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Research Article

WATER WELLS QUALITY ASSESSMENT USING WATER QUALITY INDEX FOR THE PURPOSES OF DRINKING OF M'ZAB WADI REGION

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ABSTRACT

The present work aims to assess the groundwater quality using Water Quality Index (WQI), which can be considered as major factor for controlling quality of water with regarded to drinking purposes. Water quality index is used to illustrate the general state of water quality in a single number. This study concerns specifically Daia area upstream region of M'zab valley. Water samples have been collected at eighteen groundwater points in two years 2016 and 2017. Then, different parameters are analyzed and compared with Algerian standards for drinking water. The hydrochemical study shows significant variations in physico-chemical measurement. Also, the obtained results of the water quality index in Daia region show an excellent ranking with 94%, 88% in years respectively.

Keywords: Groundwater, drinking, water quality, the hydrochemical, WQI.

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1. INTRODUCTION

Water is a precious and essential natural resource for humans, animals and plants [1], used for multiple purposes domestic, industrial and agricultural. Therefore, the water quality has a big effect on health status and mortality in both humans and animals [2]. In the last few decades, water pollution becomes a severe worldwide problem [3]. Population growth and the modernization of agriculture cause a major problem of deterioration of water quality [4,3]. The assessment of water quality is therefore an essential issue and requires more adequate protection [3]. In many countries, and more particularly in arid zones, groundwater is the main water resource commonly used for drinking and irrigation [5, 6]. However, groundwater quality is governed by lithology, groundwater flow, nature of geochemical reaction, residence time, solubility of salts, and human activities [7].

The current study is based on the valley of Oued M 'zab where the commune of Daia Ben Dahoua is located upstream of the valley. Groundwater in Daia region is the main source of meeting water demand. However, these water points have physico-chemical characteristics that can be recognized from each other and vulnerable to pollution [8]. These characteristics may change severely by pollution effect in the source. Water quality index is an important parameter for evaluations and classification of water. In addition; it offers a simple and reproducible unit of measure [9]. Various studies have focused mainly on the water quality index (WQI) as a method to evaluate groundwater for drinking and irrigation purposes [10, 11, 12]. However, the characteristics of the groundwater quality in the Daia region have not been studied using a WQI and multivariate statistics [13].For this,the objective of this study is to evaluate the quality of groundwater in Daia region, which is a function of its physical and chemical parameters[14] and to calculate the water quality index (WQI). The samples are collected in two years 2016 and 2017 in winter period, and the physico-chemical parameters are analyzed (Hydrogen Potential, Electrical Conductivity, Dry residues, Turbidity, Total Hardness, Calcium, Magnesium, Sulfates, Chlorides, Nitrite, Iron, Ammonium, and Phosphates) in order to assess their suitability for drinking water supply or consumption[15].

2. MATERIALS AND METHODS

2.1. Presentation of the study area

The Valley of M'zab is located in the south of Algeria [16], 600 km from Algiers. It is bounded to the north by Daïas region, the south by El Golea, and the east by Ouargla and to the west by the Grand Erg Occidental [17]. Five ksours were built on the M’zab valley: El'Atteuf, Melika, Bounoura, BeniIzgen and Ghardaïa [18]. Ghardaïa city covers 300 km2as surface areaand situated at 526 m high. It is irrigated by the extension of the tableland plain which is carved by the waters named the Chebka (desertic network) [19].

The climate of Ghardaia region is typically Saharan, characterized by two seasons, hot and dry from April to September and another temperate from October to March [20]. The annual average temperature value is 22.5 °C [21]. Also, the degree of evaporation is great. It reaches its maximum in July with 452 mm, and the minimum is recorded during the month of January of 110 mm [21]. The prevailing summer winds are strong and warm however the winter winds are cold and wet. The Precipitation is low [22], with an annual average equal to 74 mm, and this over a period of 32 years [23]. Data from O.N.M show that there is a drought period from June to August; the humidity does not exceed 30%, whereas there is a wet period which is in autumn and winter but does not exceed 60% [21].

The wilaya of Ghardaïa is located on the western borders of the secondary sedimentary basin of the Sahara, on a large sub-horizontal plateau limestones of Turonian age commonly called "the M'zab ridge», whose altitude varies between 300 and 800 meters[24].Under the Turonian limestones, which cut an impermeable layer of green clay and marl rich in gypsum and anhydrite (Cenomanian), The Albian level is represented by a large mass of fine sandstone and green clays (Fig.1). Quaternary alluvium is formed by sands, pebbles and clays line the bottom of the valleys of the wadi of the ridge [25].The watershed of the M’zabwadi covers an area of 6114 km2, it flows substantially from west to east; from the region of Botma Rouila, to the Sebkhet Safioune (outlet of the basin), covering a total length of 301.4 km [26].

Surface water is rare, as in all Saharan regions. The flow of M'zab valley is intermittent. It manifests itself as a result of stormy showers. The consequences are sometimes catastrophic and the damage is often remarkable. For irrigation and shallow aquifer recharge, the M'zab water management system recovers floodwater during rainy periods to allow its use during dry periods [27,28].

Water resources are located in two different levels of aquifers: the Complex Terminal, which is the main water supply resources of M'zab valley[29] is found mainly under the valley floors in the form of infra-flux tables in alluvium , and the Continental Intercalaire aquifer contained in the sandy-sandstone levels of the Albian that are found at different depths [30].

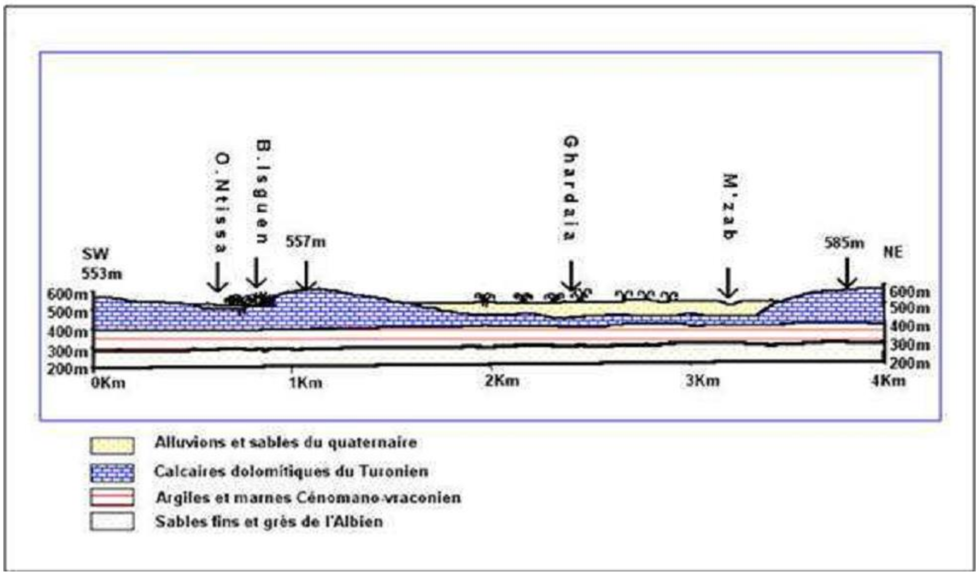

Fig.1. Schematic geology section of the M’zab region [20]

The study site is located upstream of M'zab valley in the commune of Daia Ben Dahoua north-west of Ghardaia at a distance of 10 km. Itis characterized by agricultural activity and husbandry and covers area of 2175 Km² (Fig.2).

In order to start this study, eighteen samples are taken and analyzed for the 2016 and 2017 campaign. These analyzes have been carried out at the water laboratory of Algerian Water in Ghardaia. For each bottle sample has its specific information such: the date and time of sampling, and the name of well waters. At the time of sampling the flasks in plastic material[31] should be rinsed three times with water being analyzed and filled them to the brim. Then samples have been packed in a solid box and shipped them to the laboratory at a storage temperature from 4 to 10 °C. The geographical coordinates of wells are obtained using a GPS.

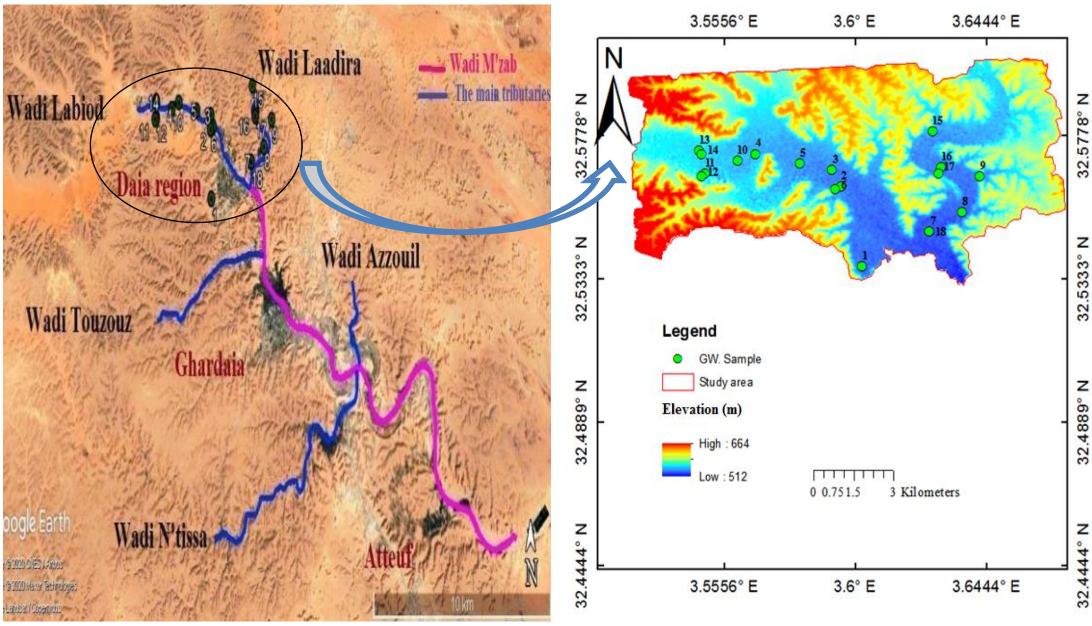

Fig.2. Location of the study area and groundwater sampling sites [32]

2.2. Physico-chemical analysis

The parameters studied are: Hydrogen Potential (pH), Electrical Conductivity (EC), Calcium (Ca^{2+}), Magnesium (Mg^{2+}), Total Hardness (TH), Chlorides (Cl^{-}), Sulfates (SO_4^{2-}), Phosphates (PO_4^{3-}), Iron (Fe^{2+}), Ammonium (NH_4^{+}), Nitrite (NO_2^{-}), Turbidity, and Dry residues. The analysis methods are those recommended by Rodier (1984,1996, and 2005).

The pH is determined by a pH meter (HACH). The Electrical Conductivity is measured by a conductivity meter (HACH), and the Turbidity is measured using a turbidimeter (HACH). The dosage of Calcium and Total Hardness is done by the complexometry method [33,34]. The determination of Chlorides is carried out by the titrimetric method. The Sulfate dosing method is done by gravimetric. The principle for determining Dry residues is to evaporate a certain amount of water in tared capsules, the residue dried and weighed [35]. The determination of Phosphates, Iron, Ammonium, Nitrite are carried out by Spectrophotometer [33,36].

The maps of the spatial distribution in the concentration of chemical elements are prepared using Geographic Information System (GIS).

2.3. Water quality index (WQI)

The WQIs is developed to evaluate the groundwater suitability for drinking purposes [37,38]. The WQIs is used to present large quantities of water quality data into a single number, which is an effective estimation method of the groundwater quality [38,39]. WQIs can be considered as an effective tool to estimate the overall groundwater quality for drinking purposes by examining individual water quality parameters (e.g., pH, TH, Ca^{2+}, Mg^{2+}, SO_4^{2-}, …)[40].WQI is used to define water quality for different uses such as irrigation, water supply and navigation, as well as for various water bodies (lakes, reservoirs and rivers)[41].The WQI used in this study is the weighted arithmetic index method of the parameter [42,13], and using Algerian recommended water quality standards[43] as illustrated in Table 1.

The WQI is obtained from the relation:

$$WQI = \frac{\sum_{i=1}^{n} q_i . w_i}{\sum_{i=1}^{n} w_i} \qquad (1)$$

qi and wi are quality rating and unit weight for the ith water quality parameters respectively.

n: number of water quality parameters.

The quality rating qi is obtained from the relation:

$$q_i = 100.\left(\frac{v_a - v_i}{v_s - v_i}\right) \qquad (2)$$

qi Quality rating for the ith water quality parameters

Va: actual value present of the (ith) parameter at a given sampling well.

Vi: ideal value (0 for all parameters excepts pH which is 7.0).

Vs: standard value

The quality rating qi is obtained from the relation:

$$w_i = \frac{k}{v_s} \qquad (3)$$

k: relative constant. For the sake of simplicity, its value can considered 1 (k=1).

In general case (ours for example) k can calculate using the following equation:*

$$k = \frac{1}{\sum_{i=1}^{n} \frac{1}{v_s}} \qquad (4)$$

We can note that:

$$\sum_{i=1}^{n} w_i = 1 \qquad (5)$$

Which gives:

$$WQI = \sum_{i=1}^{n} q_i . w_i \qquad (6)$$

3. RESULTS AND DISCUSSION

The results of the physico-chemical analyzes obtained during the various campaigns are shown in the following figures (Fig.3- Fig.7):

The pH of a solution is a measure of the concentration of hydrogen ions in the solution. The pH scale extends from very acidic (0) to very alkaline (14) with 7 being the “neutral” point [44].The results obtained (Fig.3) show that the pH values for the different wells oscillate from 6.77 to 7.6 in 2016 and between 7.28 and 8.2 in 2017. These values represents slight alkalinity, are acceptable according to Algerian standards (6,5-8,5).

The Electrical Conductivity values (Fig.3) vary between 739 to 3211 µs / cm for the year 2016 and from 830 to 5001 µs /cm for the year 2017. 95% of these wells are admissible according to Algerian standards (2800 µs/cm), On the other hand, 72% of the wells analyzed are admissible according to Algerian standards (28% of the wells have high water salinity) in 2017.This increase,it could be due to the high rate of different chemical ions already determined in the groundwater of these wells (high concentration of minerals) [45],and by anthropogenic influence (agricultural activities) [46].

The determination of the Dry residue on unfiltered water makes it possible to evaluate the content of dissolved and suspended matter, non-volatile, obtained after evaporation of water [34].The Dry residue concentrations reached a minimum of 345 mg / l and a maximum of 3255 for the year 2016 exceeded the Algerian standard(by 34%, on the other hand, in 2017, 39% of the wells analyzed are below the standard Algerian for drinking (Fig.4).

The Turbidity of all the water sampled (Fig.4) in 2016year and 2017year complies with the Algerian standards (5 NTU).

The Total Hardness of water is due to the presence of magnesium and calcium.From the figure4, the concentration of Total Hardness is high and exceeds the Algerian standard (500mg/l) in all the wells analyzed. This is due to the calcareous nature of the terrain. There is signifcant variation in the TH values, in all of the sites showssignificantly higher TH values during 2016 year than during 2017 year. This could be attributed to leaching of Calcium and Magnesium ions into groundwater, and anthropogenic activities [46].

Calcium is generally the dominant element in drinking water and its content varies mainly according to the nature of the land crossed (limestone or gypsum soil) [31].The Calcium content map (Fig.5) shows that the Calcium values are between 83 mg /l and 435 mg / l for the 2016 year and between 200.4 mg/l and 801.6 mg/l for 2017 year.

The results obtained show that the Magnesium concentration in 2016 varied between 113.3 mg / l and 726.6 mg / l, with 17% of the wells meeting the Algerian standard (150mg/l). While, in 2017, the concentration of Magnesium varies between 121.5 mg / l and 1215 mg / l, with 5% of the wells being admissible according to the Algerian standard (Fig.5).

This variation in Calcium and Magnesium levels might be related to the weathering of rocks and mineral content of each ion, such as sedimentary rocks, limestone, dolomite, gypsum[47].It can be noticedan increase in Magnesium and Calcium concentrations in 2017 compared to 2016, this can only be explained by the massive and irrational use of fertilizers in this region.

According to the results, the Sulphate content exceeds by 67%, 89% the Algerian standard (400mg/l) in 2016 and 2017 respectively (Fig.5). These high values come from the dissolution of gypsum constituting the land crossed, and this elevation during 2017year, is probably due to a source of surface pollution by the use of agricultural pesticides.

The Chloride content varies between 89,3 mg / l and 875,3in 2016 and between 189 mg / l and 1418 mg / l in 2017. Thus, 94%, 67% of the water points have a Chloride lower than the Algerian standard (500mg/l) in the two years respectively (Fig.6) The increase of concentration of Chloride in 2017 year is may be caused by pollution sources such as fertilizers and septic tanks, and from natural sources such as rainfall, the dissolution of fluid inclusions and chloride-bearing minerals[48]**.**

According to the map of Nitrite, Iron, Ammonium, and Phosphate concentrations (Fig.6 and Fig.7), no water point exceeds the Algerian standard admissible for the two years. Only one water point has a phosphate concentration greater than the maximum permissible concentration in 2017. This may be due to the excessive use of fertilizers.

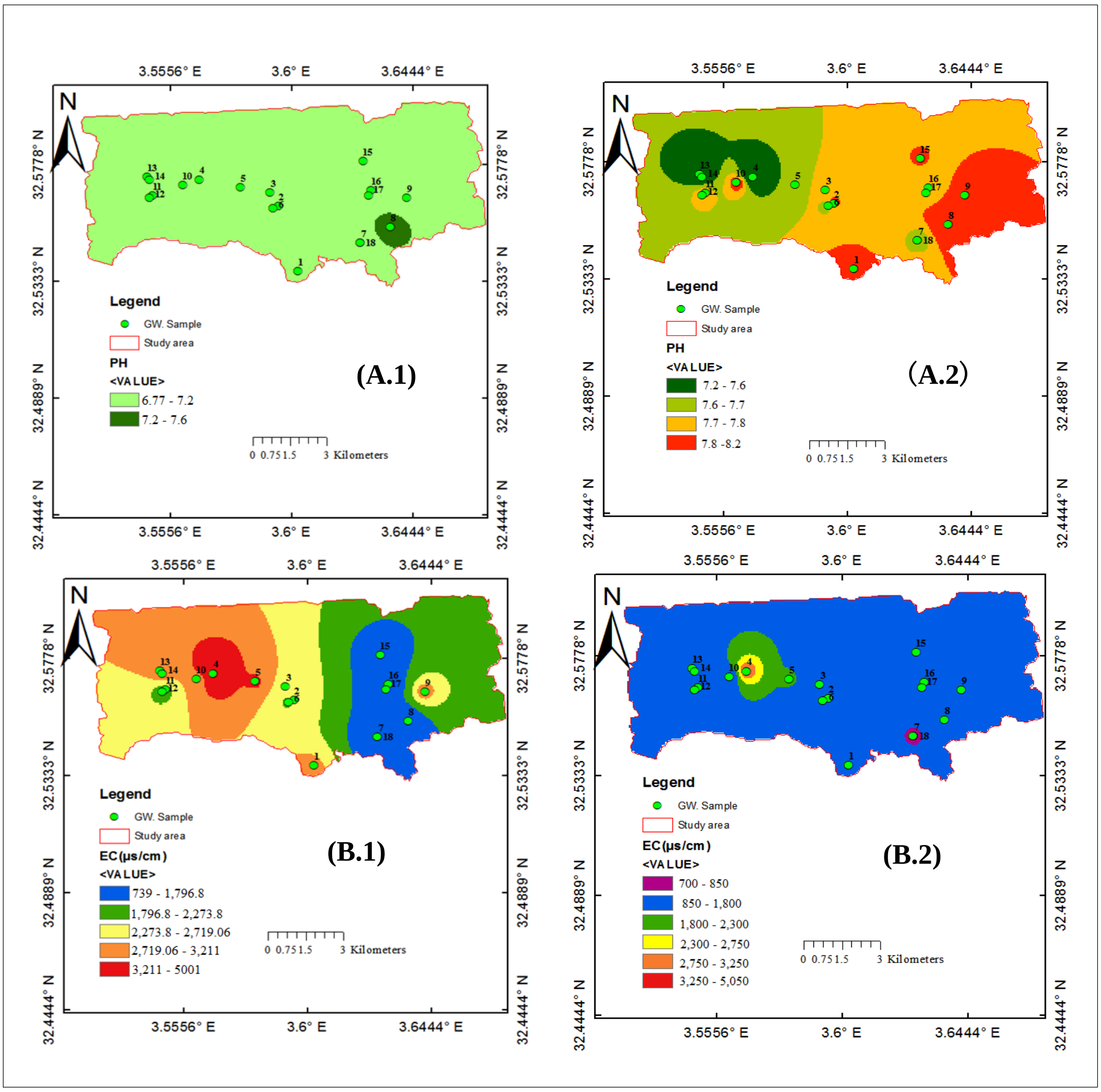

Fig.3. Spatial distribution maps of (A.1, A.2) pH, (B.1, B.2) Electrical Conductivity, in groundwater samples from the Daia region

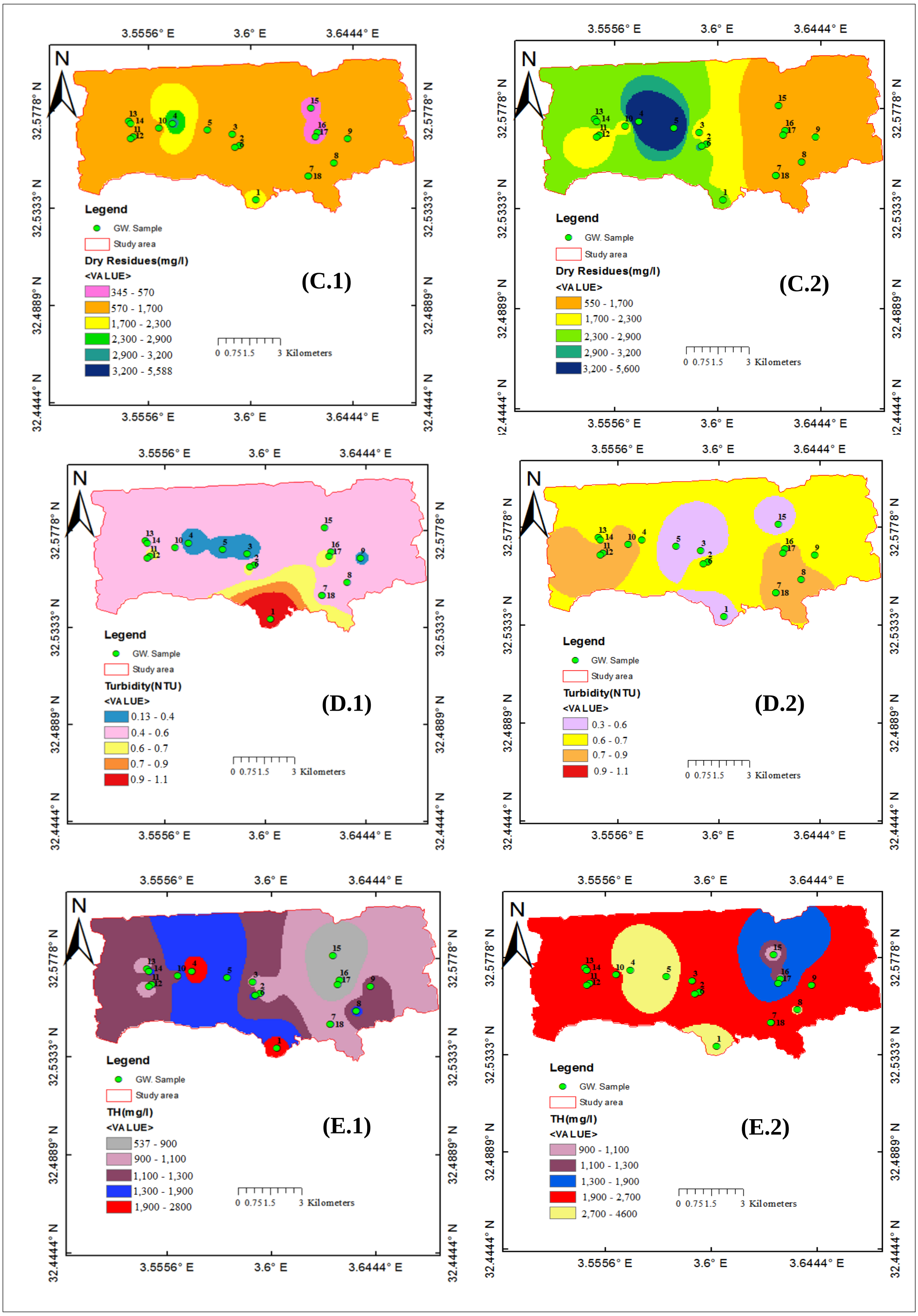

Fig.4. Spatial distribution maps of (C.1,C.2) Dry residues ,(D.1,D.2) Turbidity, (E.1,E.2) Total Hardness, in groundwater samples

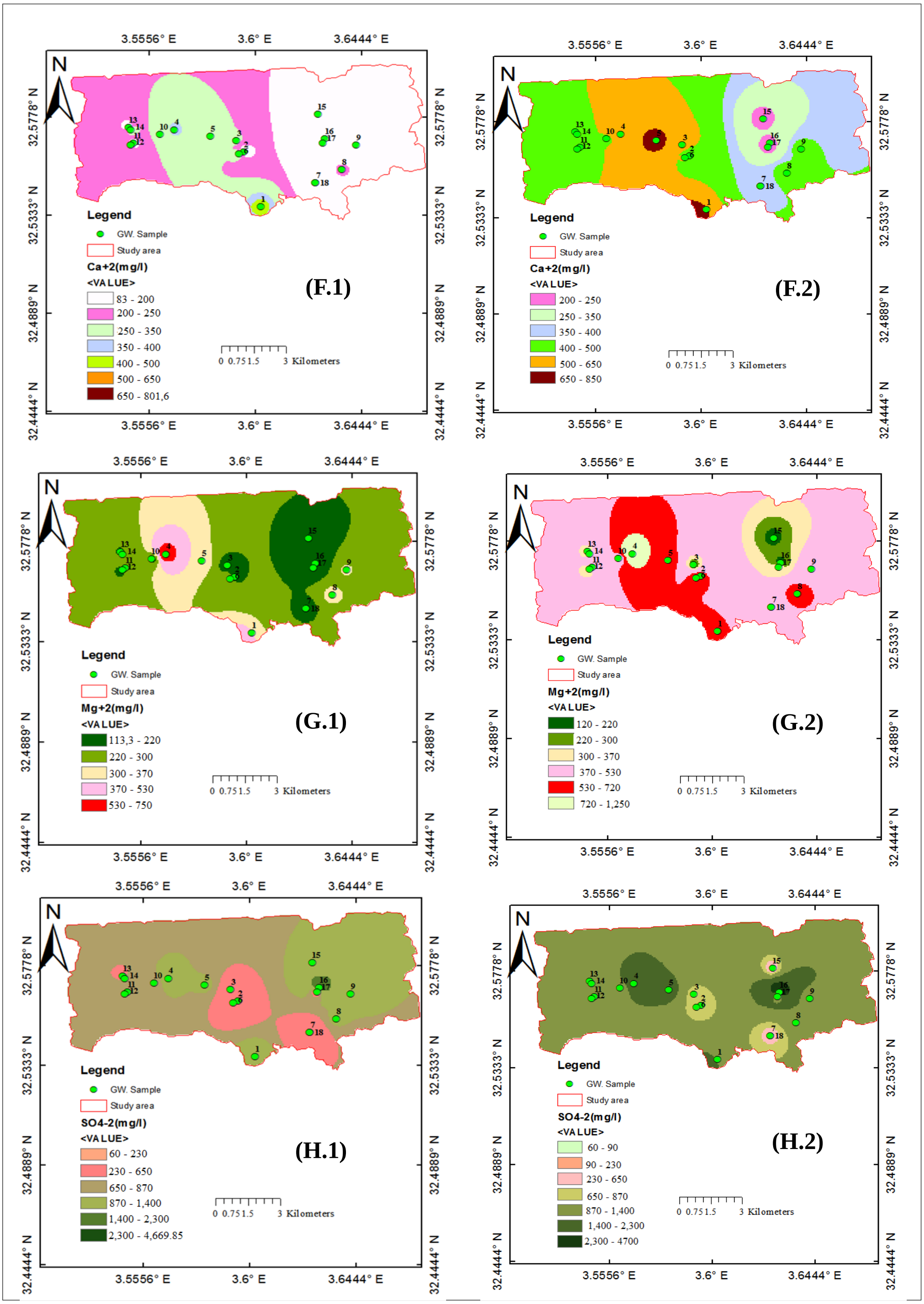

Fig.5. Spatial distribution maps of (F.1,F.2) Calcium, (G.1,G.2) Magnesium, (H.1,H.2) Sulfate,in groundwatersamples from the Daia region

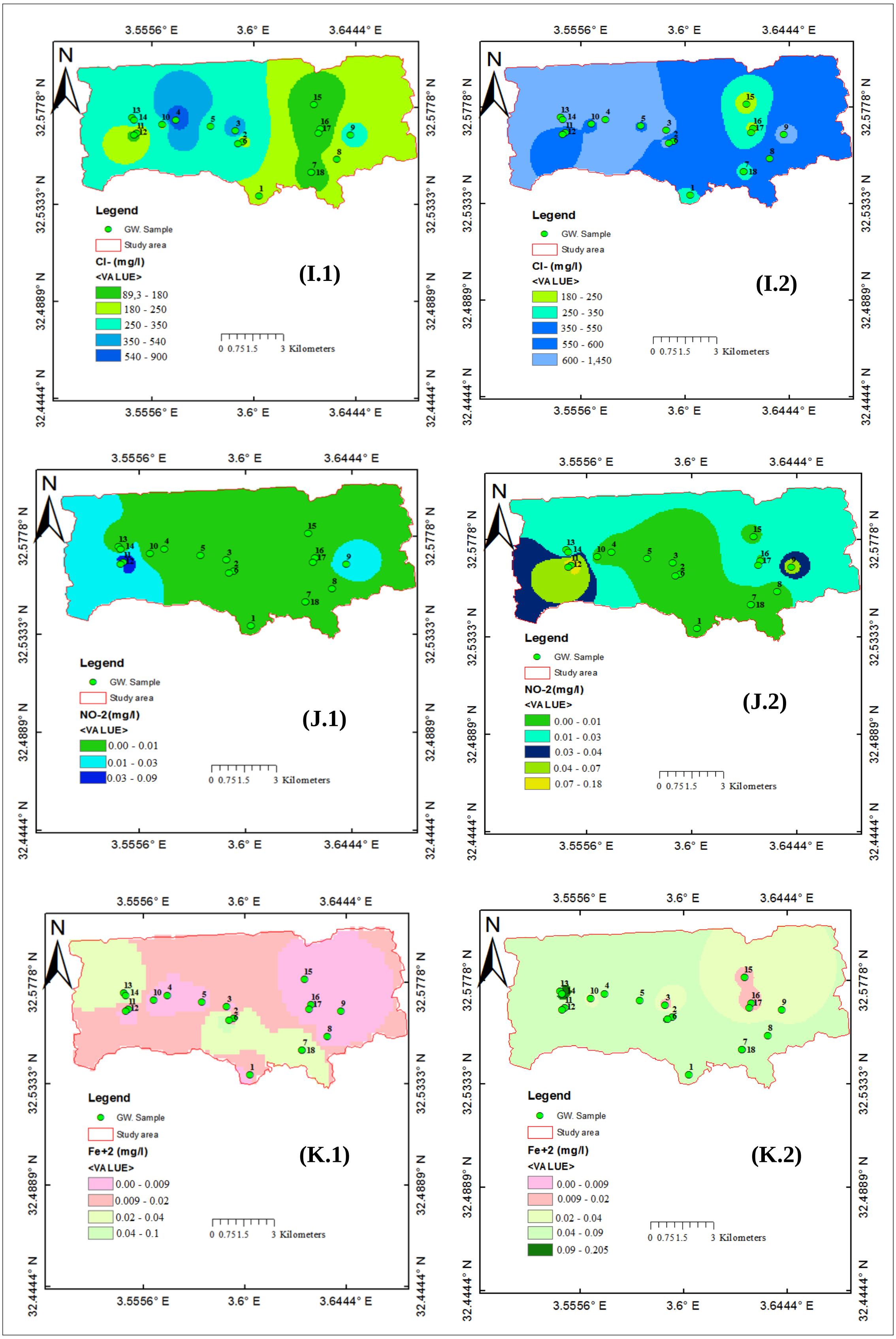

Fig.6. Spatial distribution maps of (I.1, I.2) Chloride, (J.1,J.2) Nitrite, (K.1,K.2) Iron, in groundwater samples from the Daia region

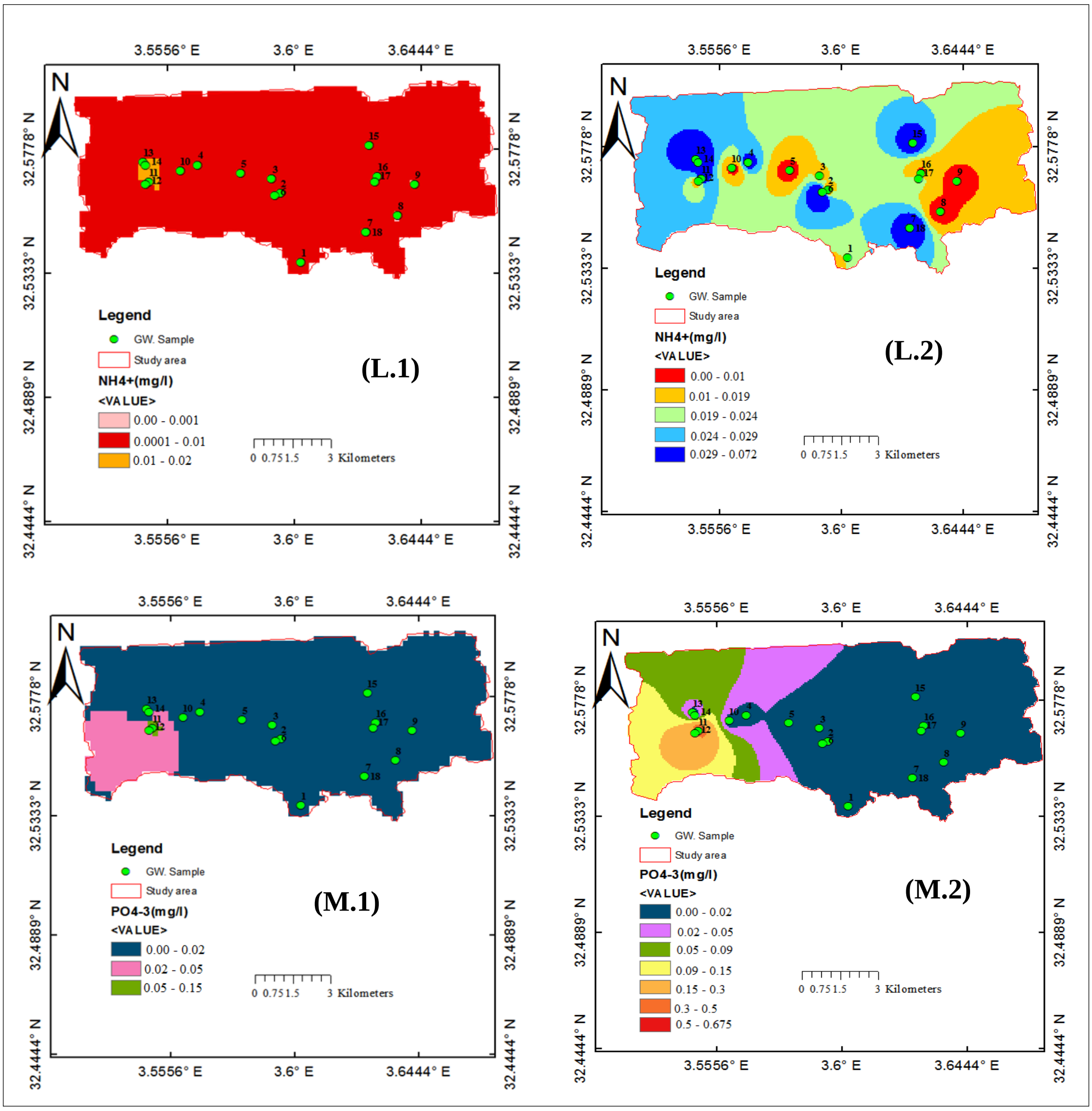

Fig.7. Spatial distribution maps of (L.1, L.2) Ammonium, (M.1,M.2) Phosphate, in groundwater samples from the Daia region.

3.1. Water quality assessment

The initial objective of WQI is to classify waterinto classes by aggregating and weighting different data [49] .The computed WQI values are classified into five categories in order to determine the water quality status (WQS) [50, 51] as following: Excellent, Good, Poor, Very poor water quality and Unsuitable for drinking purposes for WQI ranges 0-25, 26-50, 51-75, 76-100 and above 100 respectively.

In the present study, the WQI iscalculated for the area of Daia (upstream of the M'zab valley

).The WQI values for all wells samples are shown in Table 2.The WQI values vary between 1,25 to 54,49 in 2016 year; and 1,22 to 124,04 in 2017 year.

The WQI values of Daia region indicate “excellent” class for drinking purposes and appeared by 94% of cases in 2016 year. But, in 2017 the excellent class dropped to 88%.

There is some exception such as:

-Welle number 9 becomes from excellent in 2016 to good water in 2017.

-Welle number 11 becomes poor in 2016 to unsuitable for drinking purposes in 2017. In addition, for the same classe (excellent) water quality index (WQI) values have been obviously increased between two years. This increase could be due to the agricultural activities, the presence of dirty drainage behind the area of well-studied. However, this unsuitable well for drinking purposes could be suitable once a purification treatment isdone.

Table1. Recommended Standards for drinking water quality and individual unit weight of parameters

Parameters	Algerian recommended water quality standards (V_s)	Units weight (Wi)
pH	8.5	0.006658
Electrical Conductivity (µs/cm)	2800	0.00002
Turbidity (NTU)	5	0.011319
Dry residues (mg/l)	2000	0.000028
Calcium (mg/l)	200	0.000283
Magnesium (mg/l)	150	0.000377
Total hardness (mg/l)	500	0.000113
Chloride (mg/l)	500	0.000113
Sulfate (mg/l)	400	0.000141
Ammonium (mg/l)	0.5	0.113186
Iron (mg/l)	0.3	0.188644
Phosphate (mg/l)	0.5	0.113186
Nitrite (mg/l)	0.1	0.565931

Table 2.WQI and rating for the water wells samples

Wells	Year 2016		Year2017	
	WQI	Rating of Water Quality	WQI	Rating of Water Quality
WGW_01	1,6	Excellent water quality	5,11	Excellent water quality
WGW_02	1,25	Excellent water quality	2,4	Excellent water quality
WGW_03	1,47	Excellent water quality	1,62	Excellent water quality
WGW_04	1,69	Excellent water quality	5	Excellent water quality
WGW_05	1,37	Excellent water quality	5,54	Excellent water quality
WGW_06	6,27	Excellent water quality	8,92	Excellent water quality
WGW_07	1,72	Excellent water quality	4,92	Excellent water quality
WGW_08	1,56	Excellent water quality	4,96	Excellent water quality
WGW_09	13,36	Excellent water quality	30,56	Good water quality
WGW_10	1,35	Excellent water quality	3,28	Excellent water quality
WGW_11	54,49	Poor water quality	124,04	Unsuitable for drinking purpose
WGW_12	1,79	Excellent water quality	3,97	Excellent water quality
WGW_13	1,28	Excellent water quality	2,34	Excellent water quality
WGW_14	7,16	Excellent water quality	20,4	Excellent water quality
WGW_15	1,45	Excellent water quality	6,96	Excellent water quality
WGW_16	1,35	Excellent water quality	2,12	Excellent water quality
WGW_17	7,31	Excellent water quality	21,18	Excellent water quality
WGW_18	6,14	Excellent water quality	13,01	Excellent water quality

4. CONCLUSION

It can be concluded that the assessment of the water table which has been done in Daia region upstream of M'zab valley in 2016- and 2017-years using water quality index for the purpose of drinking allowed to identify some interesting and valuable results.

The groundwater in thisstudy area is slightly alkaline and very hard. The analysis of the results shows that the majority of parameters of the water table exceed the Algerian standard of potability, with the exception of some parameters such as Turbidity, Iron, Ammonium, Nitrite and Phosphate.The WQI values of Daia indicate "excellent water" and "poor water" are appeared in 94%, 6% respectively in 2016 year.However ,in 2017 year, the results of WQI show that 88%, 6%,6% of wells are rating "excellent water","good water" and "unsuitable for drinking " respectively.In 2017 year the "excellent water" class dropped by 6%.This increase could be due to the influence natural and the anthropogenic activities.

In overall the quality of water table in the Daia region is highly susceptible to vulnerable, which requires a good management of this important resourcetopreserveit.

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