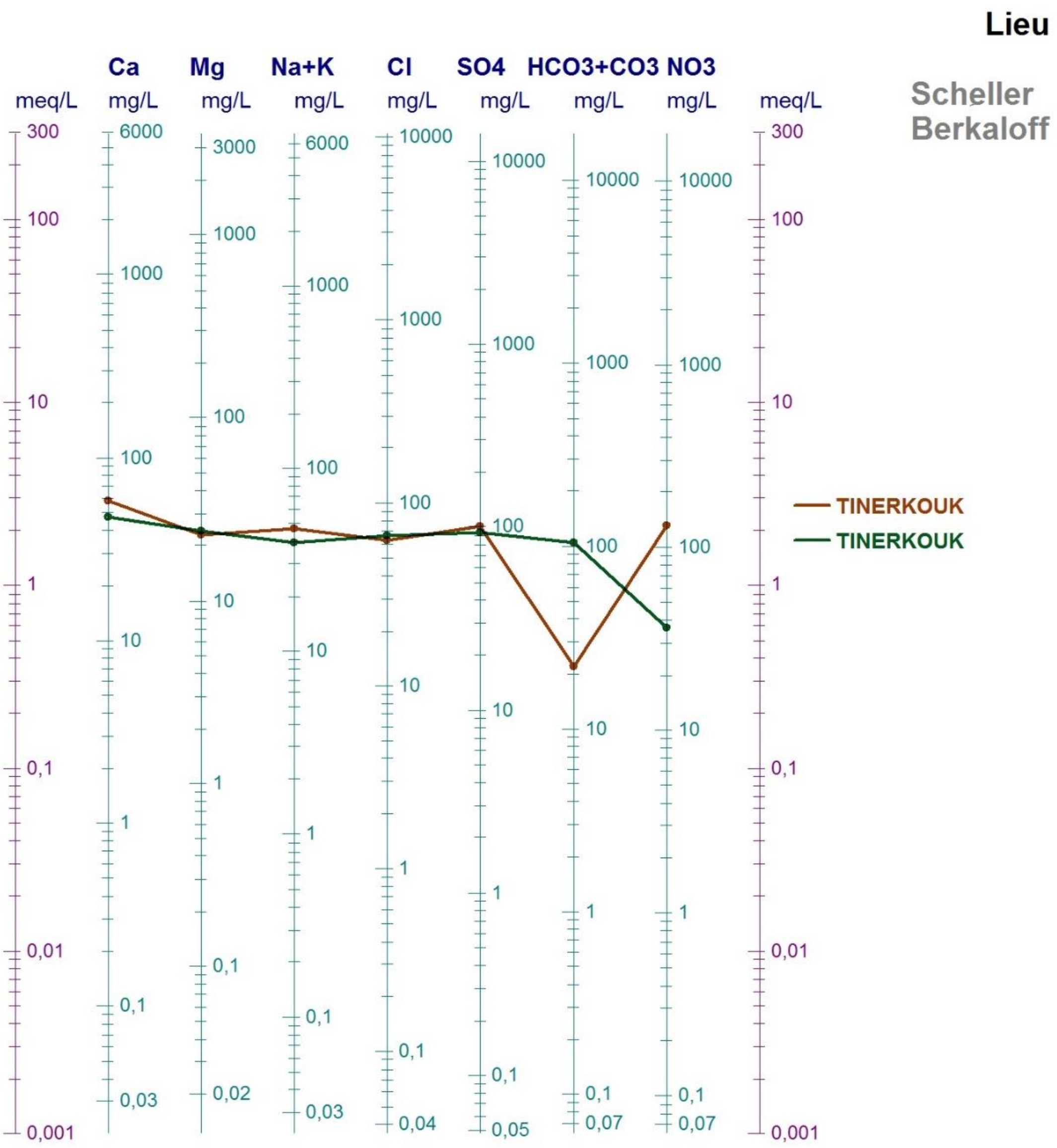
❖ Sodium Sulphate facies: it is from evaporates gypsum and anhydrite formation it present 27% of water sample of our case study.the figure below show the diagramme:



❖ Sulphate chloride facies: it present 23 % of water sample



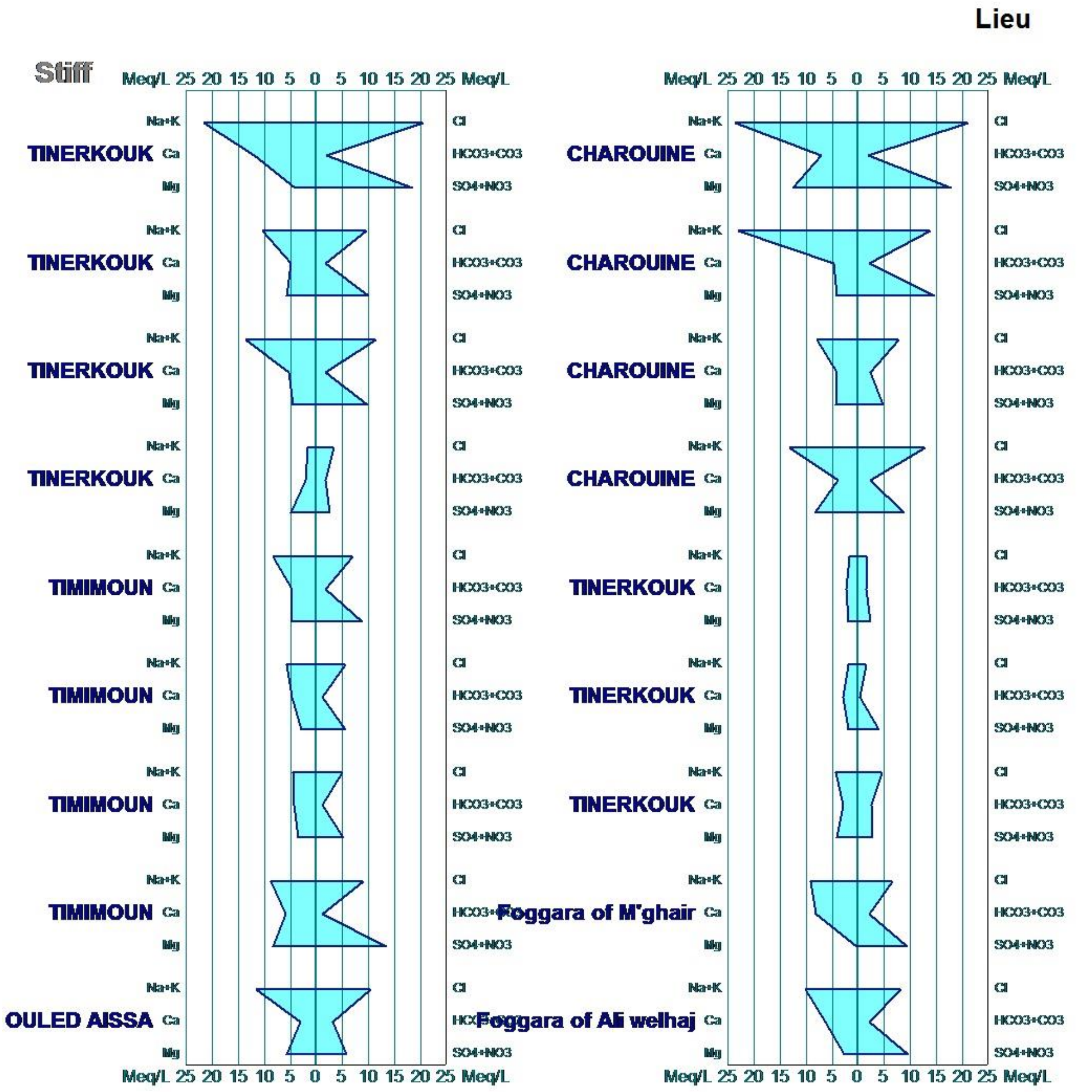
❖ Sulphate Calcium facies: it present 11% of water sample



6.3 STIFF classification:

This kind of diagram provides a polygonal geometrical figure characteristic of a given water family. The major ion analysis data plotted on the horizontal axes on either side of the original vertical axis. Cations are represented on the left and anions to the right side.

According to this chart notes that the quality of the majority of water is passable. We also note that we have: 61% from water sample are Sodium chloride facies, 11% Sulphate Calcium facies and 5% Magnesium chloride it also from evaporit formation.


Lieu
Stiff
Meq/L 25 20 15 10 5 0 5 10 15 20 25 Meq/L
Na+K
Ca
Mg
Cl
HCO3+CO3
SO4+NO3
TINERKOUK
TIMIMOUN
OULED AISSA
CHAROUINE
Foggara of M'ghair
Foggara of Ali welhaj

6.4 Classification PIPER:

The Piper diagram graphically displays the hydrochemical facies. It consists of two triangles representing the distribution of those anions and cations, respectively, in an appointed represent distribution of major ions, in this appointed, the top pole corresponds to 100% of sulfates and chlorides and 100% of calcium and magnesium, lower pole representing 100% of carbonate and bicarbonate, and 100% of sodium and potassium. Thus, in this diagram, a calcium bicarbonate water would be located in the left center of the appointed while a water sodic chlorinated would be located to the right pole. The superposition of several analyzes on the same chart compares their facies

hydrochemical.

According to this chart notes that the quality of the majority of water is passable. We also note that we have:

- ❖ The majority of waters of the Continental Intercalary aquifer of our study area are grouped into two main facies according to the Piper diagram: sodium chloride and sodium Contains sulphate.

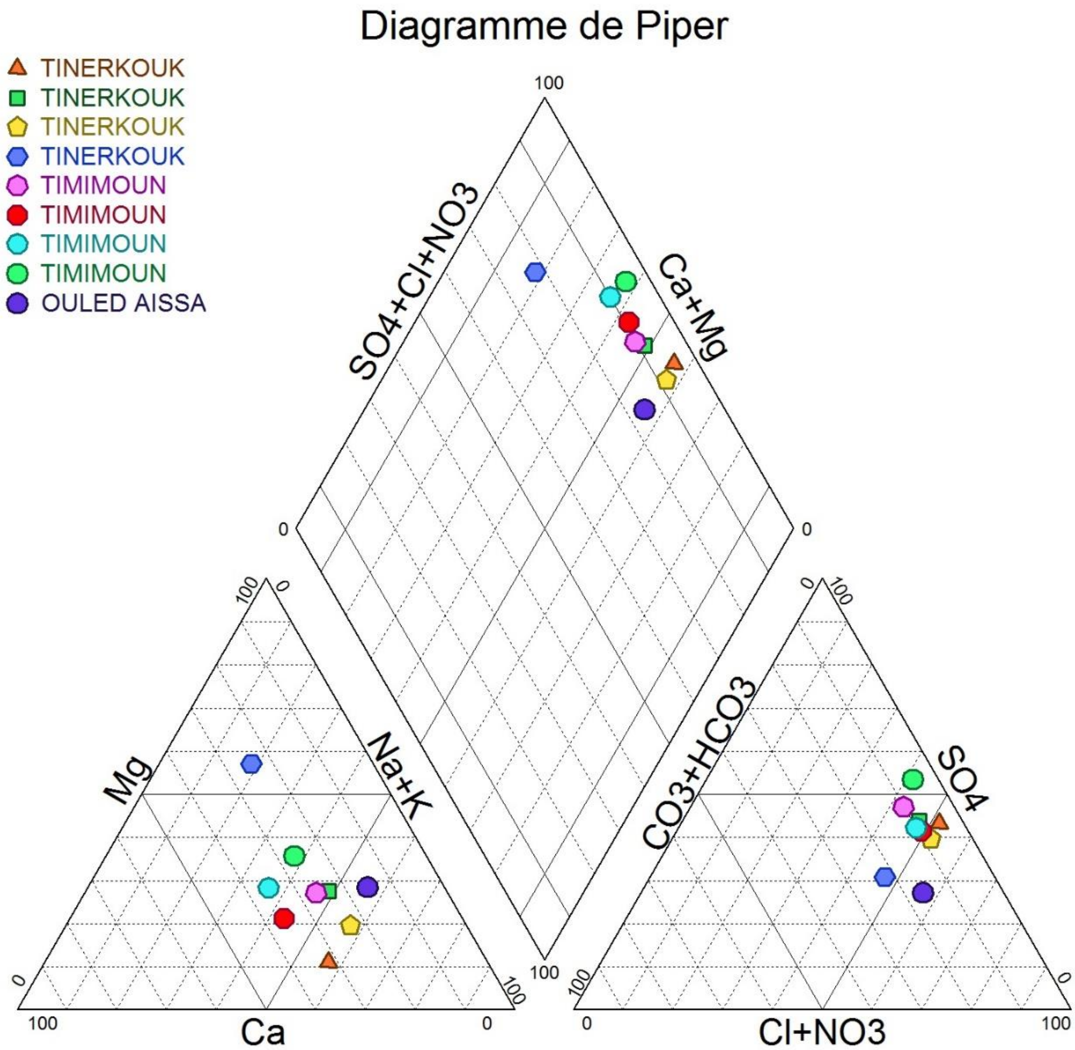


Diagramme de Piper
TINERKOUK
TINERKOUK
TINERKOUK
TINERKOUK
TIMIMOUN
TIMIMOUN
TIMIMOUN
TIMIMOUN
OULED AISSA
SO4+Cl+NO3
Ca+Mg
Mg
Na+K
Ca
CO3+HCO3
SO4
Cl+NO3
100
0

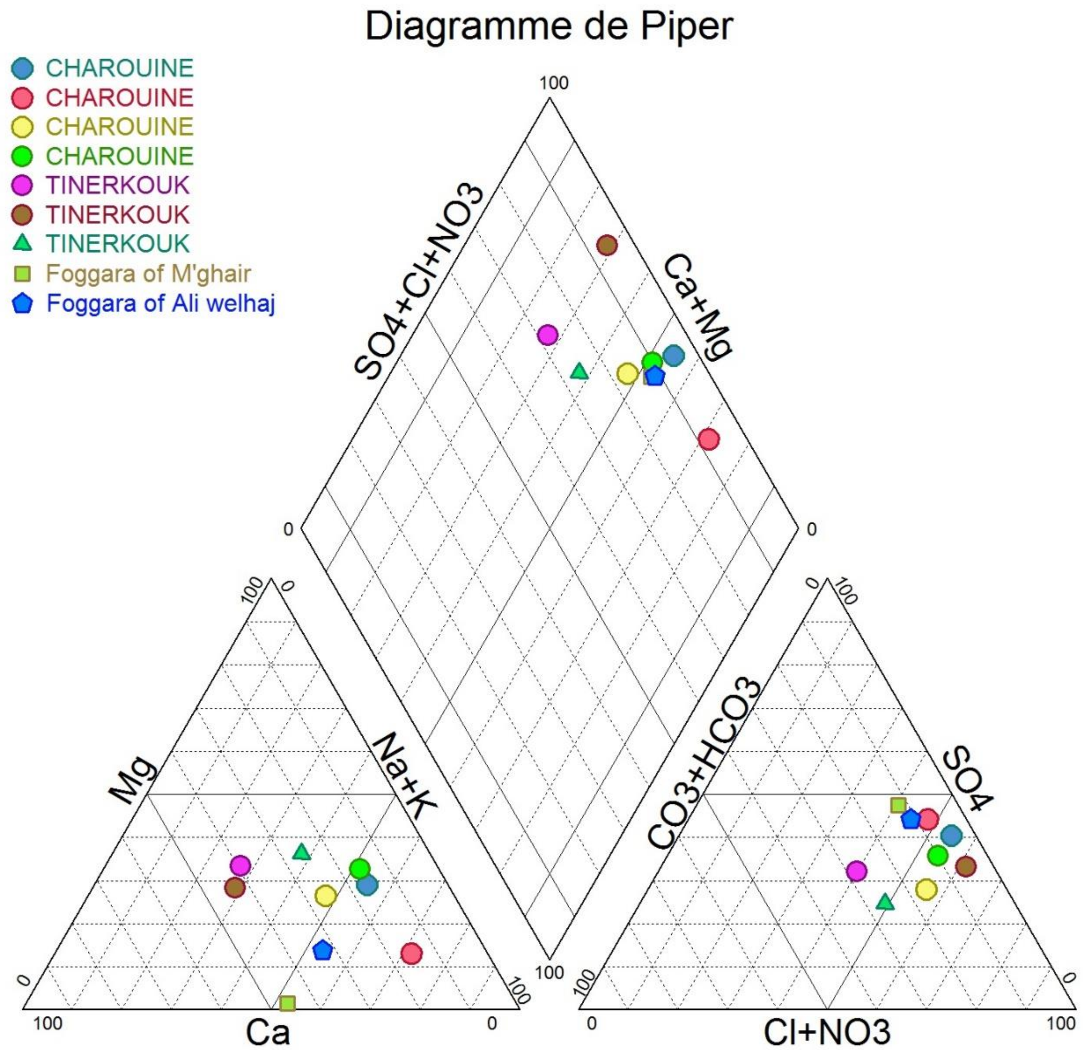


Diagramme de Piper
CHAROUINE
CHAROUINE
CHAROUINE
CHAROUINE
TINERKOUK
TINERKOUK
TINERKOUK
Foggara of M'ghair
Foggara of Ali welhaj
SO4+Cl+NO3
Ca+Mg
Mg
Na+K
Ca
CO3+HCO3
SO4
Cl+NO3
100
0

6.4.1 Quality of water for irrigation.

The quality of water used for irrigation is a critical parameter for the crop yields, maintain soil productivity and protecting the environment.

The ability of water to be used for irrigation can be evaluated by a number of more or less reliable coefficients including:

The percentage sodium (Na%).

Sodium adsorption ratio (S.A.R).

The quality of the irrigation water can be best determined by chemical analysis laboratory.

6.4.2 Reverside diagram:

Sodium is an element of alkaline bases and alkaline earth plays a role significant in maintaining soil permeability for irrigation. To determine this risk, Reverside created a classification that considers the report sodium absorbed by total mineralization (SAR).

$$S.A.R = \frac{\mathrm{rNa}}{\sqrt{\frac{\mathrm{rCa} + \mathrm{rMg}}{2}}}$$

The S.A.R is an index that measures the danger the existence of a content given sodium in water. It is calculated by the following formula:

The concentration of each ion is expressed in meq / l. to the rate of absorption of sodium (S.A.R), we have the following classification:

- SAR <10: low water hazard alkalizing soil (excellent water).
- 10 <SAR <18: water with a risk of significant enough alkalizing (good water).
- 18 <SAR <26: water with a significant risk of alkalizing (suitable water).
- SAR> 26: water with a risk of very strong alkalizing (poor water).

The nature and proportion of chemical elements dissolved in water have an influence on the type of practice culture.

Sodium is a base member of the alkali and alkaline earth playing a role in maintaining the permeability of the soil. The percentage sodium is an important factor in the implementation of the quality of irrigation water, it is given by the formula.

Na% = (Na+K)*100/Ca+Mg+ (Na+K)

The table below (Table : 26) allows you to see after calculating S.A.R that the waters of our region are excellent for irrigation and can be used with low risk of alkalizing soles.

Table 26: S.A.R calculation

	S.A.R	Na%
TINERKOUK	5,15	63,34
TINERKOUK	3,00	58,87
TINERKOUK	5,15	63,34
TINERKOUK	3,00	58,87
TIMIMOUN	5,15	63,34
TIMIMOUN	3,00	58,87
TIMIMOUN	5,15	63,34
TIMIMOUN	3,00	58,87
OULED AISSA	5,15	63,34
CHAROUINE	3,00	58,87
CHAROUINE	5,15	63,34
CHAROUINE	3,00	58,87
CHAROUINE	5,15	63,34
TINERKOUK	3,00	58,87
TINERKOUK	5,15	63,34
TINERKOUK	3,00	58,87
Foggara of M'ghair	5,15	63,34
Foggara of Ali welhaj	5,15	58,87

6.4.3 Permeability index:

Recent studies (Younsi 2001 Debieche, 2002) demonstrated that soil permeability depends on several other factors such as the total concentration of water, the amount of sodium, the bicarbonate concentration and the nature of the soil itself even. The first three terms have been combined in a single formula giving what is called the permeability (IP) defined by (Doneen, 1961).

6.4.4 Magnesium Hazard:

In general, calcium and magnesium are at steady state in water, the high magnesium content in water affects the quality, when it becomes alkaline in nature.

6.4.5 Kelly's Ratio:

The suitability of water for irrigation, it is also appreciated in the base of Kelly's Ratio, the sodium rate towards calcium and magnesium levels are used as the rate Kelly's (Kelly's Ratio).

6.4.6 Chlorides:

When present in irrigation water, these elements contribute to increase the concentration of soluble salts. Excessive concentrations of chlorides and sulfates can cause burns on the tips of leaves and grass and even lead to death of plants.

6.4.7 Nitrates:

The groundwater were free of nitrates, whereas water polluted by an important supply of organic matter, fertilizer or wastewater discharges may have several hundred mg / l nitrates beyond the maximum permissible concentration. The addition of nitrates in the soil and in water is strongly related to the amount of organic substances and environmental conditions. Human actions are important: use of nitrogen fertilizers and manure. In addition, discharges of sewage or simply latrines and septic tanks represent a contribution in organic materials that may produce nitrates.

The indices of quality of irrigation water are classes in the Table 27 below:

Table: 27: The parameters of the quality of irrigation water.

Indices	Formula	Classes and Water Quality
Magnesium Hazard (MH)	$MH = \frac{(Mg \times 100)}{(Ca+Mg)}$	• MH> 50: water not suitable • MH <50: suitable water
Permeability Index	$PI = \frac{(Na+\sqrt{HCO3})}{(Ca+Mg+Na)} \times \mathbf{100}$	if : • PI upper 75% water is of excellent quality • PI between 25% and 75% water is good. • PI is less than 25% water is of poor quality.
Kelly Ratio (KR)	$KR = \frac{Na}{(Ca+Mg)}$	• KR > 1 inappropriate. • KR < 1 is suitable
Chlorides	/	• Cl <4 meq / L no water toxicity (non-toxic to plants). • 4 <Cl <10 mEq / L moderately toxic. • Cl> 10 mEq / L severe toxicity
Nitrates	/	• NO3 <5 mg / l no water toxicity. • l5 <NO3 <30 mg / l moderate toxicities. • NO3> 30 mg / l severe toxicity

The Table 28 show the result of water samples of our case study after the use of Microsoft office excel.

Table 28: Water quality of irrigation of samples of the case study

water sample	IP %	MH (meq/L)	KR (meq/L)	Cl (meq/L)	NO3- (mg/L)
TINERKOUK	63,44	17,35	1,63	20,56	55
TINERKOUK	121,51	41,38	1,32	9,86	40
TINERKOUK	66,72	33,73	1,81	11,55	44
TINERKOUK	223,37	58,65	0,34	3,52	19
TIMIMOUN	57,20	38,56	1,18	7,04	36
TIMIMOUN	71,69	26,32	0,98	5,92	30
TIMIMOUN	46,79	32,58	0,76	5,21	27,5
TIMIMOUN	25,91	45,09	0,87	9,13	51
OULED AISSA	68,41	52,94	1,84	10,70	39
CHAROUINE	32,98	52,05	1,71	21,13	95
CHAROUINE	78,90	34,23	3,36	13,94	68
CHAROUINE	165,28	38,41	1,25	7,89	44
CHAROUINE	63,25	55,49	1,54	12,82	24
TINERKOUK	273,77	33,80	0,49	1,86	36,2
TINERKOUK	36,93	28,40	0,49	1,75	131
TINERKOUK	26,48	45,95	0,80	4,79	27,5
Foggara of M'ghair	58,16	1,83	1,22	6,76	49
Foggara of Ali welhaj	56,01	20,25	1,39	8,25	49

Interpretation of result from the table 28:

- The results of the permeability index varies between 62 and 223 and show that the water is excellent for irrigation.
- The Magnesium Hazard values reported that the majority of water points are suitable for irrigation but the water points OULAD AISSA and CHAROUIN.
- The values of Nitrites are between 27.5 and 68mg / L and are above 30 mg / L indicating that the water has severe toxicity.
- The Chlorides values vary between 7.89 meq / L 20.56 meq / L. According to the classification we have two classes of water quality: moderate toxicity and severe of toxicity.
- Classification by Kelly Ratio (KR) indicates that most of the water points unsuitable.

7 General conclusion:

Our study area is part of Northern Sahara. It is a region characterized by a Saharan terrain that was formed during the early Pleistocene to the present, following intensive erosion phenomena.

The drainage system throughout the Northern Sahara reflects the endorheic runoff surface during wet periods Quaternary.

The climatological analysis, based on available data, helped lead to following results:
This region is characterized by a hyper-Saharan climate regime, or drought is permanent and aridity is clearly expressed. This type of climate is characterized by two seasons:
- A relatively short cold season.
- A hot season where the temperature is clearly above 20 ° C (spread over a period from about 7 to 8 months).
- The humidity is very low, it indicates a sign of severe drought.
- The temperatures are very high, it exceeds 45 ° C in summer with annual average of about 25-26 ° C.

Rainfall is almost zero and irregular in time and space, they do not exceed 25 mm / year.
- The frequency of winds is considerable, it is of the order of 3 to 4 m / s throughout the year with a boost in March, April and May.

From geological point of view the lower Cretaceous land outcrop extensively in the region, they are essentially gréso clay, they rest unconformably on the grounds of Paleozoic. These lands are covered with clay and gypsum land from the Cenomanian transgression, which are themselves overlain by a limestone slab Turonian and Senonian age.

The hydrogeological approach allows to show that the continental Intercalary also called Albian aquifer is the only resource in underground waters in the area, it is contained in the gréso-clay formations of the Lower Cretaceous. It has a large regional extent, it forms with the Terminal Complex called the Northern Sahara Aquifer System (SASS). This aquifer is captive in the central and eastern part of the basin, and free on the western part of the basin which forms the natural outlet of the aquifer.

According to the map developed by OSS on the 14C content, the waters of our study area have an age range from 1000 to 10 000 years. We have seen that these reserves are from the wet periods Quaternary, they are subject to a dynamic and they finally have a low current charging to check if we have not removed the age).

Water level map of the continental Intercalary shows two main flow directions: generally from north to south (Saharan Atlas to Gourara and Tuat) and East to West (Plateau Tademaït to Tuat).

The hydrochemical study of the waters of the web of the region shows that Gourara all the water has a high electrical conductivity values vary between 660 and 4430 µs/cm.

The study area is situated in the Algerian South-west is characterized by a climate hyper arid high evapotranspiration, rainfall is scarce low quantitative importance and variable from one year to another. The prevailing winds are from the Northeast North, silting threatens Foggara and palm groves.

The water chemistry of the waters of the table is an infill Continental essential complement to the hydrogeological study, it can bring extensive information on the environment in which groundwater around, the nature of the formations crossed.

The importance of the mineralization of the waters of the IC sheet is largely explained by the geological nature of the terrain of the Lower Cretaceous (gréso clay, carbonate, and sandy clay gypsoévaporitiques), it is between 409 and 3292mg / l.

Other factors may be less important statements, including human activity (domestic waste, landfills, industrial discharges, practices agricultural) and climatic zonation which is the degree of aridity.
These factors cause the concentrations and of varying dilutions great waters. It is accentuated by the phenomena of evaporation, and is more sensitive to the effect of temperature, due to its shallow depth).

Two chemical facies characterize the waters of the region: a dominant facies is the facies chlorinated sodic, and the other smaller the sodium sulphate.

The study of the main features reports confirmed that the leaching and dissolution Gypso-evaporite formations, limestone and Gypso sabloargileuse are responsible for the mineralization of water of the Continental Intercalary IC.

After the calculating S.A.R that waters of the our region are excellent for irrigation and can be used with little risk of alkalizing soles.

Several factors contributed to the acquisition of the mineralization of the aquifer of Continental Intercalary:

- Mainly by the lithological contamination of geological terrains in the region and primarily land Lower Cretaceous (sandstones, clays).
- By leaching and dissolution of the overlying land at the regional scale (limestone Cenomanian calcairo marl land Turonian, lagoon formations of Senonian lower carbonate terrains upper Senonian, carbonate and evaporite land Eocene and the grounds of the Mio-Pliocene-Quaternary).

The use of chemical fertilizers in agriculture as fertilizer, increases concentrations NO3 elements.
The irrigation with salt water and causes soil salinization and increases mineralization in the water back to the table

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