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# Characterization of the State of Pollution by Nitrates in the Groundwater in Arid Zones Case of Eloued District, South-East of Algeria

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***Abstract*—**This study aims to assess sensitivity to nitrate pollution and monitor the temporal evolution of nitrate contents in groundwater using statistical models and map their spatial distribution. The nitrate levels observed in the waters of the town of El-Oued differ from one aquifer to another. Indeed, the waters of the Quaternary aquifer are the richest in nitrates, with average annual contents varying from 6 mg/l to 85 mg/l, for an average of 37 mg/l. These levels are higher than the WHO standard (50 mg/l) for drinking water. At the water level of the Terminal Complex (CT) aquifer, the annual average nitrate levels vary from 14 mg/l to 37 mg/l, with an average of 18 mg/l. In the Terminal Complex, excessive nitrate levels are observed in the central localities of the study area. The spatial distribution of nitrates in the waters of the Quaternary aquifer shows that the majority of the catchment points of this aquifer are subject to nitrate pollution. This study shows that in the waters of the Terminal Complex aquifer, nitrate pollution evolves in two major areas. The first focus is South-North, following the direction of underground flow. The second is West-East, progressing towards the East zone. The temporal distribution of nitrate contents in the water of the Terminal Complex aquifer in the city of El-Oued showed that for decades, nitrate contents have suffered a decline after an increase. This evolution of nitrate levels is linked to demographic growth and the rapid urbanization of the city of El-Oued.

***Keywords*—**Anthropogenic activities, nitrates, pollution, El-Oued, Algeria.

## I. Introduction

IN recent years, Algeria has witnessed climatic changes and disturbances, which have led to water scarcity and thus made it difficult to obtain it. Thus, it has become one of the concerns of all humanity [1]-[3]. For this reason, for decades, states and governments in Africa in general and Algeria in particular have been working to provide their populations with adequate hydraulic infrastructure [4]-[6]. In El-Oued, the population growth and urbanization of the city have contributed to making the enormous efforts made by the State ineffective [7]-[9]. Thus, the quantity of water resources supplied to populations remained insufficient. This caused an increase in the water needs of the populations, which until then had not been met by the numerous boreholes installed by the state, at El-Oued in the deep aquifer (Continental Terminal (CT) and Continental Intercalary (CI)) [10]-[12]. Indeed, the increase in people's water needs has led to an increase in borehole flow rates, which is the cause of numerous borehole breakdowns.

The latest studies carried out on the quality of groundwater water in the El-Oued region noted that these waters were facing anthropogenic pollution [13], [14]. In addition, studies show that El-Oued's water resources are facing pollution of anthropogenic origin [16]-[20].

The aim of this work is to clearly identify on the one hand the practices which promote the entrainment of fertilizers in groundwater, and on the other hand those which slow down or prevent this entrainment. In order to know the temporal and spatial evolution in the concentrations of nitrates present in the well water of the study area, we relied on the technical data available at the level of the Algerian Water Department, Hydraulic Department, El-Oued city; we also relied on hydrogeological data and information for the study area.

Several tools (geological, hydrodynamic, chemical, statistical and computer science) were used to better interpret the data acquired.

## II. Materials and Methods

### A. Study Area

The district of El-Oued is an arid region, part of the Northern Sahara shared by Tunisia, Libya and Algeria (Fig. 1). It is located in the South-East of the Algerian Sahara. Our study area presents the commune of Eloued and the commune of Kouinine in the Oued Souf valley, at 7° E and 33.5° N (Fig. 1) [8].

The Eloued region is characterized by a hyper arid climate of the type Saharan with high temperatures and low precipitation [15]-[17]. The stratigraphy of the region is characterized by sedimentary series ranging from Lower Cretaceous to Quaternary deposits.

### B. Data Characterization

This study is based on 20 samples for the period of 2011, 2012, 2016, 2018 and 2020, the analyzes were carried out in the physicochemical analysis laboratory of the ADE in the commune of El-Oued. These elements are: calcium, sodium, magnesium, chloride, potassium, bicarbonate, nitrate, sulfate, electrical conductivity and pH values.

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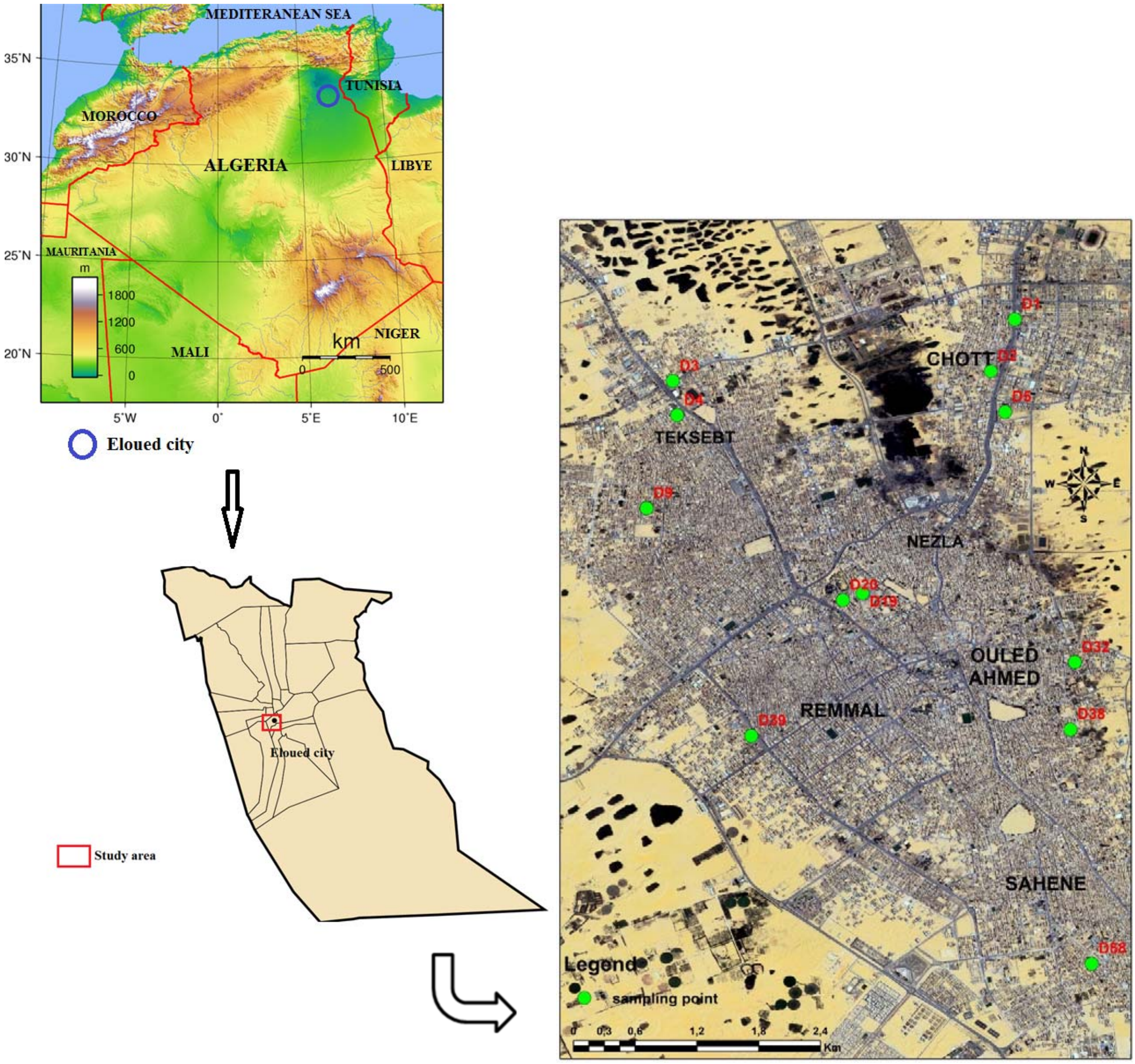


Fig. 1 Geographic location of the study region

*C. Phreatic Nappe*

After selecting the dataset for trend determination, the first step is to study their characteristics. This evaluation generally begins with the graphical representation of the data followed by the calculation of the basic statistics that characterize the chronicle [18], [19]. Fig. 2 shows the nitrate contents (mg/l) of the free water table in the study region at different periods.

The median weights of the box groups are more variable to the next. The interquartile range box indicates a long distance between the first quartile and the third quartile [19], [20].

Generally speaking, the nitrate levels measured are generally moderate to high, but vary in a range of two orders of magnitude, between 0.26 mg/l and 176 mg/l. The highest content (176 mg/l) was measured at well D6 during the 2018 period.

The 2016 period presents generally low nitrate levels, varying between 0.26 mg/l to 19.8 mg/l (n = 15) with an average of around 9.11 mg/l and a median of 13.5 mg/l (Fig. 2).

The 2018 period presents generally high nitrate levels, varying between 2.33 mg/l to 176 mg/l (n = 15) with an average and median of around 59 mg/l and 30 mg/l respectively (Fig. 2).

The water points in our study are represented by drains (Fig. 3). The total collection points in the study are drains capturing the free aquifer with pumping. Water points are located in public spaces and private gardens.

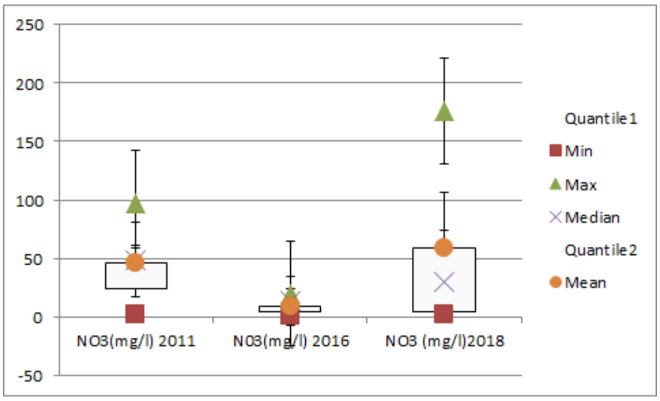


Fig. 2 Statistical indicator for the nitrate levels (mg/l) of the phreatic nappe in the study region

*D. Determination of the Nitrate Content Curve at Each Water Catchment*

The first objective is to identify the temporal evolution of nitrate concentrations, on an annual scale. Once these graphs were obtained, we linked each graph of evolution of nitrate levels to its catchment. Based on the shape of the nitrate content evolution curves, we determined three types of curves (Table I and Fig. 4).

- Type 1: levels less than 20 mg/l;
- Type Z: stabilization of contents after a reduction;
- Type M: the contents show after stabilization or reduction.

The nitrate levels and their evolution over time in a given catchment are linked to the land use of the study area and the evolution of this use. On the other hand, type 1 and Z only cover 8.33% and 16.66% of the area of the study sector.

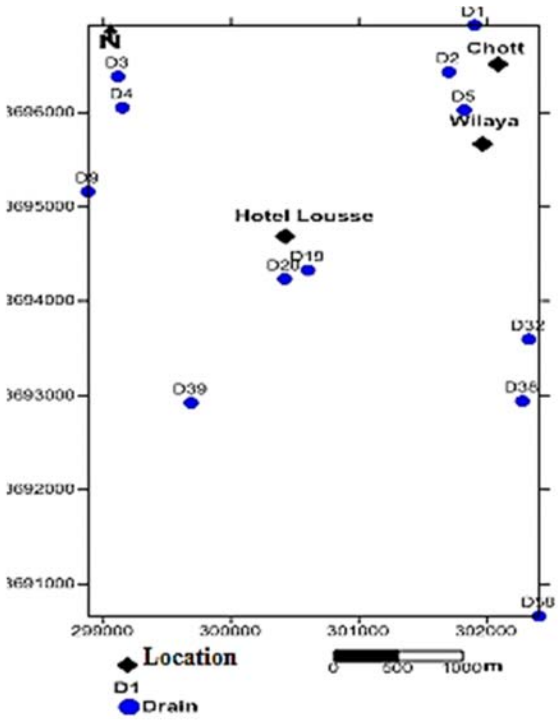


Fig. 3 Spatial distribution of water points (2011, 2016 and 2018)

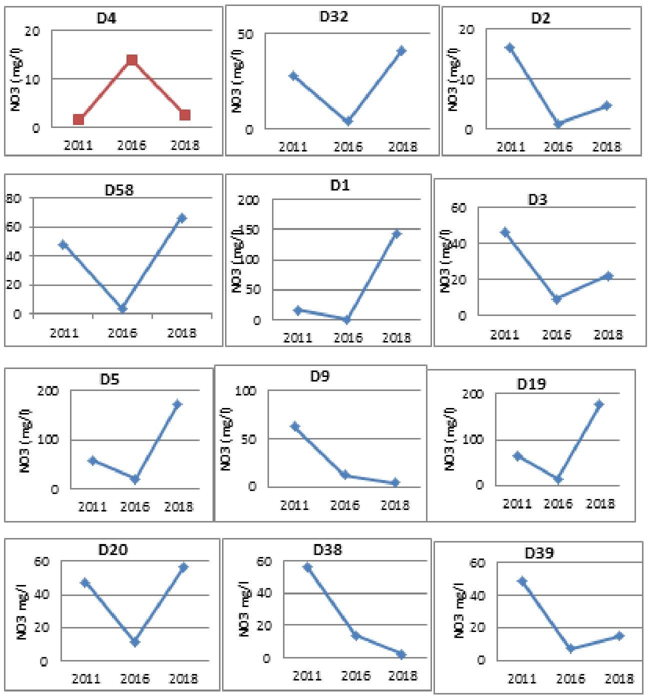


Fig. 4 Evolution curves for nitrate contents (mg/l) for the free water table

We note that type M occupies almost the majority of the surface of the study area with a percentage of 75%.

Table I shows the types of evolution of nitrate contents (phreatic map), we note that type M occupies almost the majority of the surface of the study area at 75%, on the other hand, type 1 and Z only covers 8.33% and 16.66% of the area of the study area.

TABLE I
TYPE OF ELEVATION OF NITRATE CONTENTS (PHREATIC NAPPE)

| Type | Number | % |
|---|---|---|
| Type 1 | 1 | 8.33 |
| Type M | 9 | 75 |
| Type Z | 2 | 16.66 |

Observation of the spatial distribution of the type of evolution of nitrate contents of the waters of the surface aquifer of the city of El-Oued (Fig. 5) indicate a convergence of growth of these for seven years (2011 to 2018). This variability of evolution is a function of the capturing fields.

Three types of changes in nitrate levels are defined:

- Type 1 less than 20 mg/l, it only covers 8.33% of the study area.
- Type Z covers 16.33% of the surface of the study area extending from the North of the study region to the South-East.
- Type M, occupies 75% respectively of the study area, and covers the majority of water points.

*E. Calculation of the Average Nitrate Content in Each Catchment per Three-Year Period*

Based on the nitrate content values measured at the catchments, the average contents were calculated in each catchment for three periods of three years each (Fig. 6). Average1: average for 2011, 2016 and 2018.

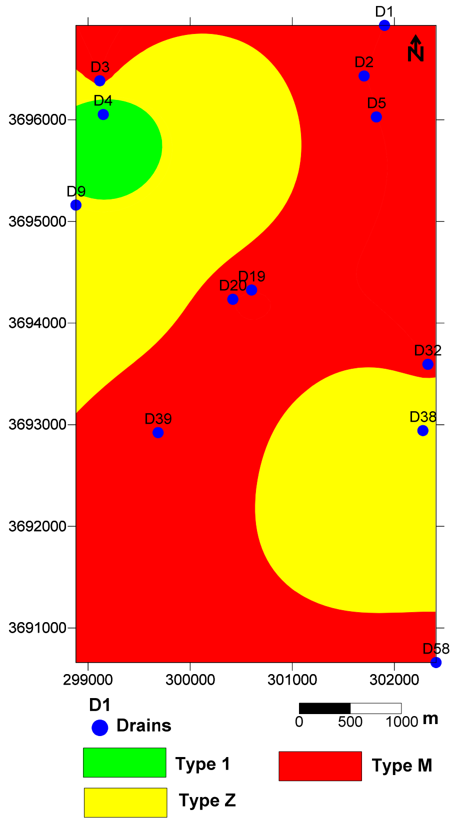


Fig. 5 Spatial distribution of the type of evolution of nitrate contents (Phreatic nappe)

Observation of changes in average nitrate levels (mg/l) for 2011, 2016 and 2018 of the waters of the free aquifer of the city of El-Oued (Fig. 6) indicates a variable growth of these. In the extreme Southwest of the study region there is a lower growth in nitrates, it is less than 20 mg/l. This shows that these waters are of good chemical quality and more protected against pollution. Average levels vary from 20 mg/l to 50 mg/l. This increase is oriented from South to North of the study region. Except in the far North, the study region records low nitrate levels of less than 20 mg/l.

In the center of the study region towards the east, average nitrate levels exceed WHO standards. The high values are measured at the Teksabt, Chott, Sahenne and Louss hotel sample, they mainly come from wastewater and waste pits, in urban areas.

*F. The Deep Aquifer*

After selecting the dataset for trend determination, the first step is to study their characteristics. This evaluation generally begins with the graphical representation of the data followed by the calculation of the basic statistics that characterize the chronicle [16]-[20].

Fig. 7 shows the nitrate contents (mg/l) of the deep aquifers in the study region at different periods; there is data symmetry for each data series.

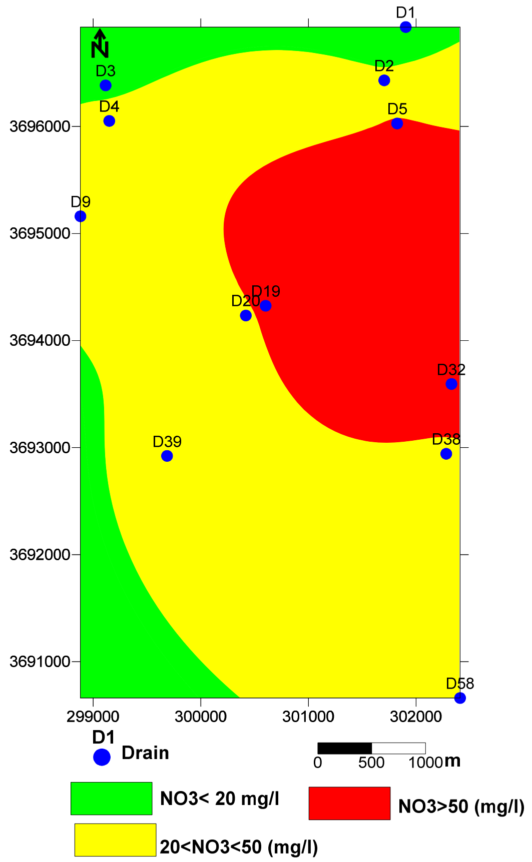


Fig. 6 Changes in average nitrate levels (mg/l) for the years (2011, 2016 and 2018), (phreatic nappe)

The median weights of the box groups are more variable to the next. The interquartile range box indicates a fairly long distance between the first quartile and the third quartile [16]-[20].

Generally speaking, the nitrate levels measured are generally moderate, but vary in a range of two orders of magnitude, between 0.125 mg/l and 62 mg/l. The highest content (62 mg/l) was measured at the Bouhmid 1 well during the 2017 period.

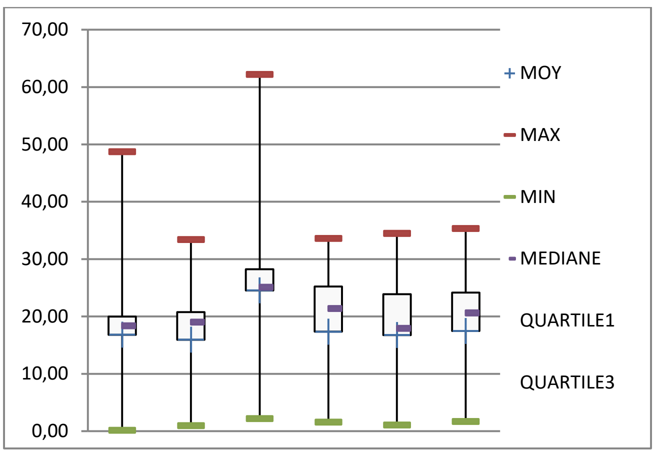


Fig. 7 Statistical indicator for nitrate levels (mg/l) (deep aquifers)

The 2015 period presents generally low nitrate levels, varying between 0.93 mg/l to 33.37 mg/l (n = 15) with an average of 15.94 mg/l and a median of 20.76 mg/l (Fig. 7).

The 2017 period presents generally high nitrate levels, varying between 2.17 mg/l to 62.17 mg/l (n = 15) with an average and median of around 25.07 mg/l) (Fig. 7).

*G. Characterization of Deep Aquifer Water Sample*

The water sample in our study is represented by boreholes. More than 80% of the catchment points in the study are boreholes that capture the aquifer of the terminal complex with pumping, and 20% capture the aquifer of the continental intercalary without pumping (Fig. 8). Water points are located in public spaces and private gardens.

The different types of catchments encountered in the study area are generally carried out as part of programs to strengthen the water supply.

*H. Determination of the Nitrate Content Curve at Each Water Catchment*

The first objective is to identify the temporal evolution of nitrate concentrations, on an annual scale and over the long term. Once these graphs were obtained, we linked each graph of evolution of nitrate levels to its catchment. Based on the shape of the nitrate content evolution curves, we determined five types of curves (Table II and Fig. 9).

- Type 1: levels less than 10 mg/l;
- Type 4: levels increase slowly from 10 mg/l to 25 mg/l and more and remain stable at this level;
- Type D: levels drop after an evolution;
- Type Z: stabilization of contents after a reduction;
- Type M: the contents show after stabilization or decline.

The nitrate levels and their evolution over time in a given catchment are linked to the land use of the study area and the evolution of this use.

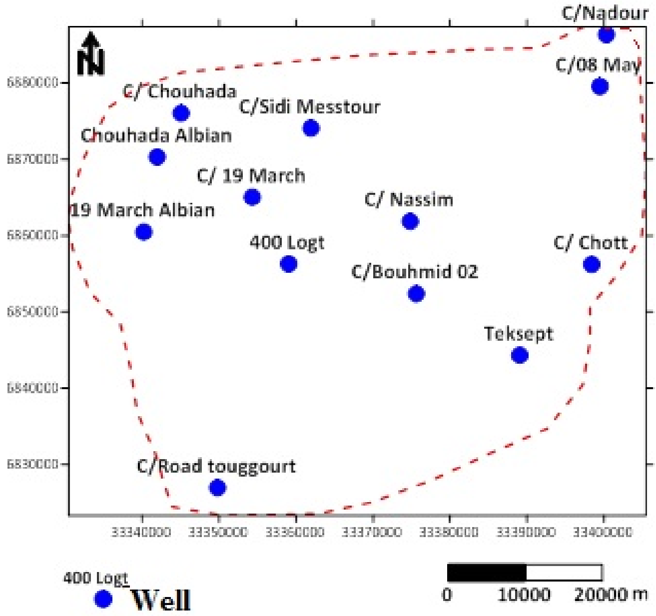


Fig. 8 Spatial distribution of water points (2012 and 2020)

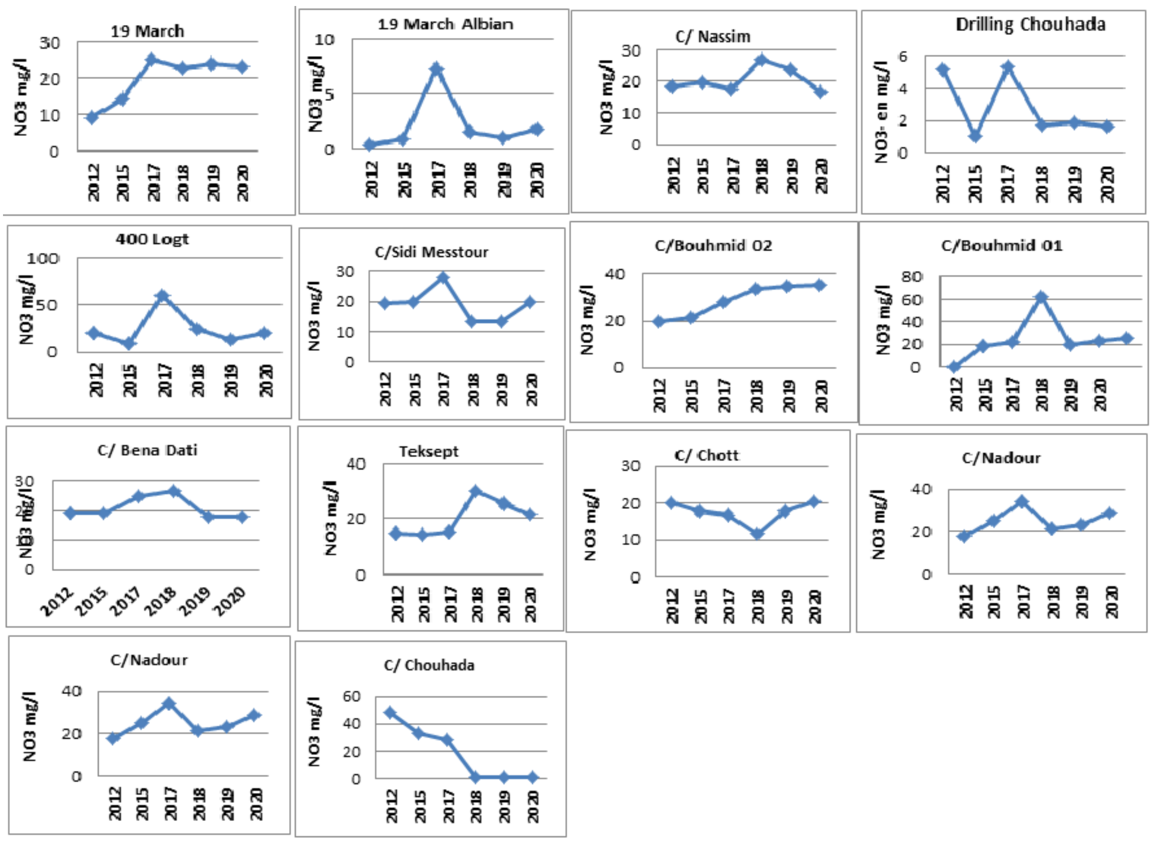


Fig. 9 Evolution curves for nitrate levels (mg/l)

TABLE II
TYPE OF EVOLUTION OF NITRATE CONTENT (CT AND CI DEEP AQUIFER)

| Type | Number | % |
|---|---|---|
| Type 1 | 3 | 20 |
| Type 4 | 2 | 13,33 |
| Type D | 7 | 46,66 |
| Type M | 2 | 13,33 |
| Type Z | 1 | 6,66 |

Table II shows the types of evolution of nitrate contents (CI and CT); we note that type D occupies almost half of the surface of the study area; on the other hand, type Z only covers 6.66% of the area of the study area.

Observation of the spatial distribution of the type of evolution of nitrate contents; drilling waters from the city of El-Oued (Fig. 10) indicate a divergence in their growth for eight years (2012 to 2020). This variability of evolution is a function of the capturing fields.

Five types of changes in nitrate levels are defined: Type 1 less than 10 mg/l, it only covers 20% of the study area, the boreholes capture the CI it is due to the depth of the water table. Type 4 and type D cover 60% of the surface of the study area extending from the North of the study region to the South-East. These types of developments are due to type M and Z, occupy 13.33% and 6.66% respectively of the study area, located at the eastern end of the aquifer.

*I. Calculation of the Average Nitrate Content in Each Catchment per Three-Year Period*

Based on the nitrate content values measured at the catchments, the average contents were calculated in each catchment for three periods of three years each, Fig. 11.

- Average 1: average for 2012, 2015 and 2017;
- Average 2: average for 2018, 2019 and 2020;

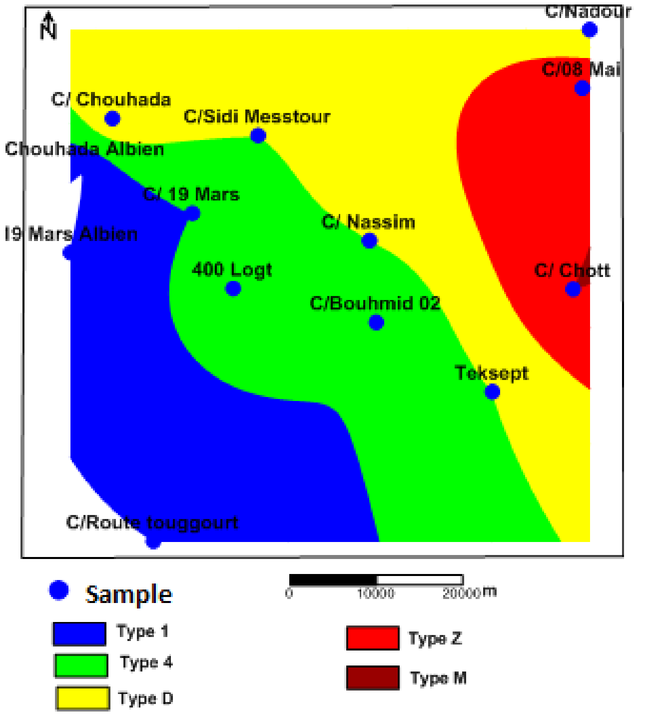


Fig. 10 Spatial distribution of the type of evolution of nitrate contents (deep aquifers CT and CI)

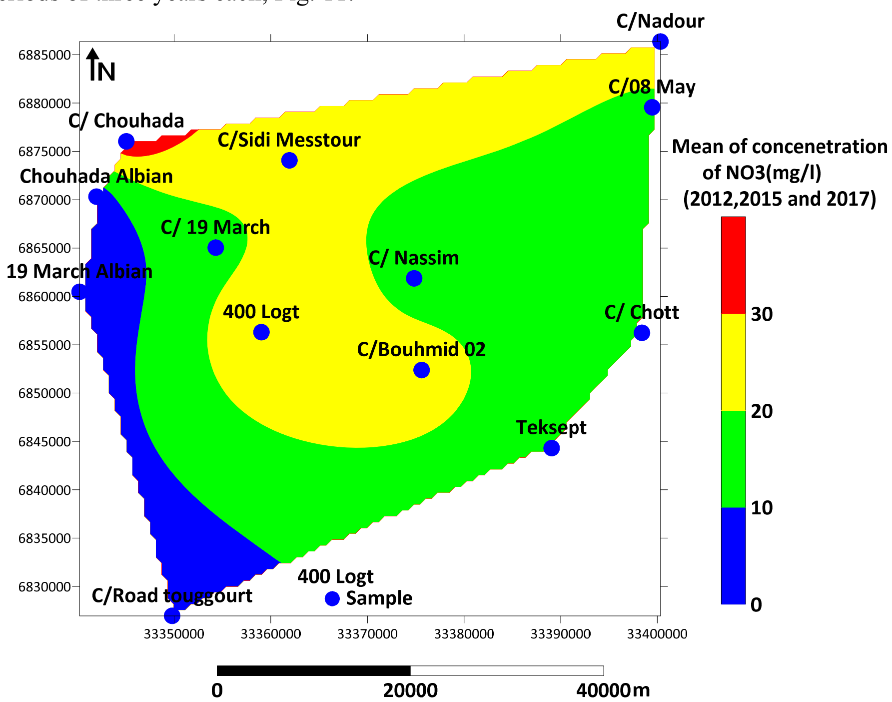


Fig. 11 Changes in average nitrate levels (mg/l) (2012, 2015 and 2017); (deep aquifers CT and CI)

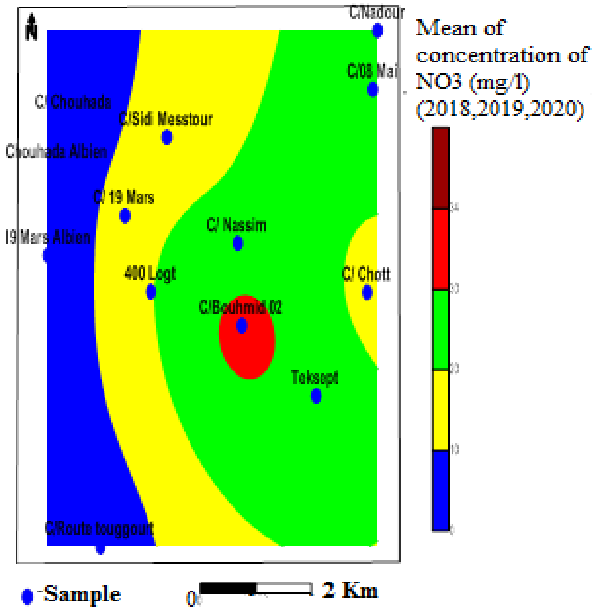


Fig. 12 Changes in average nitrate levels (mg/l) for the years (2018, 2019 and 2020), (deep aquifers CT and CI)

Observation of changes in average nitrate levels (mg/l) for the years (2012, 2015 and 2017); drilling water from the city of El-Oued indicates variable growth therein. In the extreme southwest of the study region there is a lower growth in nitrates, it is less than 10 mg/l. This shows that these waters are of good chemical quality and more protected against pollution.

Average levels vary from 10 mg/l to 30 mg/l. This increase is oriented from South to North of the study region. Except in the extreme North-West of the study region, average nitrate levels are quite high, over 30 mg/l.

Observation of changes in average nitrate levels (mg/l) for the years (2018, 2019 and 2020); borehole water from the town of El-Oued (Fig. 12) indicates variable growth. In the far west of the study region there is a lower growth in nitrates, it is less than 10 mg/l. This shows that these waters are of good chemical quality and more protected against pollution. Average levels vary from 10 mg/l to 30 mg/l. This increase is oriented from West to East of the study region, it follows the direction of water flow in the ground. Except at the Bouhmid 02 borehole located in the center of the study region, the average nitrate levels are quite high, over 30 mg/l.

## III. Discussion of the Results

Nitrates constitute one of the dominant nitrogen compounds in the waters of the city of El-Oued. The nitrate levels observed in the city's waters differ from one aquifer to another. This spatial variability of nitrate contents in water also reflects diversity in their origin. In natural water, nitrate mineralization can have several origins. Indeed, in the city of El-Oued, work reporting excess nitrates in groundwater is becoming more and more frequent. The origin of nitrates in groundwater can be multiple. The high concentrations of the nitrates of the phreatic aquifer have several origins, including urban origin.

During 2011, there is the insufficiency of the sanitation network in the study region due to demographic growth resulting in additional pressures and the evolution of the urban population, this led to good communication between the well-latrine and the groundwater of the phreatic aquifer in the study region, this reduction can be explained by the execution of the El-Oued sanitation directive project.

In 2016, we recorded a reduction in nitrate levels in the study region, this reduction can be explained by the execution of the El-Oued sanitation directive project.

For the period after (2018), we notice another increase in nitrate levels in the city of El-Oued, the latter is due to the drainage network in poor condition, infiltration of wastewater, and leaks from the separative network. This risk can only concern new housing estates which are exceptionally equipped with separative networks. They are uncommon; however, these wells are undeveloped.

For the deep aquifers (the aquifer of the terminal complex), we observe values that do not exceed the WHO standards (50 mg /l), but we record values at the level of a certain borehole or location (400 housing borehole, Borehole 8 May, Bouhmid Drilling and Sidi Mastour Drilling) moderate times exceed 35 mg/l. In this case, we can explain by the influence of the layout of the structure where the surface water table and the deep water table merge, and at the following dilution of free aquifer water by water from deep aquifers.

Ultimately, we can say that the origin of this pollution in the city of El-Oued is domestic.

## IV. Conclusion

The nitrate levels observed in the waters of the city of El-Oued differ from one aquifer to another. In fact, the waters of the Quaternary aquifer are the richest in nitrates. These, given their shallow depth, are the most vulnerable. In these waters, the average annual contents vary from 6 mg/l to 85 mg/l, with an average of 37 mg/l. These levels are higher than the WHO guideline (50 mg/l) for drinking water.

At the Terminal Complex water level, the average nitrate levels vary from 14 mg/l to 37 mg/l, with an average of 18.14 mg/l. In the Terminal Complex, excessive nitrate levels are observed in localities such as Forage Bouhmide 2, 400 housing units in the center of the city.

The spatial distribution of nitrates in the waters of the Quaternary aquifer show that the majority of points which capture this aquifer are subject to nitrate pollution. In the Terminal Complex (CT) aquifer, studies show an evolution of nitrate pollution according to two major sources.

The first focus is South-North (of the study region). The second is West-East progressing towards Chott East Zone. The temporal distribution of nitrate levels in the waters of the Terminal Complex aquifer showed that for decades, nitrate levels have suffered a decline after an increase. This evolution of nitrate levels is linked to the state of infrastructure in the city of El-Oued.

Finally, we can say that one of the real reasons that led to the deterioration of the quality of this water, represented by the groundwater of the phreatic aquifer of the El-Oued, is the great pressure exerted by the anthropogenic activities.

## V. RECOMMENDATIONS

The main recommendations that we propose, based on our work, to resolve the problem of sensitivity to groundwater pollution in the study region are:

- Raising public awareness on the preservation of non-renewable captive water resources for future generations by optimizing water consumption.
- Limitation of water supplies to the free water table by reducing leaks in the drinking water and sanitation network, optimization of water consumption by installing meters, ban on watering green spaces from boreholes. Drinking water and optimization of water pumping from deep aquifers (CT and CI).
- Separating domestic wastewater which has an average conductivity, from drainage water (vertical and horizontal) which has a high conductivity.
- Stopping the direct discharge of domestic waste in the study region, by carrying out prior treatment of waste water.
- Carrying out an environmental impact study for the location of household landfills in places where pollution would be less significant in influencing water quality.
- Ensuring rational water management, in order to avoid intensive and uncontrolled overexploitation of groundwater.

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