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INSTITUTE FOR WATER AND ENERGY SCIENCES  
(including CLIMATE CHANGE)**

# **Master Dissertation**

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**WATER POLICY TRACK**

Presented by

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**Use of GIS and WQI to assess groundwater quality in Naâma, Algeria**

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## DECLARATION

This thesis is a presentation of my original work.

Wherever contributions of others are involved, every effort is made to indicate this clearly, with due reference of literature, then the acknowledgement of collaborative research and discussion.

The work has done under the guidance of Professor Chabane Sari Sidi Mohammed and Dr Abdessamad Derdour, at the Pan African University of Water and Energy Science (PAUWES)

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## **DEDICATION**

*This dissertation is dedicated to my parents, sisters, brothers, grandmother as well as my family who have stood by me and always believed in me. You are the best.*

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## ABBREVIATIONS AND ACRONYMES

ADE	Algérienne des Eaux
DPSB	Direction de la Programmation et de Suivi Budgétaire
CCMEWQI	.....Canadian Council of Ministers of the Environment Water Quality Index
EC	.....Electrical Conductivity
ESRI	.....Environmental Services Research Institute
GPS	.....Global Position System
GIS	.....Geographical Information System
IDW	..... Inverse Distance Weight
NSFWQI	.....National Sanitation Foundation Water Quality Index
OWQI	.....Oregon Water Quality Index
TDS	.....Total Dissolved Solids
WHO	.....World Health Organization
WQI	.....Water Quality Index
WAWQI	..... Weight Arithmetic Water Quality Index

## LIST OF SI UNITS

mg/L .....	Milligrams per liter
Cfu/mL .....	Colony Forming Unit per milliliter
NTU .....	Nephelometric Turbidity Unit
$\mu$ S/cm.....	Micro Siemens per centimeter

## ***Abstract***

*Groundwater is an important water resource in the world. The region of Naāma is the chief town of the Naāma wilaya which is situated in southeast of Tlemcen, Algeria. It is highly dependent on groundwater resources. In this area the groundwater is the only available source that is used for domestic household, agriculture and industrial purposes. Assessment of groundwater quality is highly important in order to safely and sustainably exploit the water resource. The aim of this study was to assess the groundwater quality by using GIS and Water Quality Index in Naāma, Algeria. Ten groundwater samples were collected from boreholes in this year 2018. This was carried out by sampling water using Duran bottles and transporting the water samples into the laboratory for analysis. The physico-chemical parameters (such as pH, Electrical Conductivity (EC), Total Dissolved Solids (TDS), Bicarbonate, Ammonium, Sulfate, Nitrate, Calcium, Magnesium, Sodium, and Potassium) were selected for the spatial analysis with the help of the Geographical Information System (GIS). Inverse Distance Weighted interpolation technique was also used for creating maps for Water quality index and physico-chemical parameters that were analyzed. The result of the analysis was compared with the guidelines of WHO and Algeria Potable Water Standard in order to set up the status of groundwater quality in this area. To compile the Water Quality Index (WQI), 11 parameters were chosen. The result of WQI showed that 40% of the collected groundwater samples were of excellent quality and 60% were found to be in good quality. The spatial distribution maps produced for several physico-chemical parameters using ArcGIS (10.3) software could be helpful for designing a water program. WQI and GIS can be adopted by water engineers, utilities and decision makers in order to assess and monitor regularly the groundwater quality in a given area.*

**Key Words:** Geographical Information System, Groundwater Resources, Physico-Chemical Parameter; Water Quality Index,

## **Résumé**

*Les eaux souterraines sont une ressource en eau importante dans le monde. La région de Naâma est le chef-lieu de la wilaya de Naâma, située au sud-est de Tlemcen, en Algérie. Elle dépend fortement des ressources en eau souterraine. Dans cette zone, l'eau souterraine est la seule source utilisée à des fins ménagères, agricoles et industrielles. Cependant l'évaluation de la qualité de l'eau souterraine est très importante afin de sécuriser et maintenir l'exploitation de l'eau dans cette région. Le but de cette étude était d'évaluer la qualité des eaux souterraines en utilisant le Système d'Information Géographique (SIG) et l'Indice de Qualité de l'Eau (IQE) à Naâma. Pour ce faire, un ensemble de dix échantillons d'eaux ont été prélevés au niveau des différents forages (2018). Ces échantillons ont été conservés dans des bouteilles en plastique et transportées au laboratoire pour les analyses. Les paramètres physico-chimiques tels que (pH, conductivité électrique (CE), solides dissous totaux (TDS), bicarbonate, ammonium, sulfate, nitrate, calcium, magnésium, sodium et potassium ont été utilisés pour l'analyse spatiale avec l'aide du système d'information géographique (SIG), de plus une carte de l'indice de qualité de l'eau a été également réalisée. Les résultats de chaque paramètre ont été comparés avec les directives de l'OMS et celles de l'Algérie afin d'établir le statut de la qualité des eaux souterraines de ladite localité. Les résultats de l'IQE ont montré que 40% de l'échantillon d'eau souterraine sont d'une qualité excellente et 60% de bonne qualité. Les cartes de distribution spatiale produites pour plusieurs paramètres physico-chimiques à l'aide du logiciel ArcGIS (10.3) pourront être utiles pour la conception d'un programme d'eau. Les ingénieurs ainsi que les décideurs du domaine de l'eau peuvent ainsi utiliser l'IQE et les SIG afin d'évaluer et contrôler régulièrement la qualité des eaux souterraines dans la région de Naâma.*

**Mots Clés :** Eaux Souterraines, Indices de la Qualité d'Eau, Paramètres Physico Chimiques, Système d'Information Géographique,

## ملخص

تعتبر المياه الجوفية مورداً مائياً مهماً في المنطقة القاحلة وشبه القاحلة خاصة في منطقة نعامة بالجزائر ، لأنه في هذه المنطقة معظم السكان يستخدمون المياه الجوفية للأغراض المنزلية والزراعية والصناعية ، إن تقييم جودة المياه الجوفية مهم للغاية من أجل تأمين واستدامة المياه لأغراض الإستغلال ، كان الهدف من هذه الدراسة هو تقييم جودة المياه الجوفية باستخدام مؤشر نظام المعلومات الجغرافية وجودة المياه في نعامة بالجزائر و تم جمع عشرات عينات من الآبار في تلك المنطقة لهذا العام 2018 ، وقد تم ذلك عن طريق أخذ عينات المياه باستخدام قارورة وأخذهم إلى المختبر للتحليل ، و تم استخدام النتائج مثل (المركبات) الفيزيائية الكيميائية [pH] ، الموصلية الكهربائية (EC) ، المواد الصلبة الذائبة الكلية (TDS) ، البيكربونات ، الأمونيوم ، الكبريت ، النترات ، الكالسيوم ، المغنيسيوم ، الصوديوم والبيوتاسيوم] في التحليل الفضائي بمساعدة نظام المعلومات الجغرافي و تم استخدام تقنية الإستقراء الترجيحي بالمقياس العكسي لإنشاء خرائط لمقياس جودة المياه وكل عينة من نوعية المياه التي تم تحليلها قورنت مع المبادئ التوجيهية لمنظمة الصحة العالمية والجزائرية من أجل معرفة وإعداد حالة جودة المياه الجوفية في هذه المنطقة ، لتجميع مؤشر جودة المياه (المركبات الإحدى عشر) (WQI) التي تم إختيارها ، وقد أظهرت نتائج قيمة WQI أن 40 ٪ من عينات المياه الجوفية تشير إلى جودة ممتازة و 60 ٪ وجدت أنها بجودة جيدة ، يمكن أن تكون خرائط التوزيع المكاني المنتجة للعديد من (المركبات) الفيزيائية الكيميائية باستخدام برنامج ArcGIS وهذه مفيدة في تصميم برنامج المياه وذلك للمهندسين وصانعي القرار من أجل تقييم ومراقبة جودة المياه الجوفية بانتظام في هذا المجال .

**الكلمات المفتاحية :** نظم المعلومات الجغرافية ، فهرس جودة المياه ، المركبات الفيزيائية ، المركبات الكيميائية ، المياه الجوفية.

# CHAPTER ONE: INTRODUCTION

---

## 1. Introduction

### 1.1. Background of the study

Groundwater is an important water resource in the world. The region of Naâma is the chief town of the Naâma wilayas which situated in southeast of Tlemcen, Algeria. It is highly dependent on groundwater resources for its welfare. In this area the groundwater is the only available source that is used for domestic household, agriculture and industrial purposes. Groundwater is the main source of drinking water for a majority of the population in Algeria, especially in rural areas (Zafane.D et al., 2016). The amount of water extracted from groundwater is about 70% of water used for drinking and irrigation services in Algeria (Bouderbala, 2017). Dependence on groundwater has increased due to changing lifestyle, urbanization and population growth. These factors impact negatively on the quantity and quality of groundwater resources (Kumar SharmaI.P et al., 2016). There are some factors that influence the characteristics of groundwater such as quality of water recharge, atmospheric precipitation and water flows on the subsurface (Hema Latha. T.et al., 2012)

However, in the arid and semi-arid region, the quality of groundwater is grossly affected by agricultural activities due to the use of chemical fertilizers (Salwa Saidi, Salem Bouri, Hamed Ben Dhia, & Brice Anselme, 2009). The degradation of groundwater quality is generally caused by natural processes and human activities (Magesh N. S. et al., 2012). Treatment of polluted groundwater is a big challenge. Before water is used in different sectors like domestic, agriculture and industry, it is mandatory to evaluate its quality.

Water Quality Index (WQI) is an important parameter which can be used for the vulnerability assessment of groundwater since it hints on the status of groundwater in an area. According to (Olayiwola Oni., 2016), WQI is a powerful tool for assessing the suitability of groundwater and surface water.

The determination of water availability, flood prevention, and water resource management are elements that can be analyzed and modeled by Geographic Information System. It is also a very effective software for the realization of maps at the local or regional level (K.Ambiga, 2016).

The researchers (Ishaku J.M et al., 2012; Hema Latha.T et al., 2012; K.Ambiga., 2016) have computed WQI and mapped their results using GIS with different objectives depending on their field of study in order to evaluate and assess the suitability of groundwater quality.

The combination of GIS and WQI provides a means of assessment of groundwater quality (Mouna Ketata.R et al., 2011). The aim of this thesis was to use GIS and WQI to assess groundwater quality in Naâma, Algeria.

## **1.2. Problem statement**

Clean water is important for human health. It has been established in Agenda 2030 as the right of every human being, but still millions of people do not have access to clean water especially in developing countries, most of which are in Africa.

Rapid urbanization and increase of human population have a negative impact on the environment such as groundwater, water supply and sanitation. The major cause of environmental problem at this time is the pollution of groundwater. Human health is adversely affected due to the contamination of surface and groundwater. However, groundwater in the area is polluted due to the reject of wastewater treatment and agricultural pollution which is coming from irrigation activities and runoff containing pollutants. Besides anthropogenic pollution, there is also natural pollution which is characterized by the presence of two saline mountains after rainy period which is percolated into the groundwater.

Further lack of good governance for groundwater and insufficient strategic management influence the groundwater resources in this region. The problem of groundwater quality has emanated from ignorance of local communities through lack of management and strategic planning for groundwater.

In wilaya of Naâma and its surrounding areas, groundwater resources have been investigated in terms of potential, hydrodynamic, hydrogeology, flows modeling, water quality assessment and vulnerability by different researchers. For example [Characterization, classification, bacteriological, and evaluation of groundwater from 24 wells in six departments of Algeria (Mostaganem, Mecheria, Naâma, Tiaret, Bechar, and Adrar)] study by (Fouad Bahri, 2012), and [Use of geographical information system in the hydrodynamic and hydro-chemical characterization of the aquifer of Ain Sefra has been conducted by (Rahmani.A., 2010)]. However, the scopes of these studies have been limited. Hence, Fouad studied only the chemical and bacteriological parameters without using GIS. Rahamani is focused only on the aquifer of Ain Sefra which does not encompass the area of Naâma.

In order to safely sustain the quality of groundwater in the area of Naâma, it is obvious that the quality of ground water needs to be assessed and evaluated, since groundwater in the Naâma is used for water supply and irrigation.



### **1.3. Objective of Study**

#### **1.3.1. General objective**

Assessing the groundwater quality for drinking water using Geographical Information System and Water Quality Index

#### **1.3.2. Specific Objective**

The following specific objectives were addressed by this study:

- To analyze the physico-chemical parameters
- To calculate Water Quality Index
- To create a spatial distribution of physico-chemical parameters and WQI by using GIS

#### **1.4. Significance of the study**

Generally, a great part of Africa relies on groundwater for domestic and irrigation purposes. In Naãma, it is the only source for water supply and irrigation. The result of the realization of vulnerability maps is in a very clear simple format which can be understood by the public sector. The spatial distribution of physicochemical parameters in the groundwater of this region is showed with different legends. This helps for easy understanding by the policymakers in taking decisions easily. In general, the maps are practical tools which can help as a road map towards the sustainable use and management of the groundwater quality in the area.

#### **1.5. Scope and Limitation of the Study**

In order to describe the overall water quality condition, there is difficulty due to the spatial distribution of several pollutants and the wide range of indicators that require to be determined. So this study presented several parameters such as pH, Electrical Conductivity, Total Dissolved Solids, Calcium, Magnesium, Sodium, Potassium, Chloride, Nitrate, Bicarbonate) map distribution.

Some of the challenges encountered were:

- Lack of water quality data for Naãma boreholes
- Time limit and climate condition such that the result may not fully capture seasonal changes in groundwater quality in the Naãma

# CHAPTER TWO: LITERATURE REVIEW

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## 2. LITERATURE REVIEW

### 2.1. Ground Water Resources

Groundwater is the largest fresh water resource on earth and its quality is influenced by natural and anthropogenic sources (Gopal Krishan, 2016). Only two to three percent of total water on earth is fresh water, and groundwater constitutes a significant portion of the fresh water resources (K.Ambiga, R. Anna Durai, 2013). The major part of the population in the world uses groundwater for drinking and agriculture (K.Ambiga., 2016) . The demand for water has been increasing considerably due to increasing population and the proliferation of industries (K. Sundara Kumar, 2010).

### 2.2. Ground Water Quality

Assessment of groundwater quality is helpful for improvement of the characteristic of water. Groundwater contamination is usually caused by the infiltration of pollutants into the subsoil (Kumar, 1., et al.2015). Many authors have shown that there are some factors which may influence the contamination of groundwater such as anthropogenic activities, atmospheric precipitation, water discharge, geochemistry of the soil as well as meteorological condition. (Atiemo M. Sampson, 2012; Sadat-Noori S. M et al.). Hence when the groundwater is polluted, it can cause huge economic gaps in an area.

In order to establish a good plan for water resources management, it is important to carry out an assessment of groundwater quality. This will have an impact on socio-economic development and also help in the creation of a database (Ishaku J.M et al., 2012).

### 2.3. Groundwater quality in Algeria

In some areas of Algeria, the groundwater quality was very hard, the value of conductivity and salinity have been influenced due to the lithology and mineralogy of aquifer (Chabour et al., 2018). In arid and semi-arid areas, the groundwater was impacted due to evaporation, high rainfall and over pumping.

Therefore, in areas which are close to the sea like Algiers and Annaba, it was observed that there is salt pollution in the groundwater due to the sea water intrusion. In Southwest of Algeria, the groundwater quality is influenced by the wastewater discharge (A. Hadidi, 2018).

## **2.4. Water Quality Index**

Water Quality Index is a computation of each water quality parameter which has an influence on the overall quality of water (K.Ambiga, R. Anna Durai, 2013). It is a great tool which produces effective assessment of water quality. It compiles several parameters into a unique value. Therefore, WQI gives a clear indication of water quality in order to understand and make decisions (Kumar Sharma I.P et al., 2016). The researchers (K. Sundara Kumar et al., 2015) carried out a case study on assessment of ground water quality using water quality index which showed the suitability of the method in groundwater classification. It gives the assessment of water quality and classifies them into categories such as excellent, good and bad for ease of understanding (Akoteyon, 2013).

In addition, WQI method is widely used for groundwater quality assessment around the world due to the capability of fully expressing the information of water quality and it is the only effective tool used to evaluate and manage water quality parameters (Sadat-Noori S. M et al., 2013).

## **2.5. Geographic Information System (GIS)**

Geographic Information System (GIS) is a tool for the management of spatial and geographical data. It is capable of analyzing a large volume of data. It is a great environment for data processing (Machiwal.D et al., 2010) . In general it is used for water resources management such as water availability, flood and drought at the local or regional level (K.Ambiga, 2016).

GIS is also used to assess the vulnerability and suitability of groundwater based on water quality parameters (Kumar Sharma I.P et al., 2016). Many researchers have used GIS in order to assess the suitability and vulnerability of groundwater quality such as (Kiplangat Cheron Nelly, 2016; Rabia Shabbir, 2015; S. Packialakshmi, 2015). Therefore GIS provides more information about the assessment of groundwater quality and it helps policy makers to make decisions (Mouna Ketata.R et al., 2011).

## **2.6. Spatial Analysis**

Spatial analysis is an extension of GIS that enables the interpolation of groundwater quality parameters of unknown locations from known values, to create a continuous surface which then help to understand the distribution of physical and chemical parameters of the study area (Rabia Shabbir, 2015).

The concept of identifying water quality problems and relating them to land use in order to interpret the cause of environmental degradation from the spatial distribution has been implemented

by (Bairu.A et al., 2013). (Gopal Krishan, 2016) used spatial distribution method to assess water quality parameters and mapped out areas where the groundwater quality was not fit for human consumption.

## **2.7. GIS Interpolation**

GIS has two methods for interpolation which are geostatistical and deterministic. The Inverse Distance Method (IDW) and Spline are deterministic. Kriging is a geostatistical method (Hema Latha. T.et al., 2012). (Kiplangat Cheron Nelly, 2016) which has been used for interpolation of groundwater quality parameters.

## **2.8. Inverse Distance Weighted method(IDW)**

Inverse distance weighted method is an interpolation technique used to characterize the distribution of a water sample in an area. Mostly this technique has been applied in the assessment of groundwater quality. According to (Magesh N. S. et al., 2012), IDW is an algorithm used to interpolate spatial data or to estimate the values within a location.

The assessment of groundwater quality in Adamawa, Nigeria by (Ishaku J.M et al., 2012) which utilised the IDW technique in order to delineate potential areas with their respective water quality and (Bairu.A et al., 2013) who used IDW for the creation of water quality index map.

## **2.9. Source of Groundwater Pollution in Algeria**

Aquifer pollution has occurred in some areas, for example saline intrusion along the coast relating to over-abstraction, and nitrate pollution from agriculture, despite legislation to limit nitrate contamination pollution from agricultural activities.

## **2.10. Groundwater Vulnerability Mapping**

The degradation and vulnerability of groundwater quality is generally caused by natural processes and human activities (Magesh N. S. et al., 2012). There are several researchers who applied many methods in order to determine the vulnerability of groundwater. Among these methods, some worth mentioning are: Overlay and index methods (Example, DRASTIC) Process-based simulation models (Example, Numerical model) Statistical methods (Example, Kriging, Logistic Regression).

## **2.11. Statistical Methods of Modeling for ground water mapping**

There are some parameters which are estimated by using the theory of probability in the case of statistical models. The method of prediction generally follows the estimate of the prediction error. The input of Statistical methods such as drawback is a key element for the statistical assumptions.

The statistical models constitute four groups which are (Hengl, 2007).

- Kriging (plain geostatistics).
- Environmental correlation (e.g. regression-based).
- Bayesian-based models (e.g. Bayesian Maximum Entropy).
- Mixed models (regression-kriging).

### **2.12. Basic Kriging (ordinary, Universal)**

Kriging method is part of statistical models which include the statistical relationship among the measured points. It is the best unbiased predictor and if the data is normally distributed, kriging is the best predictor among all unbiased predictors (gisgeography, 2018).

### **2.13. The principles of Geo statistical analysis**

The geo-statistical analysis gathers the data from different point of an area and establish a continuous surface. It has two groups of interpolation techniques which are deterministic and geostatistical. Deterministic techniques use mathematical functions for interpolation. There are statistical and mathematical methods which are part of Geostatistics. It can serve to create surfaces and assess the uncertainty of the predictions (ESRI, 2003).

### **2.14. Description of Water Quality Parameters**

#### **2.14.1. pH**

pH determines the activity of hydrogen and hydroxyl ion in solution. It gives a clear understanding on the behavior of water such as acid or alkaline with the scale from 0 to 14. The range of pH is between 7.0 – 8.5 in normal drinking water. pH measurements below 7 indicate that the water is acidic containing high concentration of proton ( $H^+$ ) than concentration of ( $OH^-$ ). Measurement above 7 indicates that the water is alkaline (basic) thus containing high concentration of ( $OH^-$ ) than proton ( $H^+$ ). It is one of the most important water quality parameters. The parameter plays an important role in the suitability of water for different purposes (Kiplangat Cheron Nelly, 2016). Groundwater sample with low pH is given to reject of acid water which the origin of discharge come from agricultural and household activities.

#### **2.14.2. Turbidity**

Turbidity is a physical parameter which allows to determine the transparency of a liquid. It has an expression of the quantity of light produced from the material into the water which the light is flashed through the water sample (U.S. Geological Survey, 2016).

Turbidity can affect negatively the efficiency of disinfection. It is measured in order to know the processes and nature of treatment required.

#### **2.14.3. Total Hardness**

The principal cause of hardness in water is generally due to the presence of some chemical elements such as carbonates, bicarbonate of calcium, magnesium, sulphates, chloride and nitrates (Hema Latha.T et al., 2012). The tolerance limit for total hardness in drinking water is 300 mg/l of calcium carbonate (Kiplangat Cherono Nelly, 2016).

#### **2.14.4. Total Alkalinity**

Alkalinity can be defined as the buffering of a water body. It is a measure of the capacity of the water body to balance acids and bases (U.S. Geological Survey, 2016).

#### **2.14.5. Nitrate**

Nitrate is derived from aerobic stabilization into organic nitrogen and nitrogenous substances. Nitrate is dangerous and toxic for humans when it is transformed into nitrite. The high rate of nitrates in water causes an infant disease called blue baby syndrome (Kiplangat Cherono Nelly, 2016)

#### **2.14.6. Chloride**

The origin of Chloride in drinking water is from natural sources, wastewater and Industry. It does not have a threshold value in the health guideline. However, excess of chloride concentrations above 250 mg/litre can add taste to water (U.S. Geological Survey, 2016).

#### **2.14.7. Fluoride**

Fluoride is a chemical element derived from fluorine. It is used in drinking water to prevent some diseases such as tooth decay. High quantity of fluoride in water is unsafe as it can weaken bones, and nervous problems ( Natural Medicines Comprehensive Database, 2009).

#### **2.14.8. Sulfate**

The sulfate has three different origins which are: external (rain fall and anthropogenic), internal (gypsum dissolution, oxidation of mineral rock sulfured), and biological (degradation of

organic matter). The presence of sulfate in drinking water can effect a bad taste, and with high amount can cause a laxative effect for human consumers (Sadat-Noori S. M et al., 2013).

#### **2.14.9. Chromium**

The nature of chromium is a metallic element generally found in the environment and inside of human being. It is used in metal industries, paints, wood and corrosion. The guidelines of World Health Organization (WHO) give the value of total chromium in drinking water to be about 0.05 mg/l. However, chromium has effect on human health which can cause cancer. (American Water Works Association, 2013).

#### **2.14.10. Phosphate**

Phosphate is a chemical component which has three forms in the environment such as orthophosphate, metaphosphate, and phosphate which is organically bound. The orthophosphate forms are derived by natural cycle, however there are some external sources of orthophosphate which come from wastewater and agricultural practice.

Phosphate has a negative impact in the environment which can produce a rapid growth of algae population that may cause the death of vegetation and aquatic life. (Brian Oram, 2014)

#### **2.14.11. Iron**

Iron is an important chemical element in the body composition and is essential for human health. The presence of iron in water is from the weathering of rocks and industrial effluents discharge (Gopal Krishan, 2016).

#### **2.14.12. Sodium, Potassium, Calcium**

They have an origin form natural and anthropogenic. It may be internal when water flows inside an aquifer. These elements can result from different formations which are:

- Evaporation and evapotranspiration from aquifer less deep
- Biological process is kind of producing the potassium  $K^+$  which enable to tree to absorb it
- They have exchange with clay (Na, K, Ca, Mg) and organic matter

#### **2.14.13. Magnesium**

The nature of magnesium comes from aquifer. The kinetic dissolution is very slow if it takes calcite rock but it has rapid dissolution with evaporate rock. The acquisition of magnesium rock is correlated with calcium (Ca) and Sulfate ( $SO_4^{2-}$ ). It is the main cause of water hardness. Magnesium



is washed from rocks and subsequently ends up in groundwater. However, magnesium contributes to water hardness, according to WHO (2004) the permissible limit of magnesium in drinking water is to be between 100 and 150 mg/L.

#### **2.14.14.Manganese**

Manganese is a key important element for human beings and other living organisms. It can effect negatively on the health due to improper consumption or its spread into the environment (Rabeiy, 2017)

#### **2.14.15.Electric Conductivity**

Electrical conductivity is described as the capacity of electrical current to pass through water (Kiplangat Cheron Nelly, 2016). It is a measure of water capacity to convey electric current. Electrical conductivity depends on temperature, the concentration of the ions presents in the solution and high concentration of hardness. Therefore, wastewater and agricultural activities may contribute to increase in value of conductivity because of the presence of some pollutants in water like nitrates and phosphates. Sewage and farm runoff can raise conductivity due to the presence of nitrates and phosphates. According to the guideline of **WHO (2004)** the maximum limit of EC in drinking water in 1500  $\mu\text{S}/\text{cm}$ .

#### **2.14.16.TDS**

The concentration of TDS in water depends on different geological layers in a region due to its particular aspect in the solubility of minerals. Total Dissolved Solids (TDS) have a major part of inorganic salts such as (chlorides, bicarbonates, sulfates, calcium and magnesium...) and little quantity of organic matter which are soluble in water. The total dissolved solids concentration is the sum of the cations and anions in the water. The presence of a high amount of TDS in groundwater may be explained by the discharge of some pollutant such as sewage, industrial waste and urban runoff.

#### **2.14.17.Bicarbonate**

The cause of Alkalinity is due to the presence of carbonates in the water resource, its concentration is expressed in mg/l and the limit for drinking water is 100 mg/l. A high concentration in water is harmful for irrigation and may cause soil damage and decrease in crop yield. Water having bicarbonate less than 100 mg/l is desirable for household consumption (Hema Latha. T.et al., 2012).

## 2.15. Guidelines for water quality parameters

Potable water is used in the household for different purposes such as drinking, cooking and personal hygiene. It is encouraged to make efforts in order to produce drinking water that is as clean as practicable (WHO, 2011). The guidelines of drinking water may vary among countries and regions. There is not one method that is universally applicable. It is important in the development and implementation of standards that the legislation relating to water, and local authority is taken into account and that the capacity of regulators in the country is assessed. If one method is applicable in one country, it will not necessarily apply to another country. It is essential that each country reviews its needs and capacities in developing a regulatory framework (WHO, 2011). Based on the water quality standards stipulated by the WHO, ranks were assigned for each parameter depending on the respective tested values, as given in the Table 1

*Table 1 Water Quality Parameters standard*

<b>Parameters</b>	<b>Unit</b>	<b>Standards WHO &amp; Algerian Standard</b>
pH		6.5-8
TDS	mg/l	600
Phosphate		
Sodium	mg/l	200
Sulfate	mg/l	250
Calcium	mg/l	75
Potassium	mg/l	12
Magnesium	mg/l	50
Nitrate	mg/l	3
Chloride	mg/l	250
Electric Conductivity	µs/cm	1500
Bicarbonate	mg/l	100

# CHAPTER THREE: MATERIALS AND METHODS

## 3. Materials and Methods

### 3.1. Description of the study area

#### 3.1.1. Location

Naâma is the capital city of the Wilaya of Naâma and it is located inside of synclinal of Naâma which covers an area of about 2 525,93 km<sup>2</sup>. The geographical situation is between 33° 16' 18.3" North and 0° 18' 54.2" West.

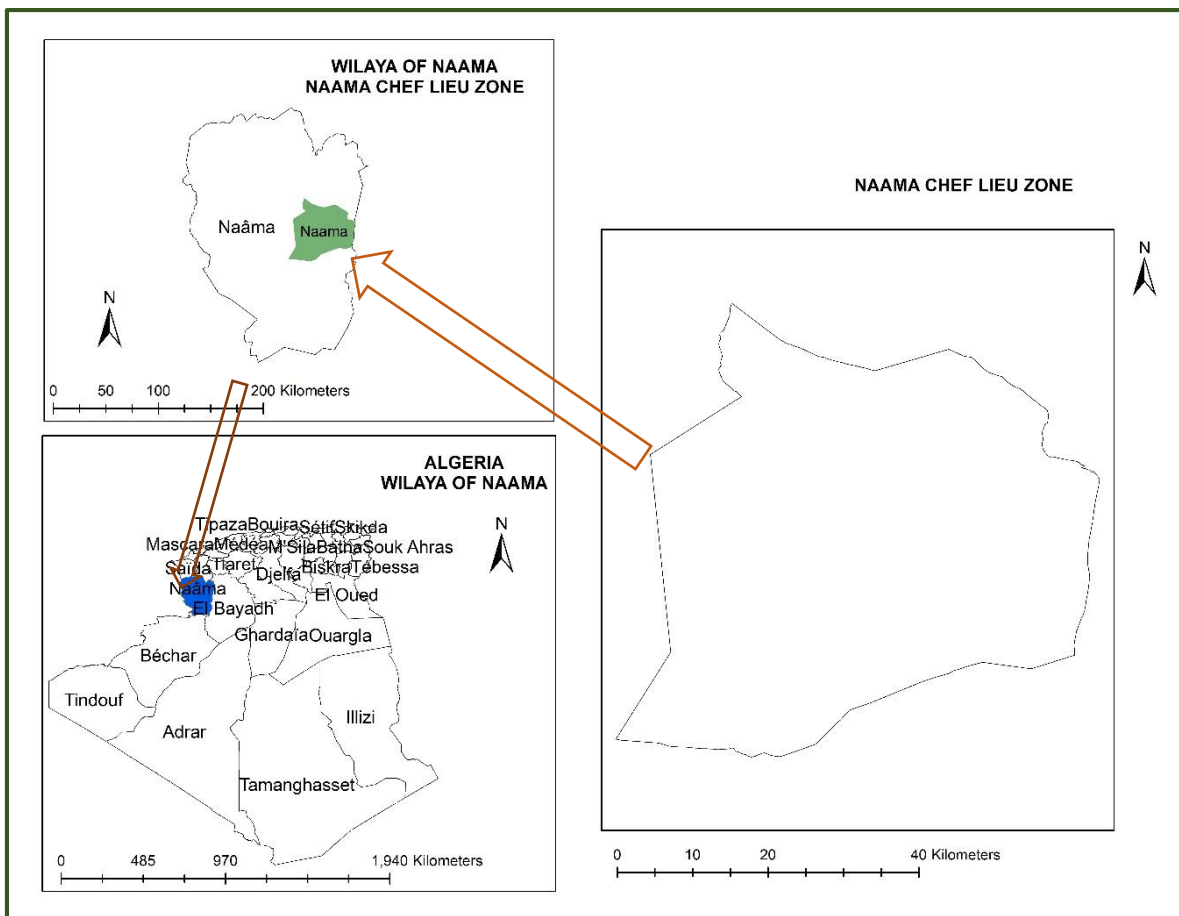


Figure 1 Location of Study area

**Population**

According to Department of Programming and Monitoring Budgetary of Naãma (direction de la programmation et de suivi bugetaire, 2017), it was estimated that the total population of wilaya of Naãma is around 25.2593 inhabitants, with a density of 10.35 (Hab / Km<sup>2</sup>). The majority of the population depends on groundwater resources for drinking and agriculture.

**3.1.2. Climate**

The climate of Naãma is arid and semi-arid with averages of -10 ° C in winter and more than 45 ° C in summer. Generally, the climatic year of the commune is divided into two main seasons: winter and relatively wet season starts from November to April, hot and dry season from May to October. The vegetation is negatively impacted due to high temperatures during the dry season.

Naãma has an annual average temperature of around 24.9°C. The region faces desertification which affects the groundwater resource. Its annual average rainfall is about 2076 mm. The maximum and minimum for temperature and precipitation from (1980-2017) are shown in the following two figures.

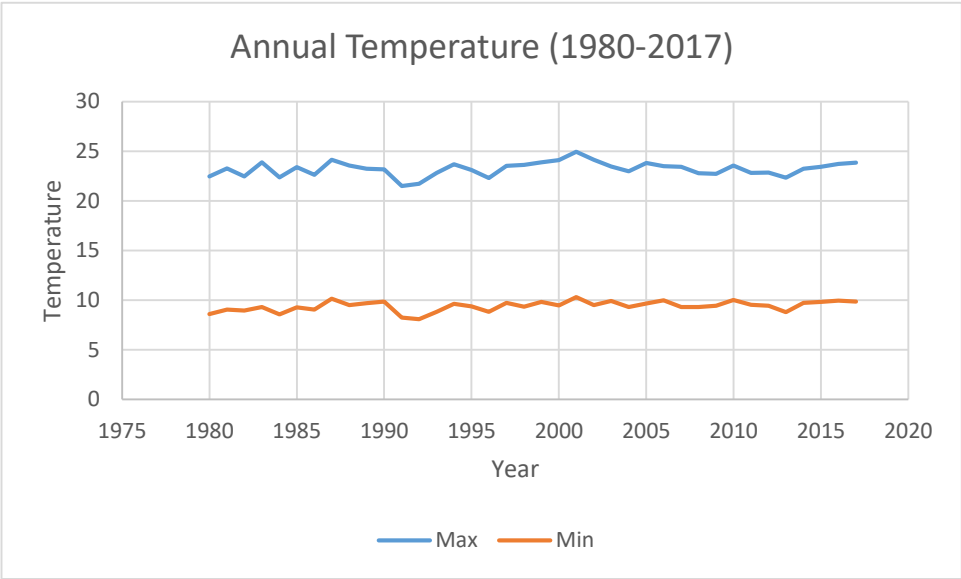
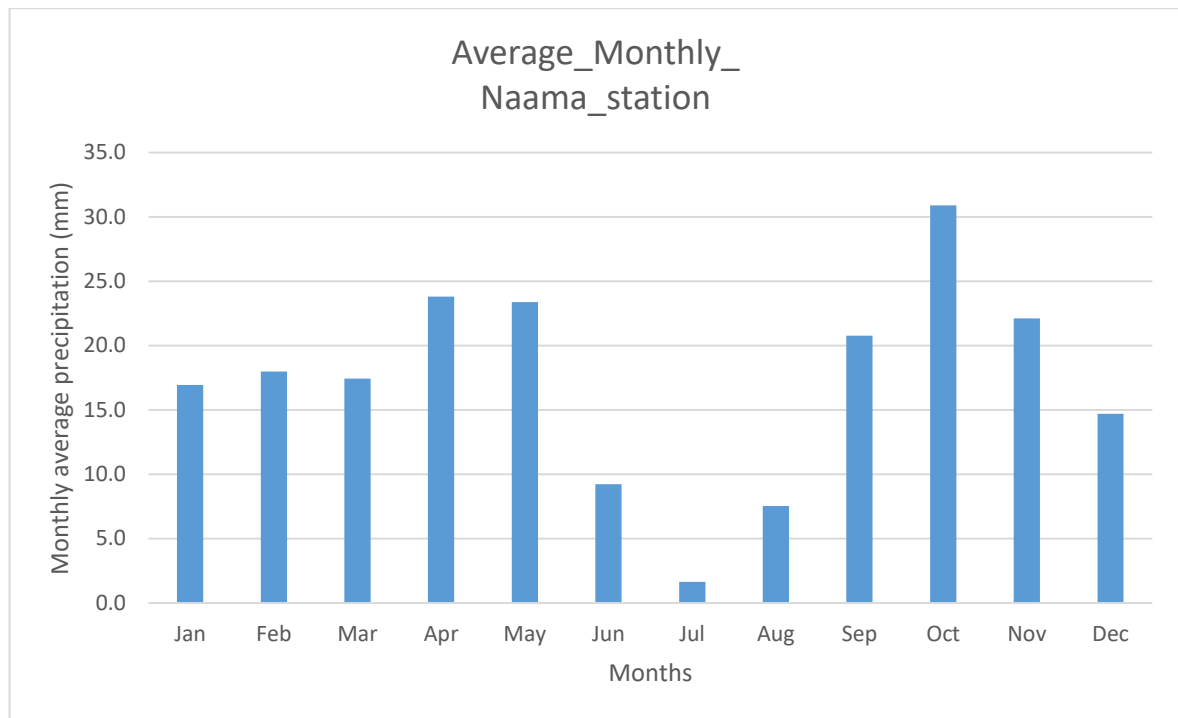


Figure 2 Maximun and Minimum Temperature of Naãma from 1980-2017



*Figure3: Average Monthly precipitation of Naãma from 1980-2017*

### 3.2. Geology

The Naãma syncline is characterized by predominantly sandstone-dominated continental formations by Tertiary, Cretaceous and Jurassic terrains.

There is a formation of the tertiary continent consisting of sandstone levels with highly permeable and known in the region by Albine Gréseux.

#### ❖ Jurassic Medium

The bajo-bathonian: constituted by dolomitic limestones.

The callovo-oxfordian: is characterized by alternating clay-sandstone

#### ❖ The Upper Jurassic

Characterized by a series of sandstones at the top then another sizzling series between cut by a thick clay series

### **3.3. Geography**

The geography of Naâma is divided into three regions which include a flat northern steppe zone representing 74% of the total area of the wilayas where pastoral activity predominates (the herd is estimated at over 1200 000 head). A mountainous area occupying 12% of the territory of the wilayas, part of the Saharan Atlas where there is oasis agriculture. In South Pre-Saharan zone that extends over the remaining 14% of the wilaya (direction de la programmation et de suivi bugetaire, 2017).

### **3.4. Water Resources and Supply**

Drinking water supply is important for improving the living condition of the urban and peri-urban population. The capital city of Naâma provides water for its residents from underground which has a total storage capacity of around 2 450 m<sup>3</sup> (DPSB, 2017).

The potential water resources in and around Naâma are generally classified into two major groups:

- ❖ Surface water resources (Oued, Spring, Hillside retention)
- ❖ Ground water resources (Wells, Boreholes), currently many of water supply are using boreholes for drinking water and wells in some areas for irrigation purposes. The subsoil of the wilayas contains great water potential, which is a little exploited.

The different groundwater Storage are located in the wilayas of Naâma:

- Chott EL-Gherbi
- Chott Echergui
- Syncline of Naama
- The acquiferes of the valley of Ain Sefra and Tiout

### 3.5. Methodology

#### 3.5.1. Sources of Data

The water samples were collected from 10 boreholes which are located in the area zone of Naãma. The water sample are analyzed in the laboratory of Naãma.

*Table 2: Sample Location and some measure of aquifer*

ID	Sample location	X(m)	Y(m)	Z(m)	condition	use
1	Naãma	217400	297150	1179	Exploited	AEP
2	Naãma	220800	300100	1170	Exploited	AEP
3	Horchaia	223900	307300	1179	Exploited	AEP
4	Naãma	206500	289000	1200	Non exploited	IRR
5	Naãma	215600	299900	1166	Exploited	Autre
6	Naãma	218500	303100	1164	Non exploited	Autre
7	Touadjeur	229200	316500	1140	Exploited	AEP
8	Naãma	215500	301000	1171	Non exploited	Autre
9	Touadjeur	232100	315000	1170	Non exploited	Autre
10	Naãma	219449.81	300431.55	1171		AEP

#### 3.6. Technical analysis of groundwater quality parameter

The physical, chemical and biological parameters are part of water quality. Generally, the unit of these elements is milligram per liter but EC in micro-siemens per centimeter and pH has no units.

##### 3.6.1. pH

The device of the pH meter was first calibrated with standard solutions against a pH buffer calibrated against a pH of 7 and 9 at a temperature of 25°C to adjust to the response of the glass electrode.

Calibrate the device with standard solutions (pH 4 - 7 or 10) and wash the electrodes again with distilled water and dry them. Introduce the electrodes into the sample and stir gently and stop, allowing for 1-2 minutes for a stable reading to be examined and take a reading.

### 3.6.2. Electric Conductivity (EC)

It was analyzed with the help of a portable conductivity meter. The tool of conductivity was cleaned out with three portions of KCL solution at 25°C. The conductivity cells and beaker were rinsed with a dose of the sample. The beaker was filled completely with the sample. The conductivity meter was put into the beaker filled with the sample and the value read and recorded.

### 3.6.3. Total Dissolved (TDS)

Its concentration was determined by using the gravimetric method. The magnetic stirrer was used for stirring the sample. A volume of the sample was measured and poured into a 100 ml cylinder by means of a funnel on a fiberglass filter with an applied vacuum. The fiberglass filter allowed the sample to be filtered under vacuum pressure for three minutes to ensure that water was removed.

The total filtration of the sample was poured into an evaporation dish and evaporated in an oven at a temperature of 180 to 200 °C for one hour, then cooled in a desiccator and finally weighed. It was a cycle of drying and weighing in order to get a constant value of TDS. Finally, the TDS value was calculated using the following formula below.

$$\text{TDS} = (A-B) * 1000 / (\text{volume of sample}) \text{ml}$$

where:

A = weight of dried residue + dish (mg)

B = weight of dish (mg)

### 3.6.4. Sodium

The photometric flame method was used to determine the concentration of sodium (Na<sup>+</sup>). A standard solution of NaCl of 20 mg/L was made to normalize the photometer. The photometer filter selector was used to select sodium after operation of the photometer and the standard solution which is 20 mg/L. To obtain the standard concentration value of 20 mg/L the machine was calibrated. Sample readings were taken. After some sample readings, the machine was re-calibrated to ensure readings in the range of 20 mg/L. The calibration curves were drawn for sodium and found the concentration results in mg/L



### 3.6.5. Potassium

The flame photometric method was used to determine the concentration of potassium ( $K^+$ ). A KCl standard solution of 20 mg / l was made to standardize the flame photometer. The photometer filter selector was used to select Potassium after starting the photometer and the standard setting of 20 mg / L. In order to obtain the standard concentration value of 20 mg / l the machine was calibrated. Sample readings were taken. After some sample readings, the machine was re-calibrated to ensure readings in the range of 20 mg / L. The calibration curves were drawn for potassium and found the concentration results in mg / L.

### 3.6.6. Chloride

The determination of chloride by the method of Mohr.

The objective it was to determine the concentration of chloride with Mohr Method. The following equation of chloride concentration was used:

$Cl^- + AgCl$ -----white precipitate with whole the chloride will disappear

$2Ag^+ + CrO_4^{2-}$ (yellow) ----- $Ag_2CrO_4$ -----precipitate red-rosy

Some drops of silver nitrate solution were added and the solution was reacted with the chromate ions producing silver chromate, which appeared as a precipitate of pink red chloride.

#### Material:

Burette 25 ml

Stand and burettes Stirrups

Two 250 ml Erlenmeyer flasks

Automatic pipette

50 ml beaker

pH-meter

Sample of Water

#### Reagents

Solution of  $AgNO_3$ , 0.1 evaluated and 5% solution  $K_2CrO_4$ ,  $Na_2CO_3$ ,  $CH_3COOH$  and distilled water.

#### Methodology for chloride

Measure 10 ml water sample with a pipette into a 250ml Erlenmeyer flask, then add 50 ml of distilled water to dilute and better observe the turn, at least three drops of the indicator then add potassium chromate. Then verify the solution with the aid of pH meter. Then it was proceeding from 0.1N to level the burette to 0 with a silver nitrate solution and start to evaluate 0.1N by silver nitrate while the balloon flutters continuously with an appearance of red rosaceous precipitate that it showed the final evaluation.

### **3.6.7. Sulfate**

The barium made it possible to convert the sulphate ion into an acid medium with the suspension of barium chloride under a good condition. The spectrophotometer made it possible to measure the suspension of barium sulphate (BaSO<sub>4</sub>) and then the sulphate concentration is sought by reading the standard curve.

A 100 ml of sample was measured in a 250 ml Erlenmeyer flask and 5 ml of reagent added and mixed on a stirring device. A spoonful of barium chloride was put into the solution for 60 seconds while keeping the stirring speed constant. The solution was put into the absorbance cell and the turbidity measurement was made for 4 minutes with an interval of 30 seconds, the process was unrolled after stirring time. The preparation of the curve was made with a standard sulphate solution. The result was obtained from the calibration curve and expressed in mg / L. Finally the concentration of sulfate (SO<sub>4</sub><sup>2-</sup>) was found by using the following formula.

$$\text{Sulfate (SO}_4^{2-}) = \text{mg of sulfate} * 1000 / \text{volume of the sample (ml)}$$

### **3.6.8. Nitrate**

The hydrazine reduction method was used for the determination of nitrate concentration (NO<sub>3</sub><sup>-</sup>). A volume of 10.0 ml of the sample was pipetted into a test tube. An addition of 1.0 ml of 1.3 M NaOH (aq) to the test tube and carefully mixed. The nitrate is heated with a temperature of (37 ° C) to convert it into nitrite a sample with 1.0 ml of hydrazine sulfate which is under an alkaline condition and mixed gently, and finally catalyzed by the addition of cupric ions. The result of the nitrite, along with the main nitrites, was mixed to react with the sulfanilamide to form a diazo compound. Then the diazo compound was reacted with N- (1-naphthyl) Ethylene diamine dihydrochloride to form an azo dye in an acidic medium. Absorbance of the light red azo dye is measured at 520 nm and the concentration of nitrate nitrogen plus nitrite nitrogen was found by

comparison with a series of standards. Nitrate can be determined by subtracting the nitrite result from the nitrite plus nitrate result.

### **3.6.9. Determination of Calcium (Ca<sup>++</sup>), Magnesium**

In the laboratory the sample of calcium and magnesium were diluted appropriated and aspirated. A blank solution has been prepared and Atomic Absorption spectrophotometer was used for ion analyzes, with acetylene gas as a fuel and air as oxidizer. Calibration curves were effectively prepared for all the metals differently by using the concentration of the standard solutions. The results of these samples were aspirated into the air-acetylene flame and the concentrations of the metal ion were found from the calibration curves. The absorbance of the blank has been noted before the analysis of the different samples.

### **3.6.10. Bicarbonate**

The principle of analyzing the bicarbonate in drinking water. It was prepared a volume of 50 ml for the sample and has put in a volumetric flask. Second step it placed the 50 mL of water sample in a beaker. The burette was filled to zero level with a solution hydrochloric acid. It was Calibrated the pH meter and placed the electrode into the sample and determined titrimetric against standard hydrochloric acid solution.

### **3.7. Determination of Water Quality Index(WQI)**

WQI played an important role in the assessment of groundwater quality. It has been used by many researchers for the suitability of groundwater. However, WQI has been developed by many international organizations and institutions across the world such as: National Sanitation Foundation Water Quality Index (NSFWQI), Weight Arithmetic Water Quality Index (WAWQI), Canadian Council of Ministers of the Environment Water Quality Index (CCMEWQI), Oregon Water Quality Index (OWQI) (Kumar Sharma I.P et al., 2016) . Many researchers have used Weight Arithmetic Water Quality Index (WAWQI) method in order to compute the water quality parameters (Olayiwola Oni., 2016; KUMAR.A et al., 2014).

In this study, Weight Arithmetic Method was selected. There are four steps for the calculation:

**First step:** Assigning the weight for each water quality parameter. The value of weight varies from 5 to 1 where the high number will be given to one parameter which has an important impact on

assessment of water quality. As an example Nitrate is an important parameter and was assigned 5, and the lowest value of 1 was be given to Bicarbonate (Abraham Bairu Gebrehiwot, 2011).

**Second step:** Determination of relative weight by the following formula:

$$W_i = \frac{w_i}{\sum_{i=1}^n w_i}$$

- ✚  $W_i$ =relative weight
- ✚  $w_i$ =weight of each parameter
- ✚  $n$ =number of parameter

**Third step:** Determination quality rating scale according to (Hema Latha. T.et al., 2012)

$$q_i = \left( \frac{C_i}{S_i} \right) * 100$$

- ✚  $C_i$ =concentration of the parameter
- ✚  $S_i$ = concentration of each parameter of water standards (WHO 2004)

**Fourth Step:** computing the Sub index of ith chemical parameter (K.Ambiga, 2016)

$$SI = W_i * q_i$$

- ✚  $SI$ : the sub index of ith parameter
- ✚  $q_i$ =is rating scale of each parameter

Finally, the calculation of WQI:

$$WQI = \sum SI$$

Table 3: Summarize the weightage value of the parameter and the concentration given by WHO

Parameter	Units	Standard (SI) WHO	Weightages (WI)
Température	°C		
pH	Unité de	8.5	4
Electric Conductivity	μδ/cm	2000	2
TDS	mg/l	1000	2
Calcium (Ca <sup>++</sup> )	Mg/l	200	3
Magnésium(Mg <sup>++</sup> )	mg/l	150	2
Sodium(Na <sup>+</sup> )	mg/l	200	2
Potassium (K <sup>+</sup> )	mg/l	200	1
Chloride (Cl <sup>-</sup> )	mg/l	250	3
Sulfates(SO <sub>4</sub> <sup>-</sup> )	So <sub>4</sub> -mg/l	250	2
Nitrates(NO <sub>3</sub> <sup>-</sup> )	mg/l	50	3
Nitrites(NO <sub>2</sub> <sup>-</sup> )	No <sub>2</sub> -mg/l	3	
Bicarbonates(HCO <sub>3</sub> <sup>-</sup> )	HCO <sub>3</sub> - mg/l	200	2
Ammonium(NH <sub>4</sub> <sup>+</sup> )	NH <sub>4</sub> +Mg/l	1.5	
Phosphore(PO <sub>4</sub> <sup>-</sup> )	PO <sub>4</sub> - Mg/l	05	1

Table 4: Water Quality Index Designations (Bairu.A et al., 2013)

Designation	Index Value
<50	Excellent Water
50-100	Good Water
100-200	Poor Water
200-300	Very Poor Water
>300	Unfit for Drinking

### **3.8. GIS Method**

The data of the study area was downloaded from the website of DIVA-GIS. This data was used to generate a map of study area with the help of ARCGIS 10.3. The water samples were analyzed in the laboratory against international standards (WHO, 2004) combined with Algerian standards. It was organized in the excel worksheet. GPS was used to determine the localization of each borehole.

The spatial distribution tool was used to determine the distribution of water quality parameters. Interpolation technique which is IDW is used to determine the thematic layer of water parameter such as pH, EC, TDS, Calcium, Magnesium....

In order to organize the methodology of the work, Flow chart method was created.

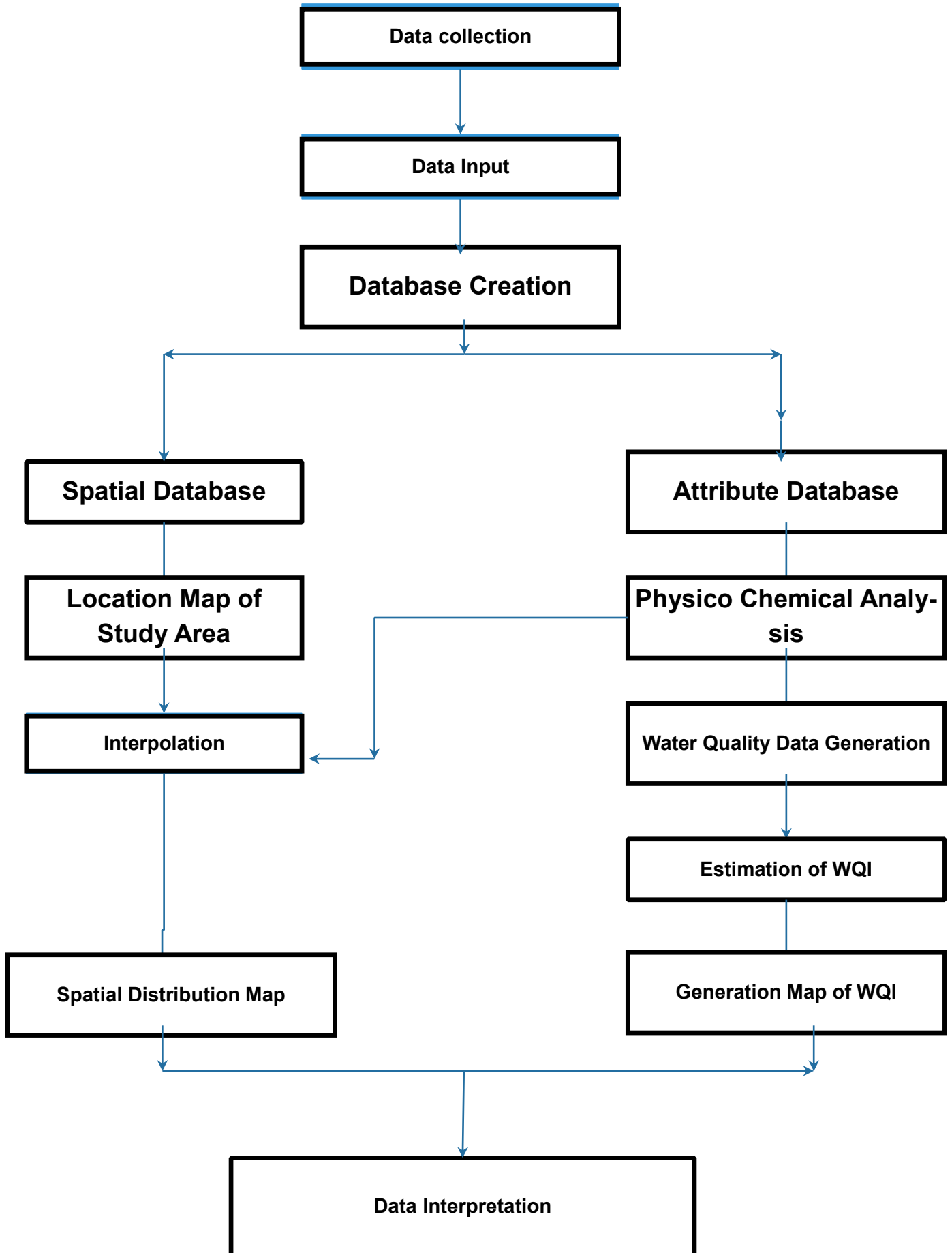


Figure 4:flow chart

# CHAPTER FOUR: RESULTS AND DISCUSSION

## 4. RESULTS AND DISCUSSION

### 4.1. Variation of groundwater quality parameters

This chapter presents results of the physico-chemical analysis of groundwater samples such as pH, electrical conductivity and turbidity as taken from field sampling.

#### 4.1.1. pH

The value of pH of water samples in the study area ranges from 7.65 to 8.03. According to the guideline of WHO (2004) and Algeria Standard the permissible limit of pH is between 6.5 – 9. All the water samples analyzed fell within this limit. The groundwater of this study area is alkaline, that is, it has a  $\text{pH} > 7.0$ . In addition, in the same region (Bouderbala, 2017) found the same value of pH to be in the range from 7.4 to 8.3.

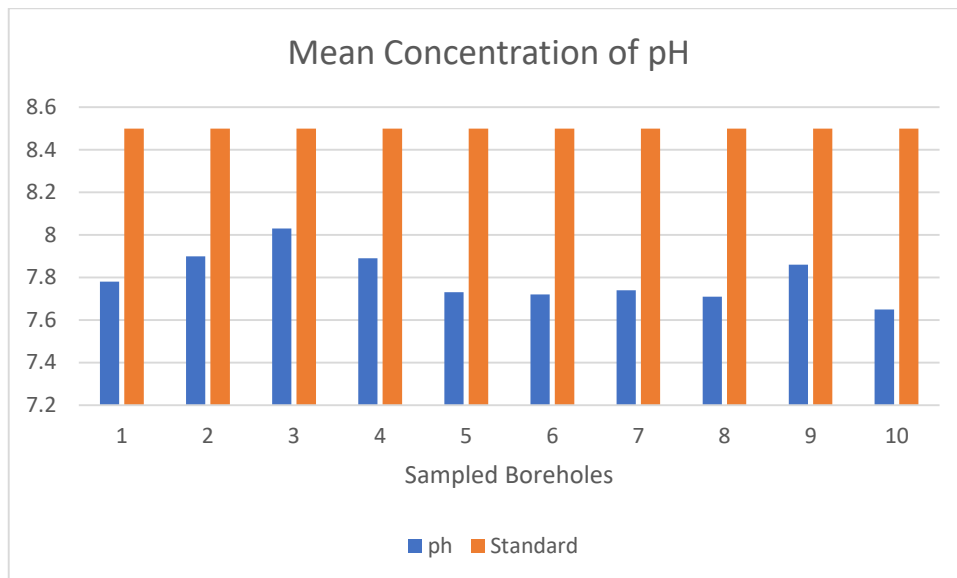


Figure 5: Mean concentration of pH

#### 4.1.2. Electrical Conductivity (EC)

High amount of dissolved solids in the water can produce distress in livestock. The EC of the groundwater samples in the study area ranges from 551 to 1084 ( $\mu\text{S}/\text{cm}$ ). It is in the permissible limit allowed by WHO (2011). The normal value is 2000 ( $\mu\text{S}/\text{cm}$ ). It was observed that at the location of borehole 10 the highest mean value of 1084  $\mu\text{S}/\text{cm}$  was recorded (figure 6). The occurrence of high electrical conductivity values in some parts of the area might be due to addition of some salts through the prevailing agricultural activities or by rain fall leaching into the



groundwater. All the values recorded for electrical conductivity were below the guideline value of 2000  $\mu\text{S}/\text{cm}$  for water stipulated by the WHO (2011).

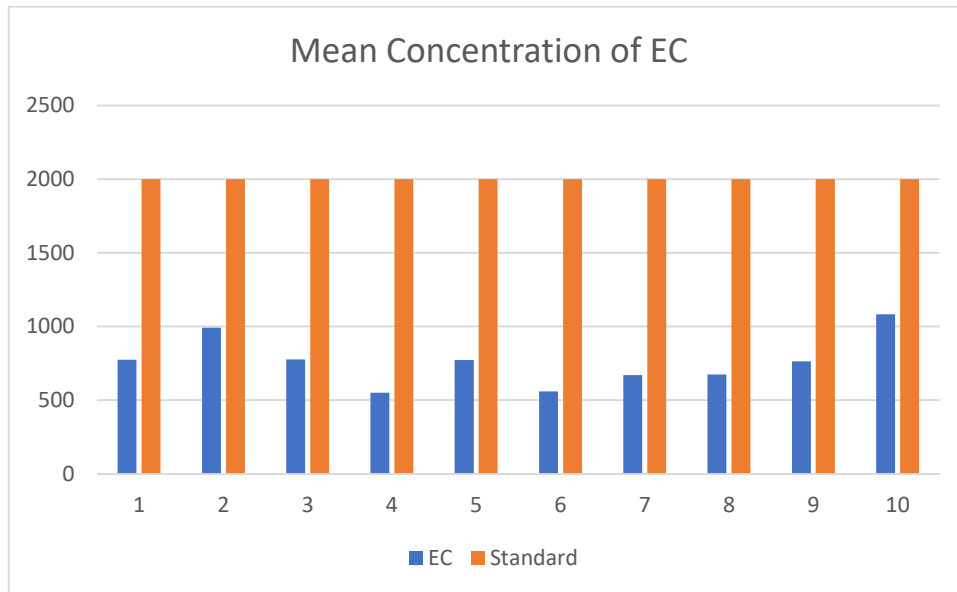


Figure 6: Mean Concentration of EC

#### 4.1.3. Total Dissolved (TDS)

Total dissolved Solids are generally due to the quantity of matter suspended in water or wastewater (K.Ambiga, R. Anna Durai, 2013). The concentration of TDS of the study area ranges from 216-535 mg/l in groundwater samples. All observed water samples are in permissible limit of 1000 mg/l.

Groundwater with TDS values less than 500 mg/L can be considered as good for drinking purpose (WHO, 1984). The presence of high levels of TDS in some of the sampled boreholes (010) may not be good to the users and may cause scaling in water pipes.

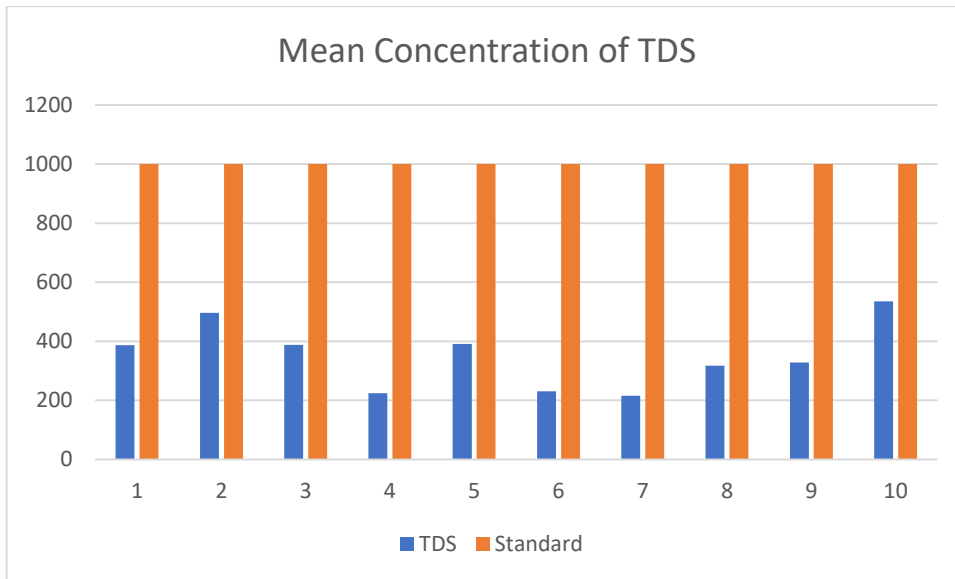


Figure 7: Mean Concentration of TDS

#### 4.1.4. Calcium (Ca<sup>++</sup>)

Calcium originates from natural and anthropological activities. It may be internal when water flows inside of an aquifer. The values of calcium in groundwater in study area range between 64 to 124 mg/l which are in the permissible limit of the standards of (WHO, 2004) 200 mg/l.

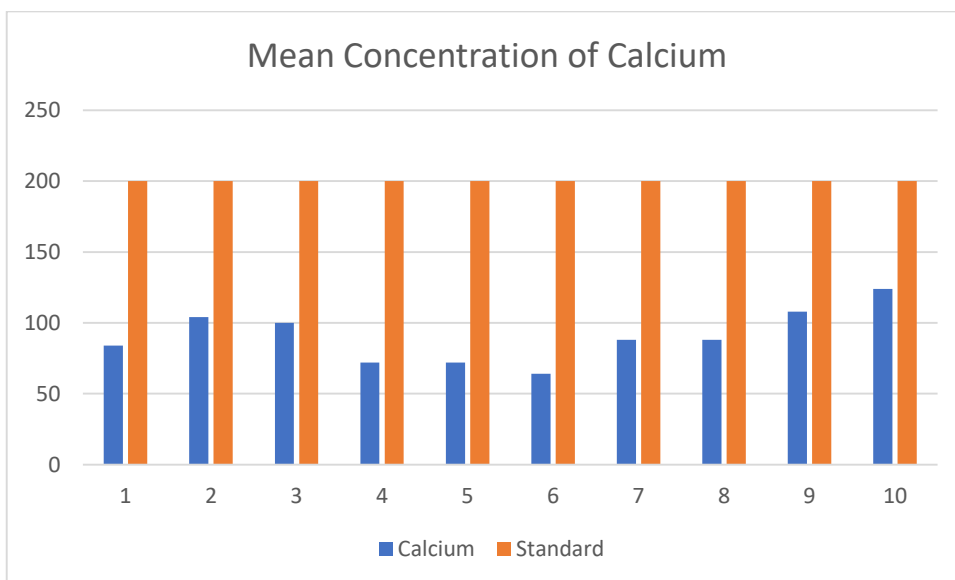
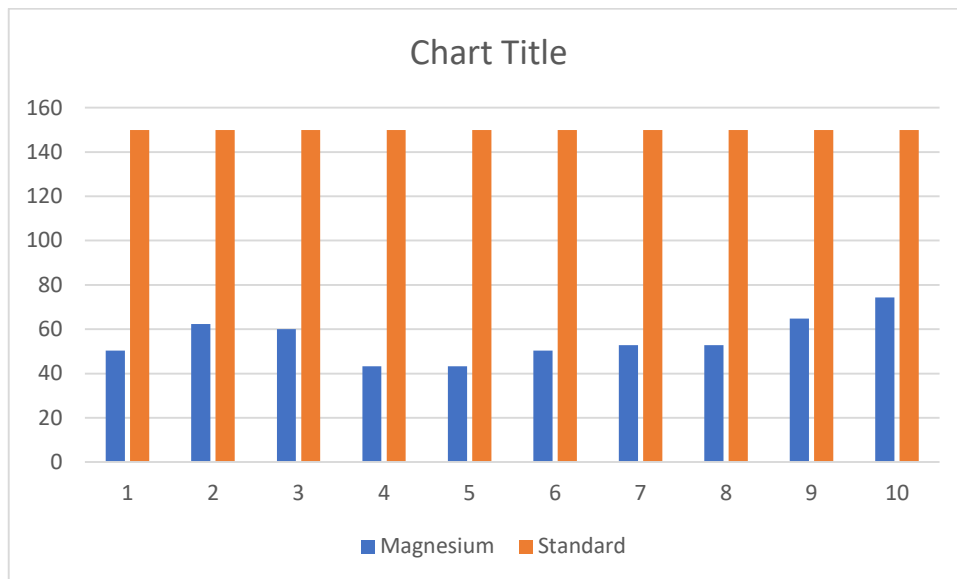


Figure 8 Mean concentration of Calcium

#### 4.1.5. Magnesium

High concentration of magnesium can cause hard water. The content of magnesium in the groundwater samples ranged from 43.2 mg/l to 74.4 mg/l and it has an average value of 55.44 mg/l. All the values of magnesium are within the WHO limit (150mg/l).



*Figure 9: Mean Concentration of Magnesium*

#### 4.1.6. Sodium

The values of sodium in the groundwater sample ranged from 48 to 806 mg/l. According to (WHO, 2004) and Algerian Standard, the maximum concentration in drinking water may not exceed 200 mg/l. Sodium, like other alkaline metals is the only metal found in significant quantities in natural waters. The primary source of the sodium ions in natural water is from the release of soluble sodium products.

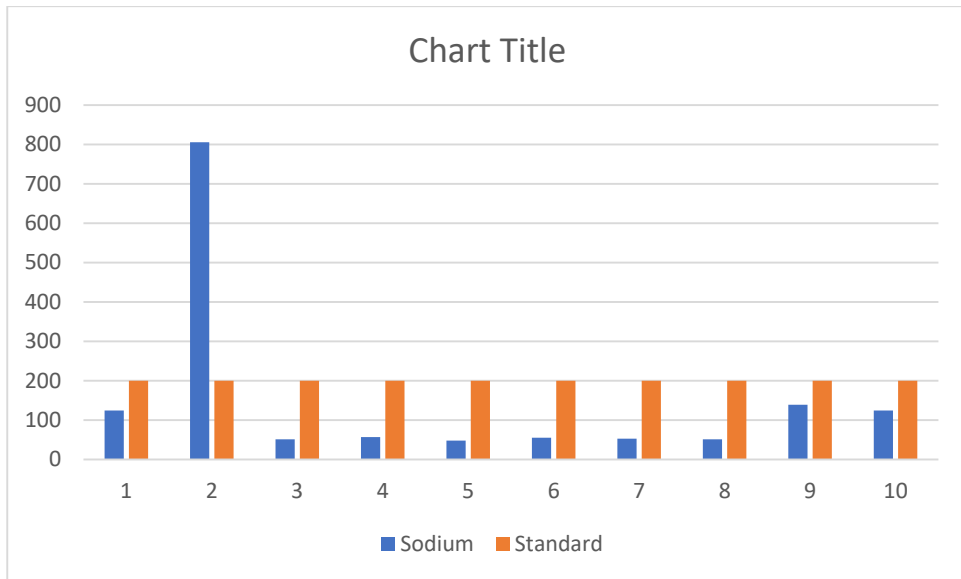


Figure 10: Mean Concentration of Sodium

#### 4.1.7. Potassium

The mean concentration of potassium ranges from 4.04 mg/L at sampling station borehole (F13) to 16.23 mg/L at sampling station borehole (N2). The maximum permissible limit given by WHO (2004) is 200 mg/l.

The borehole (F13) had a higher concentration of potassium than the other boreholes, which can be explained by the leakage of domestic and animal sewage and fertilizers applied to farms into this borehole.

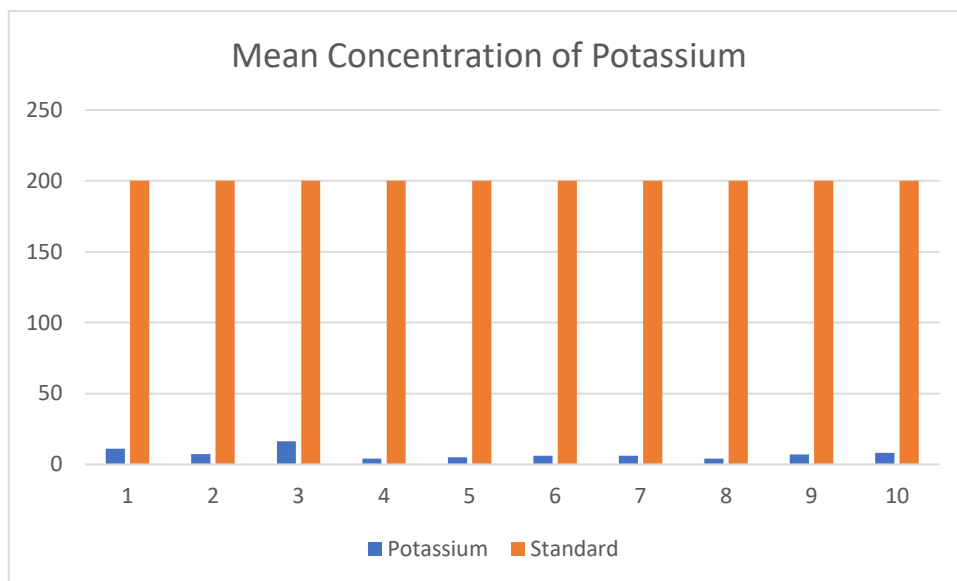
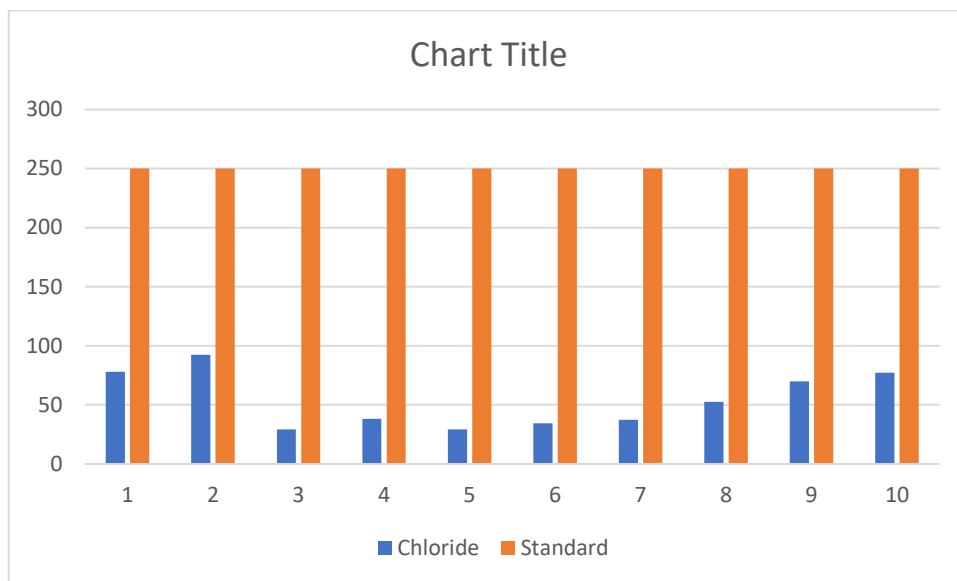


Figure 11: Mean Concentration of Potassium

#### 4.1.8. Chloride

The mean values of chloride in this study area ranged from 29 at sampling station borehole 03 to 92.2 mg/L at sampling station borehole 02. The permissible limit of chloride is given by (WHO, 2004) is 250 mg/l. In this case the concentrations of chloride are in the permissible limit of WHO.

Chloride is an important parameters used to assess the quality of water. The concentration of chloride in all the boreholes sampled were within the 250 mg/L guideline value prescribed by Algerian standard and WHO.

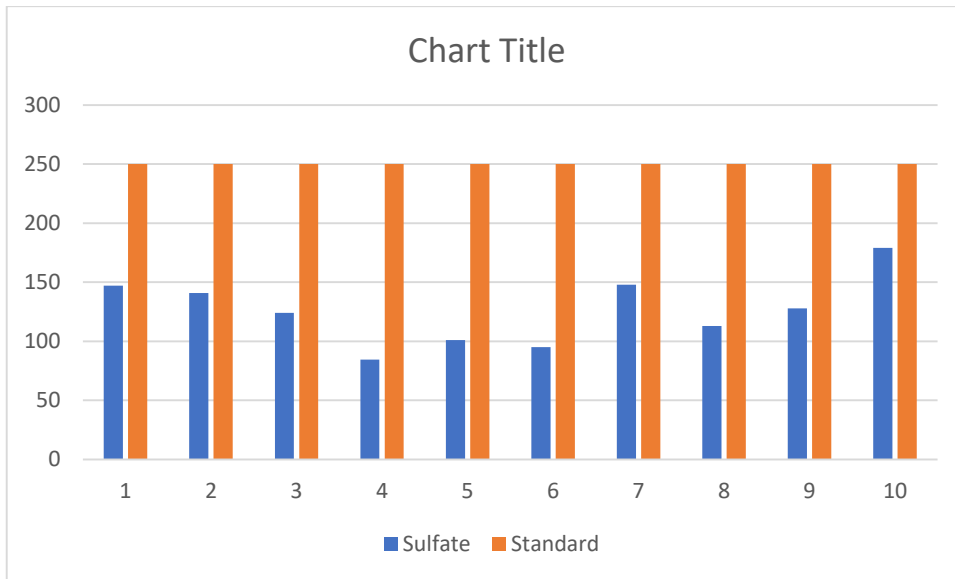


*Figure 12: Mean concentration of chloride*

#### 4.1.9. Sulfate

Catharsis, dehydration and gastrointestinal irritation can occur due to the accumulation of large amounts of sulfates. It can be the cause of corrosion in the water distribution system.

The mean concentration of sulphates ranged from 84.6 mg/L at sampling station F13 to 179 mg/L at sampling station N8 (Figure 13) in the boreholes. All the samples were below the 250 mg/L guideline value prescribed by Algerian Standard and WHO (2004).



*Figure 13: Mean concentration of sulfate*

\*\*

#### 4.1.10. Nitrate

The value of concentration in the groundwater of study ranged from 0.38 mg/L at sampling station N3 to 28.6 mg/L at sampling station N5 004. The permissible limit of nitrate is given by (WHO, 2004) and Algerian Standard is about 50 mg/l. The concentration of nitrates in all the sampled boreholes used for the present study was within the 50.0 mg/L guideline value prescribed by WHO (Figure 14).

Nitrates can occur in trace quantities in surface water but it can produce a huge amount in the groundwater. It has a toxic effect on certain aquatic organisms when the level of concentration is above 100 mg/l.

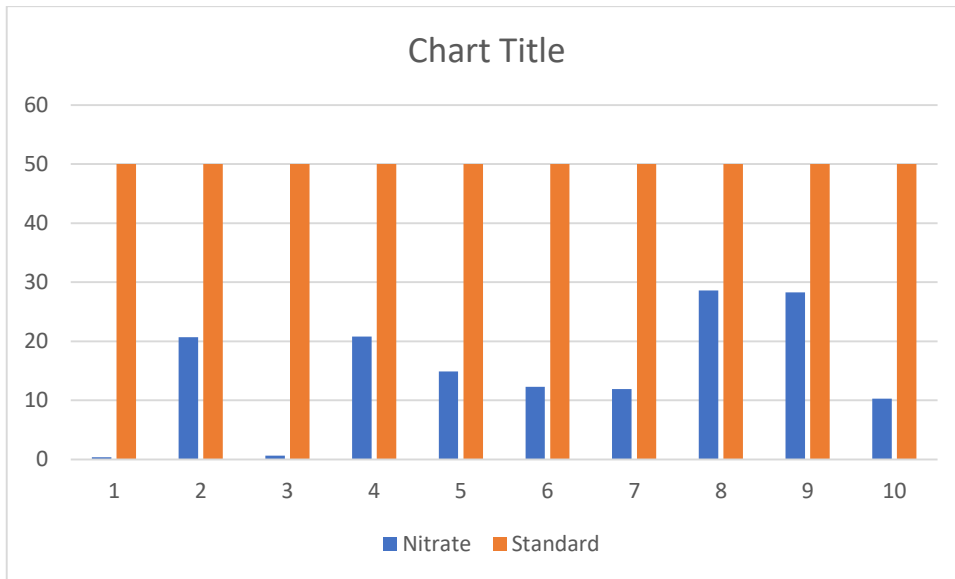


Figure 14: Mean concentration of nitrate

#### 4.1.11. Bicarbonate

The high amount of bicarbonate in water is due to the biological process of plant roots, and from the oxidation of organic matter into the soil, then in the rock and from other chemical reactions (Raju, 2006). The concentration of bicarbonate varied between 190-272 mg/l and the total permissible limit is about 200 mg/l.

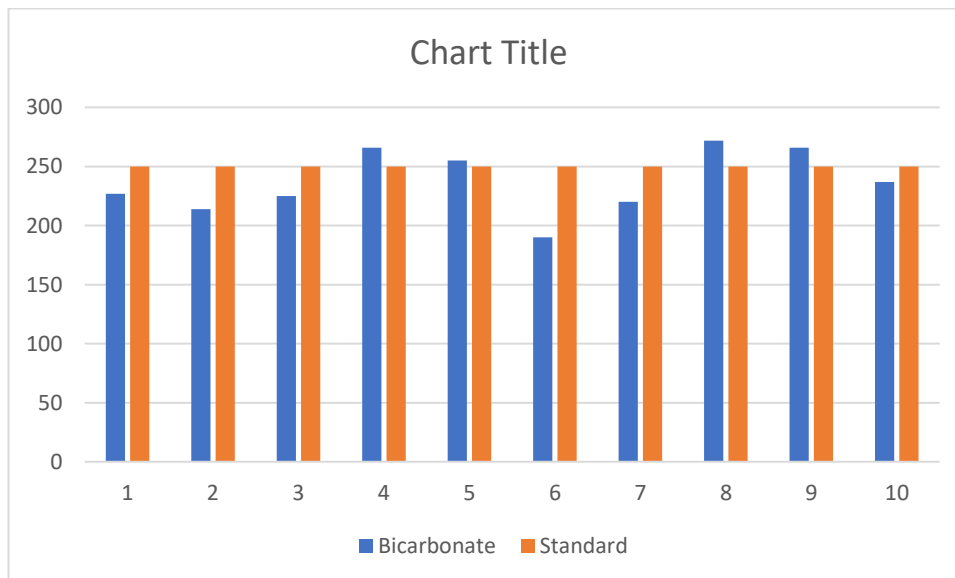


Figure 15: Mean concentration of bicarbonate

Table 5: Statistical summary of groundwater quality parameter

BORE HOLE	XUT M	YUT M	pH	con-duc-tivité( $\mu\delta/cm$ )	TDS (mg/l)	ca++ (mg/l)	mg++ (mg/l)	na+(m g/l)	k+ (mg/l)	cl- (mg/l)	so4- (mg/l)	no3- (mg/l)	Hco3- (mg/l)
Naam a (N3)	75156 8.8146	36835 18.377	7.78	775	387	84	50.4	124	11.1	77.9	147	0.38	227
Naam a (F1)	74833 2.4578	36803 84.901	7.9	993	496	104	62.4	806	7.3	92.2	141	20.7	214
Naam a(N2)	75906 6.11	37003 65.898	8.03	776	388	100	60	51	16.23	29	124	0.63	225
Naam a (F13)	74728 8.4264	36829 83.739	7.89	551	224	72	43.2	57	4.04	38	84.6	20.8	266
Naam a (N4)	74394 4.0346	36799 94.775	7.73	772	391	72	43.2	48	5.03	29	101	14.9	255
Naam a (N6)	74843 4.4846	36858 52.624	7.72	560	231	64	50.4	55	6	34.2	95.2	12.3	190
Naam a (N7)	75014 9.5972	36856 45.729	7.74	670	216	88	52.8	53	6	37.2	148	11.9	220
Naam a (N5)	74624 3.8833	36819 24.43	7.71	675	318	88	52.8	51	4	52.4	113	28.6	272
Naam a (F2)	74622 3.6481	36841 28.198	7.86	763	328	108	64.8	139	7	69.8	128	28.3	266
Naam a (N8)	75019 3	36840 52	7.65	1084	535	124	74.4	124	8.1	77.1	179	10.3	237
<b>Mini- mum</b>			<b>7.65</b>	<b>551</b>	<b>216</b>	<b>64</b>	<b>43.2</b>	<b>48</b>	<b>4</b>	<b>29</b>	<b>84.6</b>	<b>0.38</b>	<b>190</b>
<b>Maxi- mum</b>			<b>8.03</b>	<b>1084</b>	<b>535</b>	<b>124</b>	<b>74.4</b>	<b>806</b>	<b>16.23</b>	<b>92.2</b>	<b>179</b>	<b>28.6</b>	<b>272</b>
<b>Aver- age</b>			<b>7.801</b>	<b>761.9</b>	<b>351.4</b>	<b>90.4</b>	<b>55.44</b>	<b>150.8</b>	<b>7.48</b>	<b>53.68</b>	<b>126.08</b>	<b>14.881</b>	<b>237.2</b>
<b>Stand ard devia- tion</b>			<b>0.1157 06</b>	<b>169.59 72025</b>	<b>110.31 087</b>	<b>18.685 705</b>	<b>9.8922 1916</b>	<b>233.06 928</b>	<b>3.7214 3</b>	<b>23.559 65</b>	<b>28.719 9814</b>	<b>9.9279 61</b>	<b>26.877 4999</b>

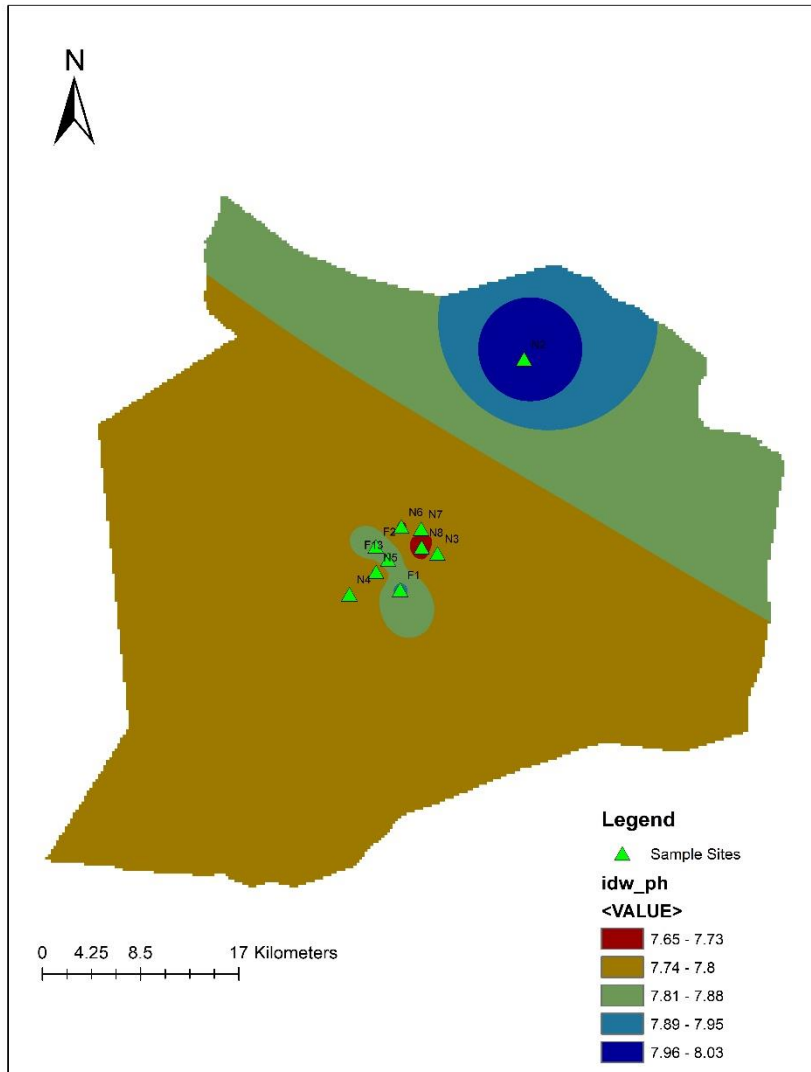


## **4.2. Spatial analysis of groundwater quality parameters**

Analysis of groundwater quality is very helpful in assessing the suitability of water for different purposes. Generation of spatial distribution maps of different water quality parameters such as pH, electric conductivity, total dissolved, Calcium, magnesium, sodium, potassium, chloride, sulfate, nitrate, nitrite and bicarbonate involves integrating the attribute and spatial data.

### **4.2.1. pH**

The value of pH of water samples in the study area are ranges from 7.65 to 8.03. The high permissible limit for pH in clean water recommended by the WHO was 9.2 mg/l. Spatial analysis of pH concentration was found in the following figure (5). It was found that the majority of the groundwater samples which are located in North-West to South-East displayed a lower pH value, except for two groundwater samples (Naãma F1 and Naãma N2) which are located in North-East which have a maximum value of pH.



*Figure 16: Spatial distribution map of pH in Naāma*

#### 4.2.2. Electric Conductivity (EC)

The presence of dissolved salts in water can affect the electrical conductivity at 25°C. The spatial distribution of EC of the groundwater samples in the study area range from 551 to 1084 ( $\mu\delta/cm$ ). Figure (6) showed the spatial distribution of EC in Naāma.

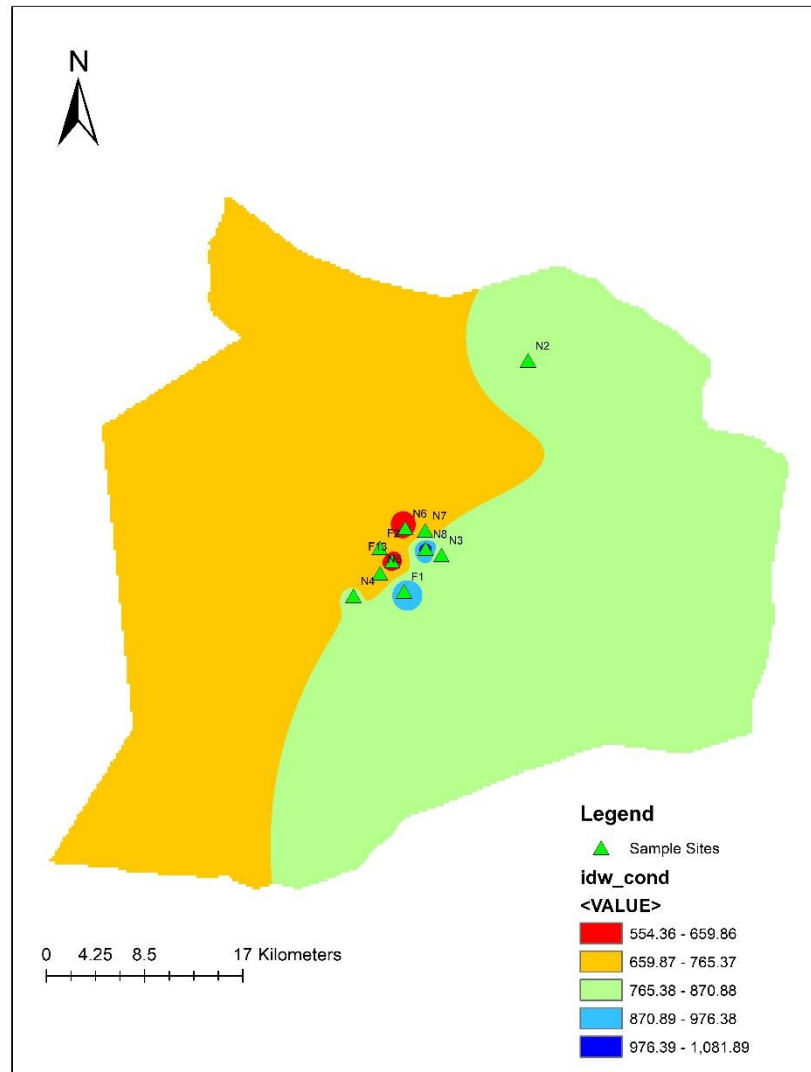


Figure 17: Spatial distribution map of EC (mg/l) in Naāma

#### 4.2.3. Total Dissolved

The concentration of TDS of the study area ranges from 216-535 mg/l in groundwater samples. According to the WHO (2004), the status of groundwater samples was classified into four steps which are: from (300-600mg/l) are good, (600-900 mg/l) are fair, groundwater sample is poor (900-1200mg/l) and from (>1200 mg/l) are not drinkable (Bairu.A et al., 2013).The spatial analysis for TDS of this study was classified into nine categories and are presented in the following figure (7). It was showed that most of boreholes in the study area range from (217 – 358mg/l) which are located in central part of study area. There is huge concentration of TDS (394 – 535mg/l) located in small central part.

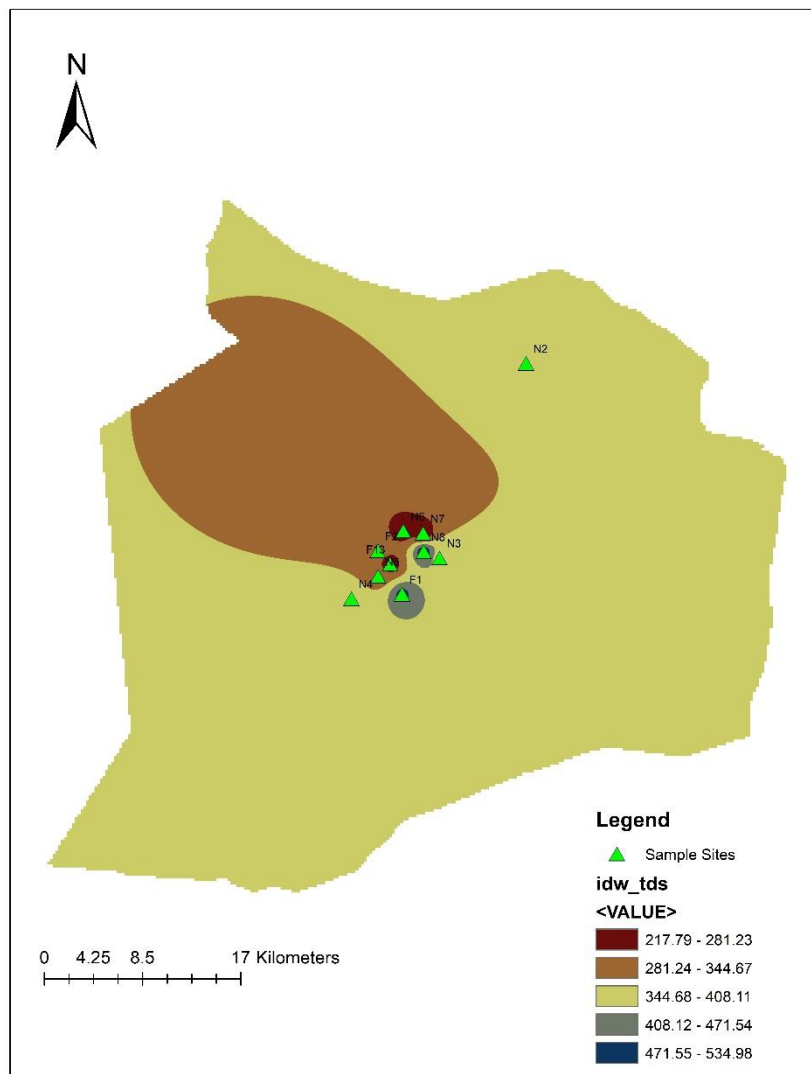


Figure 18: Spatial distribution map of TDS (mg/l) in Naāma

#### 4.2.4. Calcium

Calcium has an origin from natural and anthropogenic. (Raju.N et al., 2011) defined the rate of calcium in water into three categories which are from (0-75 mg/l) are low, (75-200 mg/l) moderate and (>200 mg/l) are poor quality. According to these values the spatial analysis of calcium in Naãma, almost all area has low (From Nord-West to South-Est) and moderate (From Nord to Nord-East) concentration of calcium. The figure (8) shown the spatial distribution of calcium is ranged from (64 -124 mg/l).

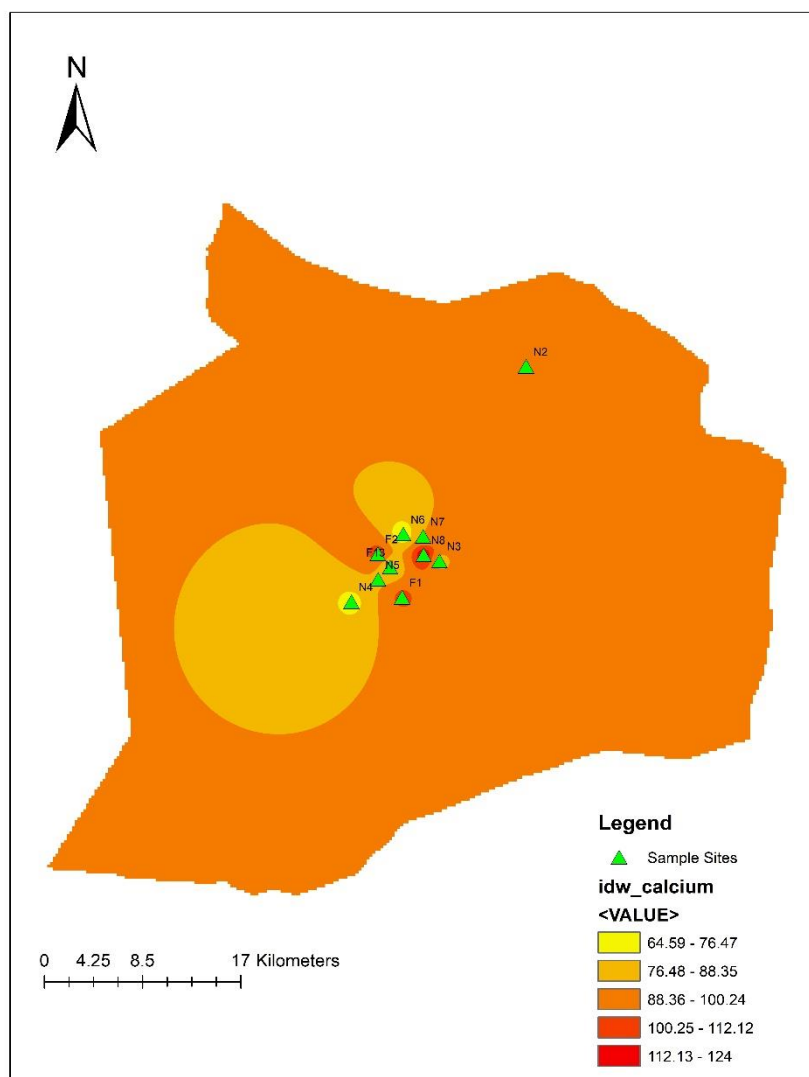


Figure 19: Spatial distribution map of Calcium (mg/l) in Naãma

#### 4.2.5. Magnesium

Magnesium is the main cause of hard water when the concentration is very high. It has been shown in the groundwater samples of Naãma the spatial analysis of magnesium is ranging from (43.2 – 74.4 mg/l) where the value of magnesium is lower than calcium (64 – 124 mg/l). In the map, it was shown that the magnesium concentration in the groundwater samples of study area ranged from (43.2 – 74.4mg/l) with the average and standard deviation as 55.44 and 9.89 mg/. There is a maximum value at Naãma (N8) 74.4 mg/l and minimum value at Naãma (F13) and Naãma (N4).

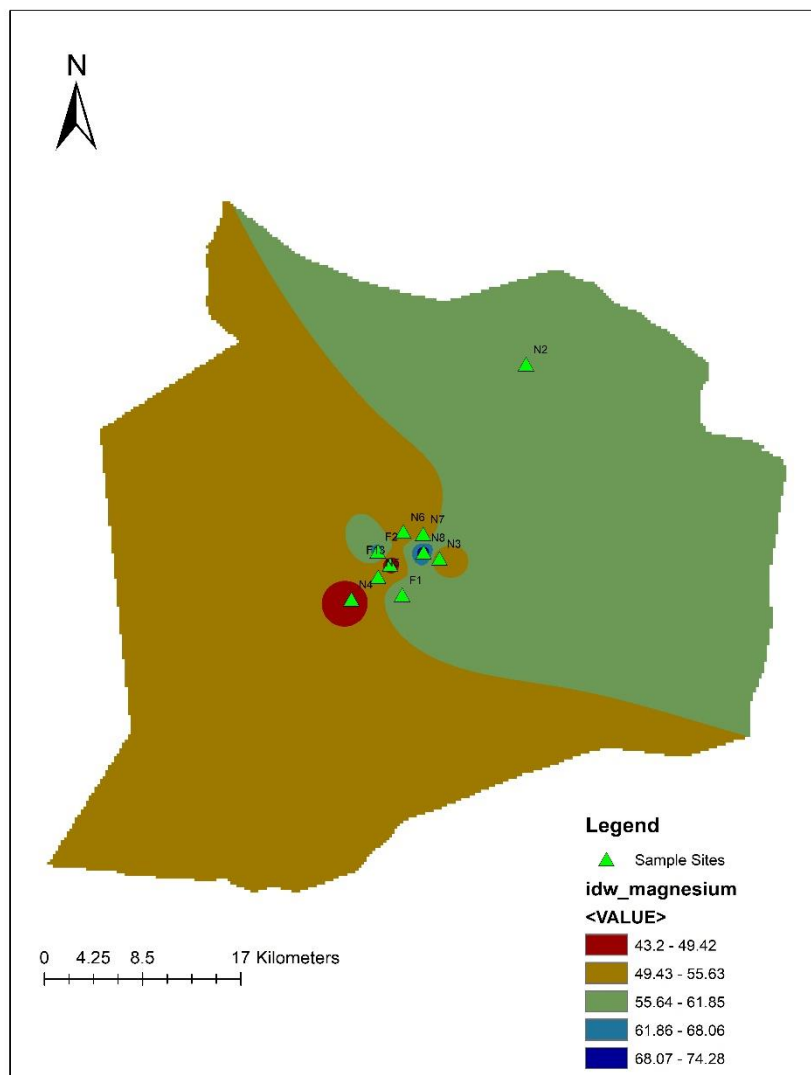


Figure 20: Spatial distribution map of Magnesium (mg/l) in Naãma

#### 4.2.6. Sodium

The association of anions and the temperature in the water solution may change the taste threshold concentration of sodium (Sadat-Noori S. M et al., 2013). According to the WHO (2004), the maximum permissible limit of sodium in drinking water is 200 mg/l. The values of sodium in study area are between 48 to 806 mg/l (Table 5). High sodium values are showed in central and south-east part of the study area (figure 10). The top high concentration of sodium (806 mg/l) was observed the in groundwater sample (Naãma F1) which is located in the down topographic area that can receive the pollution from agricultural runoff and enter into the groundwater due to leaching.

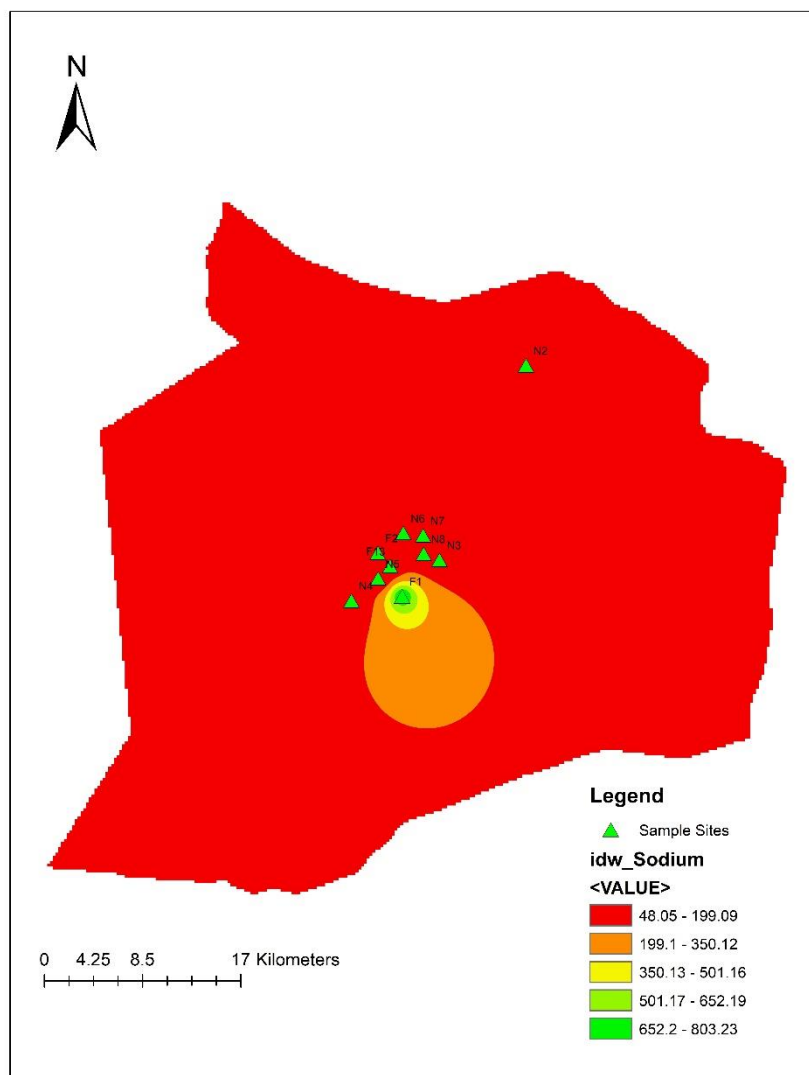


Figure 21: Spatial distribution map of Sodium (mg/l) in Naãma

#### 4.2.7. Potassium

Potassium is classed as seventh among the elements in terms of abundance. The general concentration in drinking water seldom can attain 20 mg/l (K.Ambiga, 2016). According to WHO (2004), the recommended daily requirement of potassium is greater than 3,000 mg/l. The spatial analysis of potassium of groundwater samples in the study area are shown in the figure 11. The concentration of potassium varies from 4 to 16.23 mg/l in the study area (Table 5). It was shown that the majority of the samples had potassium concentration within the desirable limit except for the groundwater sample Naãma (N2).

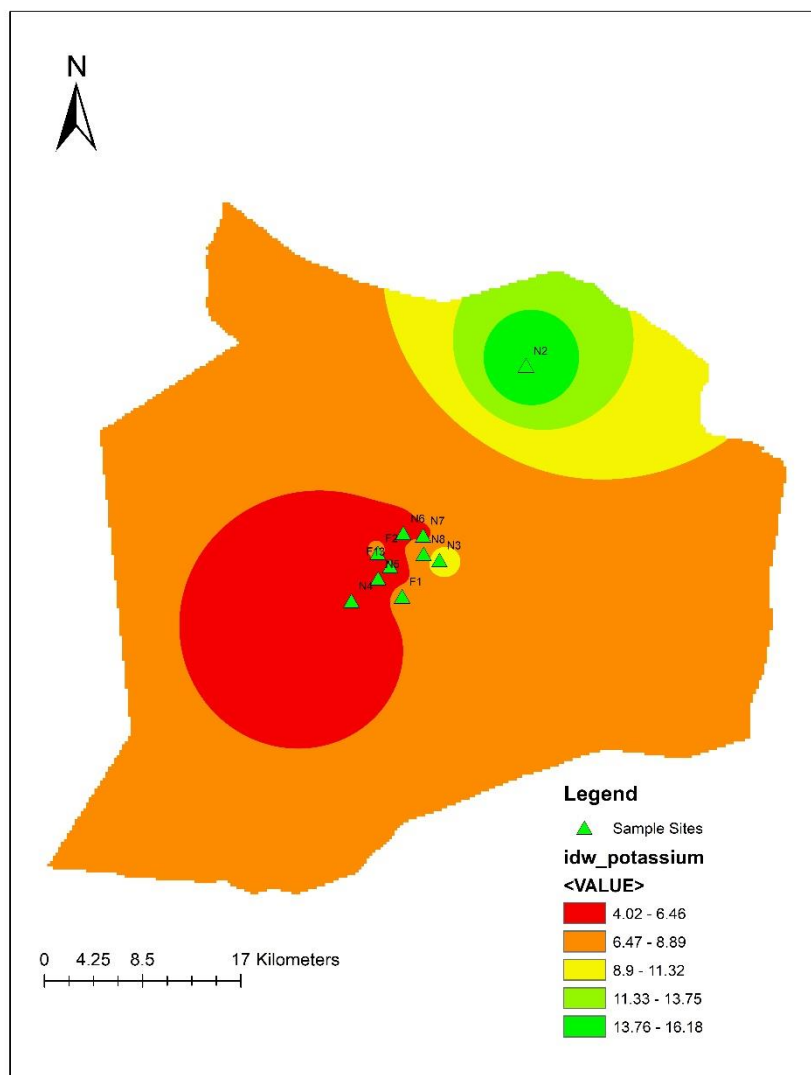


Figure 22: Spatial distribution map of Potassium (mg/l) in Naãma



#### 4.2.8. Chloride

There is a presence of low concentration of chloride in most natural water. High concentration of chloride can make water undrinkable and destroy supply pipes as well as vegetables and plants. Its concentration in the study area varies between 29 – 92.2 mg/l with average and standard deviation as 53.68 and 23.55965 respectively. The spatial analysis of chloride concentration is shown in the following figure 12 below. The concentration of chloride in all groundwater samples of the study area of Naâma was found less than WHO (2004) guidelines and Algerian standard, but relatively higher concentration of chloride was found in central and southeastern part of the Naâma. In the same study (RAHMANI, 2010) find out that in the North West and around part of Ain Sefra close to Naâma there was higher amount of chloride concentration.

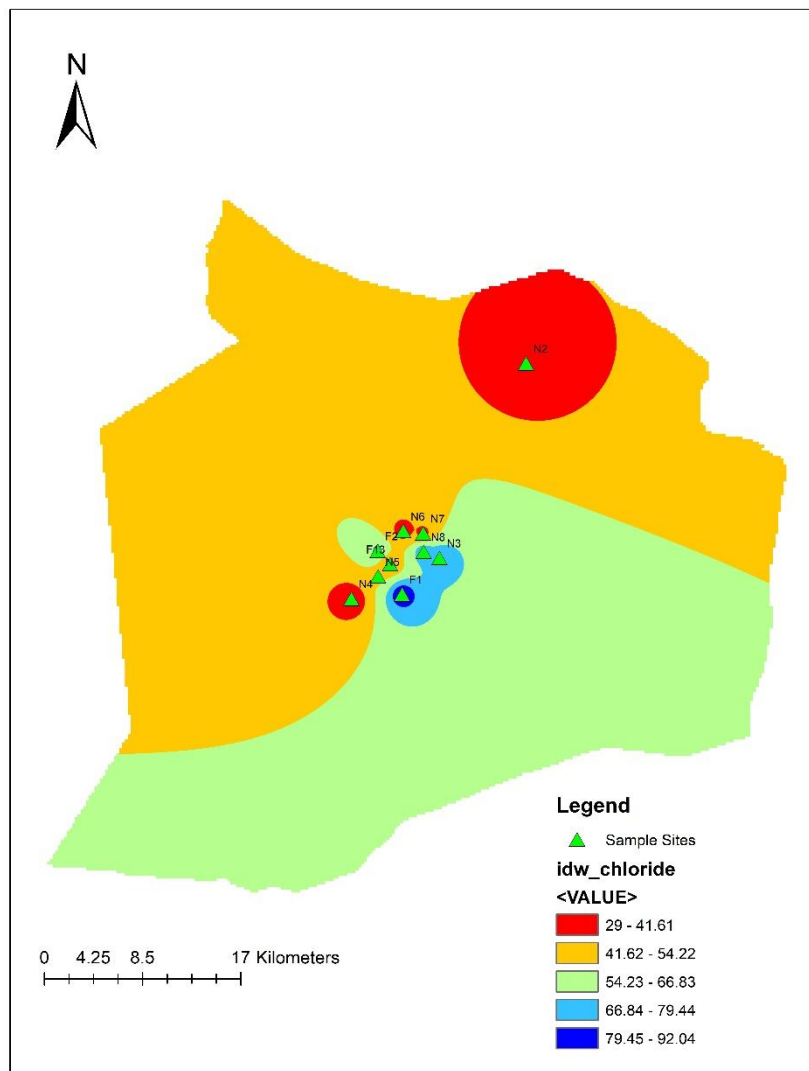


Figure 23: Spatial distribution map of Chloride (mg/l) in Naâma

#### 4.2.9. Sulfate

Sulfates originate from the dissolution of some minerals such as gypsum and anhydrite. Salt water intrusion and acid rock drainage are the main causes of the presence of sulfate in drinking water. The presence of sulfate in drinking water can make a laxative effect for consumers and very bad taste (Sadat-Noori S. M et al., 2013). The values of sulfate concentration are between 84.6-179 mg/l. high sulfate concentrations were found in groundwater samples Naãma (N8) (179 mg/l). the spatial analysis of sulfate is disturbed in south east and central part of the study area. Figure (13)

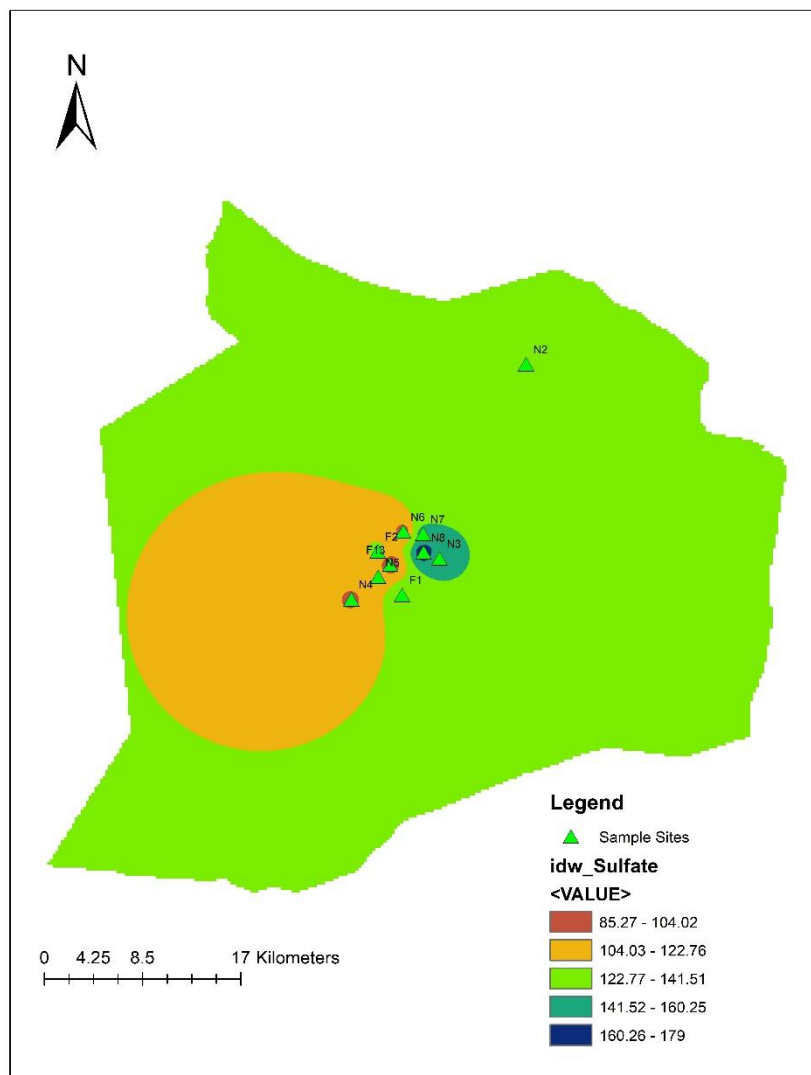


Figure 24: Spatial distribution map of Sulfate (mg/l) in Naãma

#### 4.2.10. Nitrate

The dissolution of nitrate in the water is very fast, and in groundwater the quantity of nitrate is higher than in surface water (TSEGAYE, 2014). Nitrates can find in traces quantities in surface water but it can produce a huge amount in the groundwater. It has some toxic effect for a certain aquatic organism when the level of concentration is above to 100 mg/l. The values of nitrate concentration in the groundwater samples of study area had high spatial distribution and vary from 0.38 to 28.6 mg/l with average and standard deviation of 14.881 and 9.92 mg/l respectively. It was observed from the statistical summary of water quality parameters (table 5) and figure (14) below, the maximum value of nitrate concentration was found on the central and south western sides of the study area.

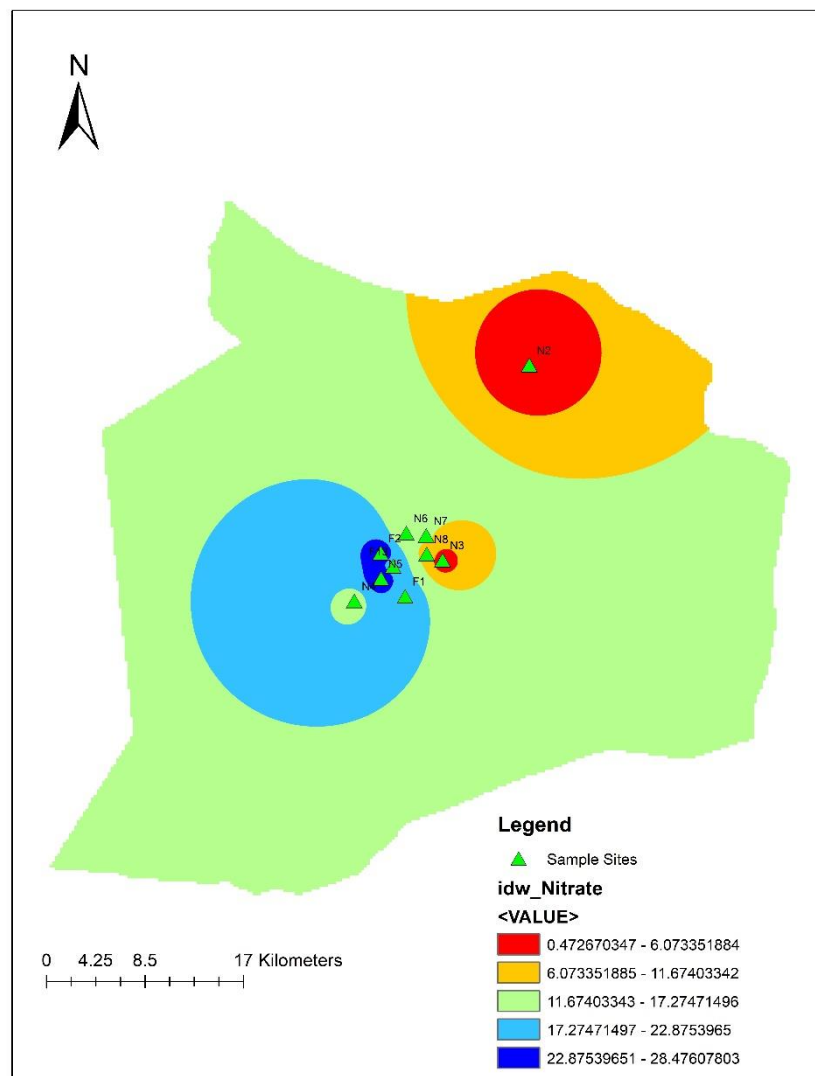


Figure 25: Spatial distribution map of Nitrate (mg/l) in Naāma

#### 4.2.11. Bicarbonate

The spatial distribution of bicarbonate concentration in the groundwater samples was shown in the following figure (15) below. According to the spatial distribution the concentration of bicarbonate ranged from 190 to 270 mg/l. The maximum values of bicarbonate concentration were found in groundwater samples in Naãma (N5). The spatial analysis of bicarbonate concentration is disturbed in central, west and south east part of the study area.

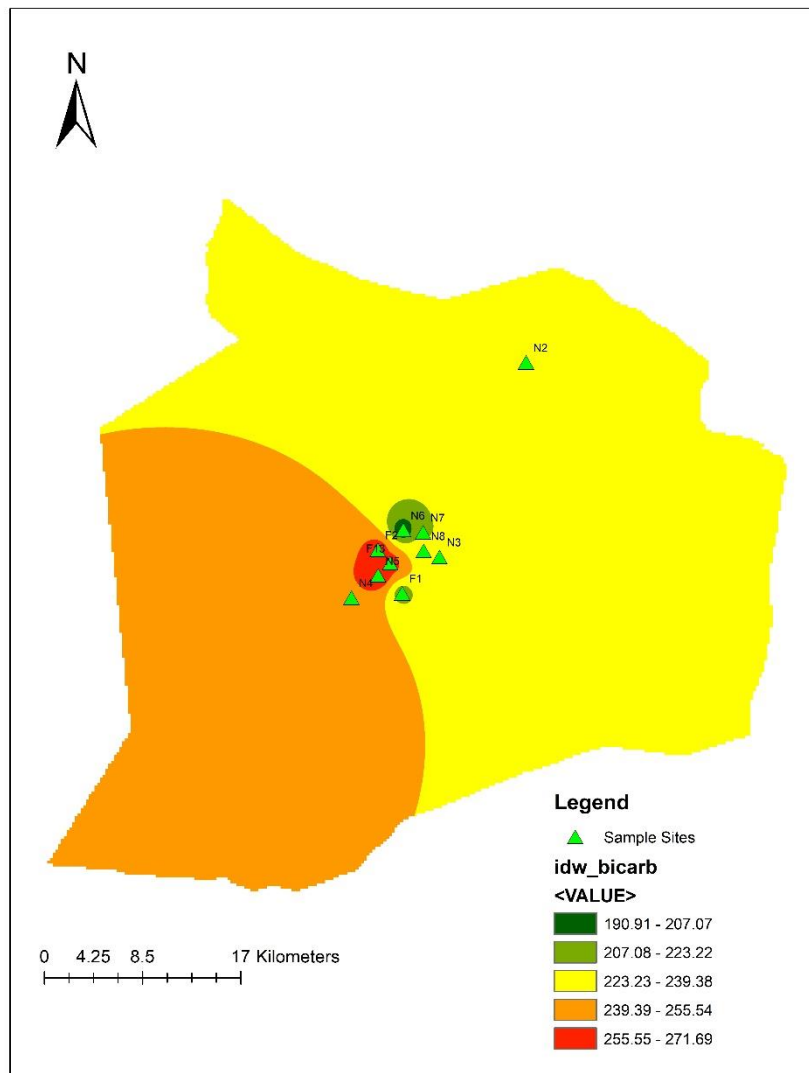


Figure 26 :Spatial distribution map of bicarbonate (mg/l) in Naãma

### 4.3. Calculation of water Quality Index (WQI)

The water quality index has been computed for this year 2018 in order to find the suitability of groundwater for drinking purposes. The first step in the computation of WQI was to choose the water quality parameters. The water quality parameters selected were pH, electric conductivity, total dissolved, Calcium, magnesium, sodium, potassium, chloride, sulfate, nitrate, nitrite and bicarbonate.

The second step was the calculation of the weights and relative weights for each water quality parameter. So the weightages were defined by using the formula mentioned in the methodology, and are shown in the following table 6

*Table 6: Resume of the statistics of the weights for this year 2018*

Parameter	Units	Standard (SI)	Weightages (wi)	Relative weight(Wi)
Temperature	°C			
pH		8.5	4	0.142857143
Electric Conductivity	μδ/cm	2000	2	0.071428571
TDS	mg/l	1000	2	0.071428571
Calcium (Ca <sup>++</sup> )	Mg/l	200	3	0.107142857
Magnesium(Mg <sup>++</sup> )	mg/l	50	2	0.071428571
Sodium(Na <sup>+</sup> )	mg/l	200	2	0.071428571
Potassium (K <sup>+</sup> )	mg/l	200	1	0.035714286
Chloride (Cl <sup>-</sup> )	mg/l	250	3	0.107142857
Sulfates(So <sup>4-</sup> )	So <sup>4-</sup> -mg/l	250	2	0.071428571
Nitrates(No <sup>3-</sup> )	mg/l	50	3	0.107142857
Bicarbonates(Hco <sup>3-</sup> )	Hco <sup>3-</sup> - mg/l	200	2	0.071428571
			Total=27	1

Table 7: WQI classification for the Groundwater sample

ID	Sample Stations	WQI	Classification
1	Naama (N3)	53.76706	Good Water
2	Naama (F1)	85.86922	Good Water
3	Naama(N2)	52.57544	Good Water
4	Naama (F13)	48.09789	Excellent Water
5	Naama (N4)	48.21005	Excellent Water
6	Naama (N6)	44.6105	Excellent Water
7	Naama (N7)	49.10983	Excellent Water
8	Naama (N5)	54.22632	Good Water
9	Naama (F2)	62.58127	Good Water
10	Naama (N8)	63.75071	Good Water

The last step was calculation of the sub index after determining the relative weights and quality rating scale. Then the water quality index values were found using this formula. WQI has been classified into five classes (Table 4): excellent, good, poor, very poor and unfit for drinking.

Geographical Information System was used to identify the area of suitable water quality based on the water quality parameters. Spatial distribution maps of WQI for the year 2018 were created for this area by using the inverse distance weighted method.

The entire water quality index (WQI) of groundwater in Naãma was found to be either excellent or good. In some boreholes of the area like Naãma (F13), Naãma (N4), Naãma (N6), Naãma (N7) the water quality was found to be excellent and suitable for drinking purposes. Meanwhile, the water quality index in boreholes for the area like Naãma (N3), Naãma (F1), Naãma(N2), Naãma (F13), Naãma, (N4) Naãma (N6), Naãma (N7), Naãma (N5), Naãma (F2), Naãma (N8) was found good. The variation of the WQI for each sampling point in the area is shown in the figure (6).

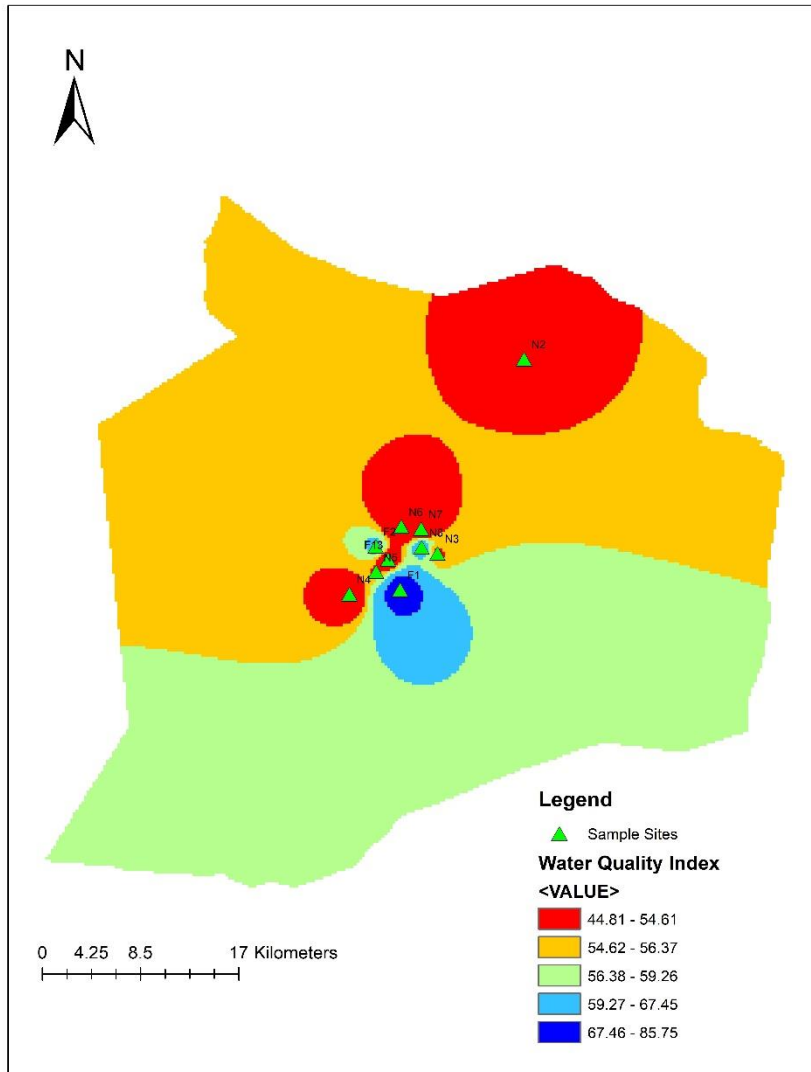


Figure 27: The value of WQI for groundwater sample

## **CHAPTER FIVE: CONCLUSION AND RECOMMENDATION**

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### **5.1. CONCLUSION**

The objective of this study was to create a groundwater quality map to easily assess the quality of groundwater in Naâma. Spatial and inverse distance weighting were used through GIS in order to interpolate the data in the area. These methods have shown their performance in terms of realization of groundwater quality in Naâma.

The physico-chemical parameters which were chosen from different sites of groundwater of the study area were analyzed in the laboratory. The results report that the different water quality parameters such as pH conductivity, total dissolved, calcium, magnesium, potassium, chloride, sulfate and nitrate were in the permissible limit given by the guideline of WHO and Algerian standard. However, bicarbonate was found to exceed the permissible limit, but it does not have any impact on drinking water purposes.

The WQI classification for each groundwater sample in the study area shown in table 7 and figure 16 ranged from 44.61 to 85.86. The estimation found that 40% of the groundwater samples were classified to be in excellent condition and the rest of 60% were found to be in a good water class according to the calculation of WQI method.

The spatial distribution maps created for several physico-chemical parameters with the ArcGIS software could be helpful for designing water program. The combination of WQI and GIS can be used by water engineering actors and decision makers in order to understand and assess groundwater quality in the study area.



## **5.2. RECOMMENDATIONS**

i. It is recommended to use GIS and its application to produce maps to communicate the water situation to the public who are managing the groundwater resources in a particular area. Water quality indices should be used to understand effectively the situation of water quality.

ii. It is recommended further investigation of microbiological parameter must be carried out in order to study the degree of pollution and anthropogenic effect on groundwater of this area.

iii. Groundwater quality monitoring should be a very important routine procedure in order to secure the protection and conservation of groundwater across the region.

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## APPENDICES

### APPENDIX I: DETERMINATION OF WQI

	ph		conduc-tivité		TDS		ca++		mg++		na+		k+		cl-		so4-		no3-		WQI		WQI Clas-sifi-cation		
	QI	Sii	QI	Sii	QI	Sii	QI	Sii	QI	Sii	QI	Sii	QI	Sii	QI	Sii	QI	Sii	QI	Sii	QI	Sii			
Naama (N3)	91.529 41	13.0 8	38.7 5	2.77	38. 7	2.7 6	4 2	4.5	100. 8	7.2	62	4.43	92.5	3.3 0	31.1 6	3.3 4	58.8	4.2	0.7 6	0.0 8	0.83	8.11	53.77	Good Water	
Naama (F1)	92.941 18	13.2 8	49.6 5	3.55	49. 6	3.5 4	5 2	5.5 7	124. 8	8.91	40	28.7 3	60.83 9	2.1 7	36.8 8	3.9 5	56.4	4.0 3	41. 4	4.4 4	1.1	7.64	85.87	Good Water	
Naama(N2)	94.470 59	13.5 0	38.8 2.77		38. 8	2.7 7	5 0	5.3 6	120	8.57	25. 5	1.82	135.2 5	4.8 3	11.6	1.2 4	49.6	3.5 4	1.2 6	0.1 4	1.27	8.04	52.58	Good Water	
Naama (F13)	92.823 53	13.2 6	27.5 5	1.97	22. 4	1.6 0	3 6	3.8 6	86.4	6.17	28. 5	2.04	33.67	1.2 0	15.2	1.6 3	33.8 4	2.4 2	41. 6	4.4 6	1.27	9.50	48.10	Excellent Wa-ter	
Naama (N4)	90.941 18	12.9 9	38.6 2.76		39. 1	2.7 9	3 6	3.8 6	86.4	6.17	24	1.71	41.92	1.5 0	11.6	1.2 4	40.4	2.8 9	29. 8	3.1 9	1.1	9.11	48.21	Excellent Wa-ter	
Naama (N6)	90.823 53	12.9 7	28 2.00		23. 1	1.6 5	3 2	3.4 3	100. 8	7.2	27. 5	1.96	50	1.7 9	13.6 8	1.4 7	38.0 8	2.7 2	24. 6	2.6 4	0.97	6.79	44.61	Excellent Wa-ter	
Naama (N7)	91.058 82	13.0 1	33.5 2.39		21. 6	1.5 4	4 4	4.7 1	105. 6	7.54	26. 5	1.89	50	1.7 9	14.8 8	1.5 9	59.2	4.2 3	23. 8	2.5 5	1	7.86	49.11	Excellent Wa-ter	
Naama (N5)	90.705 88	12.9 6	33.7 5	2.41	31. 8	2.2 7	4 4	4.7 1	105. 6	7.54	25. 5	1.82	33.33	1.1 9	20.9 6	2.2 5	45.2	3.2 3	57. 2	6.1 3	0.93	9.71	54.23	Good Water	
Naama (F2)	92.470 59	13.2 1	38.1 5	2.73	32. 8	2.3 4	5 4	5.7 9	129. 6	9.26	69. 5	4.96	58.33	2.0 8	27.9 2	2.9 9	51.2	3.6 6	56. 6	6.0 6	1.33	9.5	62.58	Good Water	
Naama (N8)	90	12.8 6	54.2 3.87		53. 5	3.8 2	6 2	6.6 4	148. 8	10.6 3	62	4.43	67.50	2.4 1	30.8 4	3.3 0	71.6	5.1 1	20. 6	2.2 1	0.93	8.46	63.75	Good Water	



**APPENDIX II: Data for Temperature and Precipitation obtained from Naãma Station: LAT:33.26 and LONG: -0.3 with the help of (Climate Engine)**

Year	Max	Min	Precipitation				
1980	22.47204781	8.581611202					
1981	23.25337452	9.032233425	124.2282				
1982	22.45934575	8.957570411	244.7072	2000	24.09934	9.451254	151.0216
1983	23.88137589	9.313678356	129.1678	2001	24.92746	10.31063	135.2135
1984	22.36775301	8.565025683	153.3635	2002	24.14922	9.501865	185.8782
1985	23.38340082	9.280516712	191.5149	2003	23.46838	9.914486	316.8249
1986	22.61476082	9.040139452	261.7178	2004	22.97439	9.294741	184.5117
1987	24.12301562	10.13038548	176.6346	2005	23.82541	9.641085	200.6838
1988	23.55485683	9.504579235	194.5373	2006	23.49483	9.977284	237.1594
1989	23.21809644	9.684490137	210.27	2007	23.44206	9.305193	209.1756
1990	23.16179753	9.846542192	219.7077	2008	22.78223	9.305186	352.7668
1991	21.50336329	8.242552877	248.8094	2009	22.71523	9.435515	230.9939
1992	21.73041721	8.091182787	164.5459	2010	23.54354	9.996681	232.6975
1993	22.82651041	8.830649041	226.7662	2011	22.81617	9.528373	245.1662
1994	23.67179233	9.609844384	199.8699	2012	22.83603	9.44203	297.5569
1995	23.11484219	9.361564658	163.477	2013	22.31704	8.788965	174.6832
1996	22.28437787	8.818775683	222.2894	2014	23.22456	9.715881	225.7647
1997	23.51537644	9.730694247	225.1255	2015	23.43202	9.817505	178.0031
1998	23.62464685	9.32054	151.3799	2016	23.71451	9.961755	232.2461
1999	23.87187918	9.80833863	187.2162	2017	23.85023	9.83885	152.7774

**APPENDIX III: Field visit**

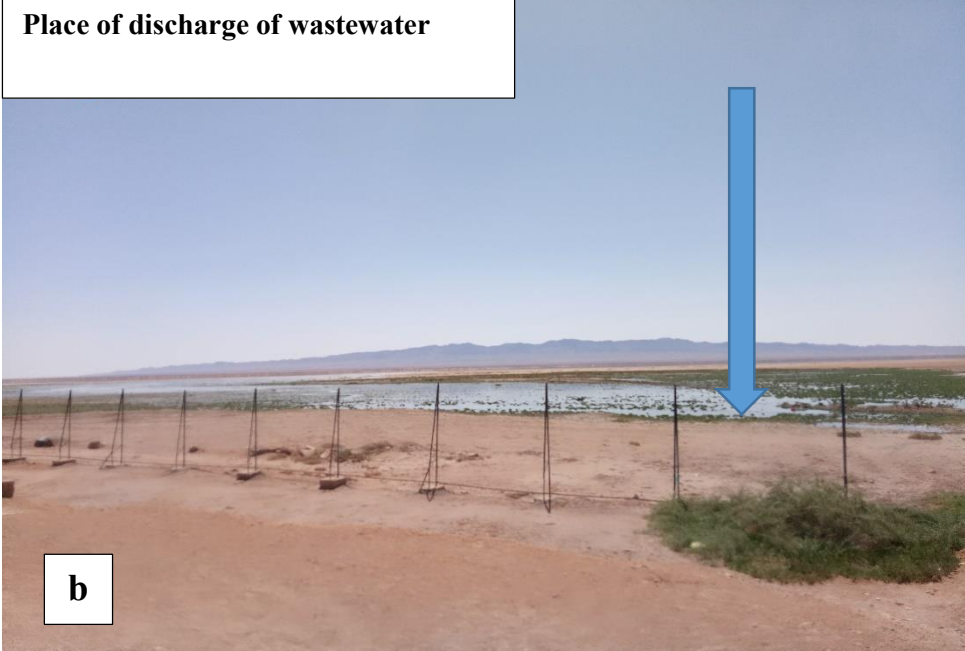




Figure: Visit of wastewater treatment plan of Naāma



**Appendices : Research budget**

<b>N°</b>	<b>Items</b>	<b>Quantity</b>	<b>Unit Price(in Dinar Dz)</b>	<b>Unit Price(in US dollars)</b>	<b>Total Price(in Di-nard dollars)</b>	<b>Total(in US dollars)</b>
1	Transport	2	11 000	104	22 000	208
2	Data Analysis and Data collection	1	190 400	1 800	190 400	1 800
3	Books -Modelling groundwater system -Groundwater Pollution in Africa - Physical and Chemical Hydrogeology	3	10 600	100	31 800	300
			10 600	100		
			10 600	100		
			10 600	100		
4	Apparatus of physical		40 000	378	44 000	416
	-Muliparameter EC 500					
	-Thermo Electronique		4000	38		
5	Miscellaneous		11300	107	11 300	106
	<b>Grand Total</b>				299500	<b>2830 USD</b>

## Appendix: Receipt



**BET AFAK**  
 N° de M fiscale : 183450300265193  
 N° de compte bancaire :  
 003 00729 101375 300 0 64 BADR Ain Sefra  
 Gérant: Khelifi Ahmed  
 E-Mail : hmida103@gmail.com

NAAMA LE : 16/05/2018

### **FACTURE N°04/2018**

**Client:** Mountassir Mahamat Ali

**Intitulée de l'opération :** ECHANTILLONNAGE ET ANALYSES PHYSICOCHIMIQUES DES EAUX DE LA REGION DE NAAMA

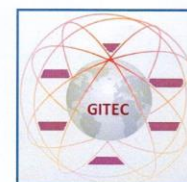
**Lieu de prélèvement :** Naama

N°	Désignations	U	Quantité	Prix U	Montant
1	Echantillonnage	U	10	4000.00	40 000.00
2	Analyses physicochimiques	U	10	12000.00	120 000.00
				<b>Le montant en HT</b>	<b>160 000.00</b>
				<b>Dont TVA 19% égale</b>	<b>30 400.00</b>
				<b>Le montant TTC</b>	<b>190 400.00</b>

Arrêté à la somme de :

**Cent quatre vingt dix milles quatre cent dinars et zéro centimes**

**Le gérant de BET**



## Geo-Spatial Information Technology Consult

**Email:** gitekconsult@gmail.com  
**Tel.:** +60149587011; +2348036224676

**Address:** 2 Muri Road/Lassa Street, Kaduna, Nigeria

**Our Ref:** GITC/1/3 **Your Ref:**

**Date:** June 19, 2018

### **INVOICE FOR BOOKS SUPPLY:**

S/No.	Book Title	Amount (US Dollars)
1	Modelling Groundwater Systems: Understanding and Improving Groundwater Quantity and Quality Management, by G. Y. Ebrahim (2013)	100
2	Groundwater Pollution in Africa, by Y. Xu & B. Usher (Eds.) (2006)	100
3	Physical and Chemical Hydrogeology, by P. A. Domenico & F. W. Schwartz (1998)	100
<b>TOTAL</b>		<b>300</b>

Yours truly,



مجمع فنادق سياحة وخدمات معدنية  
 HÔTELLERIE, TOURISME & THERMALISME

**E.G.T OUEST**  
 Au Capital social de 394.350.000 DA  
 HOTEL EL MEKHTER AIN SEFRA

HOTEL EL-MEKHTER AIN SEFRA W.NAAMA Ain-Sefra le :13/05/2018

Code fiscal N°098301019004243 01

RC N° 99 B 2222880

FACTURE N° : 0637  
 DOIT: Mrs MOHAMED MOUNTASSIF

ART N°4530010 001

CHAMBRE : 23- 1 PAX

TEL : 049 . 76 . 14 . 17 - FAX : 049 . 55 . 15 . 98

MOIS DE MAI 2018	12.05.2018	13 . 05 . 2018	14.05.2018			
Report		2000,00	4000,00			
Chambre-	2000,00	2000,00				
Lit supplémentaire						
Petit Déjeuner						
Boissons cafétéria						
Cuisine						
Lunch						
Boisson cave						
Diner						
Boisson cave						
Téléphone						
Salon de Thé						
DIVERS -						
TOTAL du jour HT	2000,00	4000,00	4000,00			
T.V.A 9%						
Droit de Timbre			40,00			
Taxe de séjour			20,00			
TOTAL enTTC			4060,00			

SOIT:QUATRE MILLE SOIXANTE DA.

LA RECEPTION



**فاوزي محمد**  
 ميسارة الأجرة  
 في المستقبل الواد الأخضر تلمسان  
 N° 15/04391

DATE تاريخ CLIENT الزبون PAGE الصفحة  
 12-05-18 Mountassif

Livré à سلمت إلى  
 Mahamet Mountassif

**Bon de Livraison N°** ..... نند تسليم رقم:

الكمية Qty	التعيين Designation	سعر الوحدة Prix-U	المجموع Total
1	Tlemcen - Andeka Transport	1100	11000



# GETALAB Sarl

Au capital de : 10 000 000 DA  
 Conseil, Formation en Entreprises, Etudes Techniques Analyses et Laboratoire  
 Fournitures de matériels scientifique, verrerie et réactifs  
 R.C N° 09B0263934 13/00 Art.Imp:1301/6140015 Mic.Fisc: 000913026393466  
 CPA agence Tlemcen El Kiffane 00454 RIB 004 400 000 6419 24

Tlemcen le 09-05-2018

## BON DE LIVRAISON N° 049

Client : Mr MOUNTASIR Mohamed

N°	Désignation	Qts	
01	Thermomètre électronique maxi mini	01	4000.00
02	Multi paramètre EC500	01	40000.00
Total HT			44000.00

Gérant  
 SARL GETALAB El Kiffane  
 781, Bis les Oliviers El Kiffane  
 Tlemcen ALGERIE  
 Tél: 043.26.63.84 Fax: 043.26.61.28

l'intéressé

E.U.R.L. GRAND HOTEL D'ORAN

FACTURE  
 DATE 12.05.2018 Dinkar  
 Table N° 0205405 N° 00636

NOTE DE RESTAURANT

QUANTITE	DESIGNATION	MONTANT
01	MILKSHAK 30000	30000
01	ENTRÉE cake + Dessert	12000
01	DISSERT 30000	30000
01	Eau MINÉRALISÉE	6500
		126500
	NT=2000	
TOTAL GENERAL ....		128500

Grand Hôtel d'Oran  
 Note de Restaurant  
 Table N° 0205405 128500  
 Date : 12.05.2018  
 FACTURE  
 TOTAL  
 N° 00636

بريد الجزائر  
 ALGERIE POSTE  
 مصلحة الطرود البريدية  
 Service des Colis Postaux  
 Arrivée N° \_\_\_\_\_  
 C. F. 22-07-18  
 ووصول رقم  
 CP 52 طاب  
 بطاقة تسليم  
 FICHE DE LIVRAISON  
 Agence Telemcen  
 M. Mohamed Marfasi  
 ال  
 Bureau de \_\_\_\_\_  
 مك

رقم الطرود N° des colis	المرسل Expéditeur	رسوم للتحميل Frais à percevoir	قصاصمة الجمرک Volet de douane
<u>CP 308256458 my</u>		رسوم الجمرک Droits de douane	N° _____ رقم
		التحويل Remboursement	قبض Reçu le _____
		رسوم عن التحويل Taxe sur rembt	colis
		الطابع Timbre	في le _____
		رسوم بريدية Taxes postales	الإمضاء Signature: _____
		خزن Magasinage	
		Total الجملة	<u>2700 DA</u>