J. Mater. Environ. Sci. 6 (9) (2015) 2400-2408
ISSN : 2028-2508
CODEN: JMESCN

Seasonal variation of physicochemical and bacteriological characteristics of groundwater using a GIS: Triffa plain (northeast Morocco)

Hameed Saleh Ali YAHYA[1], Abdelhakim JILALI[2], Mounia BATTIOUI[3], Mohammed Mohammed Mohammed MOSTAREH[1], Chaouki BELBACHIR[4], Abdelhafid CHAFI[1]

[1] *Laboratory of Water Science, Environment and Ecology, Faculty of Sciences, University Mohammed I, Oujda, Morocco*
[2] *Laboratory of Mineral Deposits, Hydrogeology & Environment, Faculty of Sciences, University Mohammed I, Boulevard Mohammed VI, B.P: 524, 60000 Oujda, Morocco.*
[3] *Laboratory of Hydrobiology and General Ecology, Oriental Center of Sciences and Technology of Water (COSTE). BP: 524, CP: 60000, Oujda, Morocco*
[4] *Regional laboratory of analysis and Research of Oujda (LRARO), Isly, Oujda, Morocco.*

Received 24 Apr 2015, Revised 04 Sep 2015, Accepted 06 Sep 2015
**Corresponding author: yamaapa@hotmail.com; Tel: (+2012673547525)*

Abstract
The aim of this work is to study the seasonal variation of the physicochemical and bacteriological characteristics of groundwater in the Triffa plain, Morocco. In total, 41 groundwater samples were analyzed for major elements. The results show that the electrical conductivity ranges between 740 and 7340 µS/cm, NO_3^- ranges between 1.7 and 269.78 mg/l, and Cl^- ranges between 29.4 and 2001.55 mg/l. Hydrochemical facies represented using a Piper diagram indicate Na-K-Cl and Ca-Mg-Cl-SO_4 water types. The bacteriological analysis showed that the majority of groundwater samples are contaminated. The mapping of global quality using the Geographic Information System (GIS) for five periods shows four classes: good, moderate, poor, and very poor quality, with the two last classes predominating. We conclude that the quality of groundwater is suitable for irrigation and domestic use.

Keywords: physicochemical, bacteriological, groundwater, GIS, Triffa, Morocco

1 Introduction
The demand for groundwater resources for drinking, irrigation, and industrial use is increasing everywhere in the world. The deterioration of groundwater quality has become the subject of several research works using physicochemical and bacteriological analysis [1-10]. In arid and semi-arid regions, the deterioration in water quality is due to physical and chemical processes, especially the recycling of water (irrigation). Therefore, it is important to understand the mechanism of interaction between groundwater and the external environment [11]. Currently, water resources are under serious pressure, and agricultural practices have negative impacts on groundwater quality in the Triffa plain [1, 5, 12, 13].
In this paper a GIS (Geographic Information System) is employed to illustrate the spatio-temporal distribution of groundwater quality and the impacts of irrigation and wastewater on groundwater in the Triffa aquifer. Therefore, 41 wells have been inventoried in the whole of Triffa plain to identify the spatial extent of contamination and to evaluate the groundwater quality.

2 Study area
The Triffa aquifer is located in the NE part of Morocco and lies between latitudes 35°5’ N, 34°55’ N and longitudes 2°23’ W, 2°11’ W (Figure 1), and has a surface area of 750 km². It is limited in the north by Ouled Mansour hills, in the west by Moulouya rivers, in the south by Beni Snassen Mountains, and in the east by Kiss River. Geologically, the plain is formed by Secondary and Quaternary formations: alluvial, silt, sandstone, limestone, and clay [5]. This region is characterized by two aquifers: (1) an unconfined aquifer of Secondary and Quaternary formations; (2) a confined aquifer of a Liasic formation (limestones and dolostones) [11, 14-16].

ISSN : 2028-2508
CODEN: JMESCN

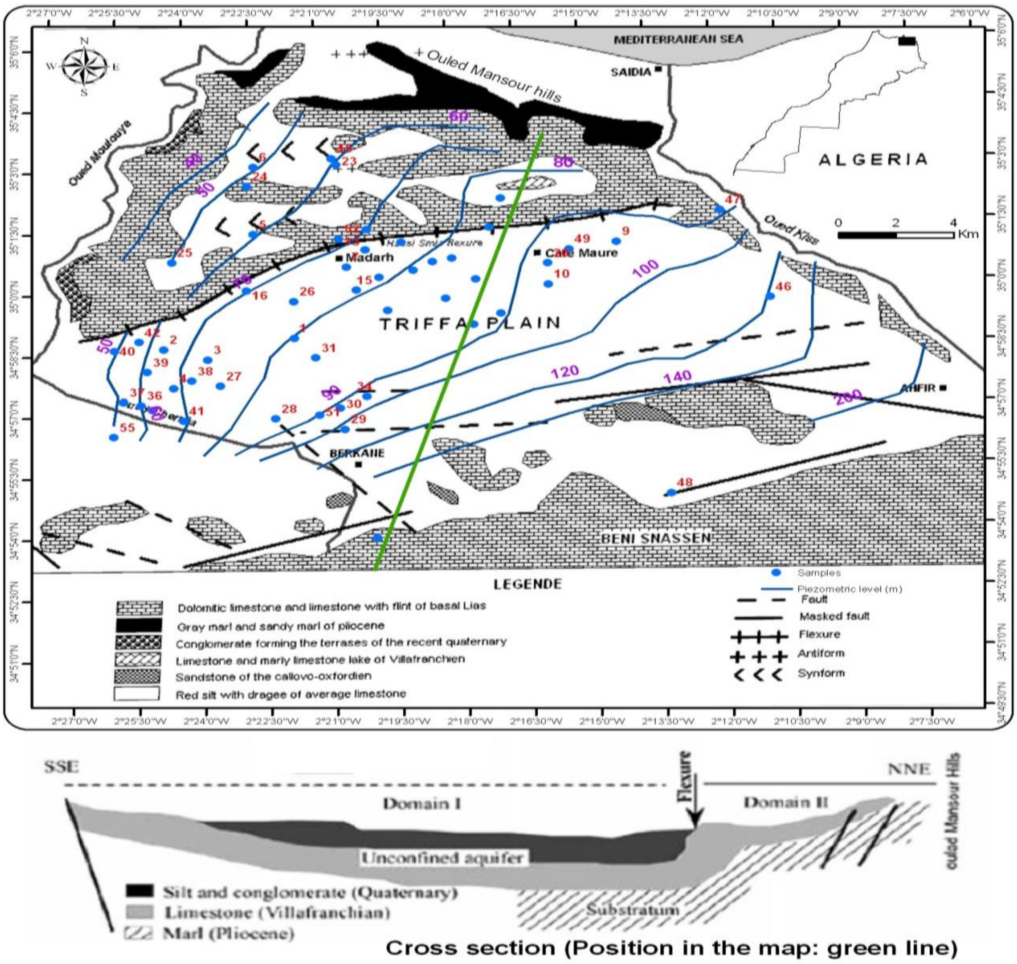

Figure 1: Study area [1, 5], modified.

The pollution caused by the use of fertilizers and phytosanitary products in agriculture is estimated to 8500 tons of nitrogen and 15 tons of pesticides: from 8 to 10% of the nitrogen used as fertilizer and is leached into the groundwater and from 0.5 to 1% of pesticides join the stream [17].
The climate is semi-arid. The total rainfall does not exceed 327 mm/year. The yearly average temperature is 17.40 °C, but seasonal variability is high, with a minimum of 11 °C and a maximum of 25 °C. The average annual evapotranspiration is about 300 mm/year [1].

3 Materials and methods

Chemical analyses were conducted on a total of 41 groundwater wells located in different parts of the study area in March, June, and November 2013 and March and July 2014. Measurements of pH, temperature, electric conductivity (EC), and piezometric level were taken in situ. All water samples were collected in polyethylene bottles and stored in the absence of light at 4 °C. Major ions were analyzed in the laboratory for K^+, Na^+, Ca^{2+}, Mg^{2+}, Cl^-, SO_4^{2-}, NO_3^-, NO_2^-, NH_4^+, $H_2PO_4^-$ (SKALAR method), and HCO_3^- [18]. The precision of the chemical analyses was defined by checking the ionic charge balance. The acceptable error in the ion balance was taken as a maximum of ± 6%.
The monitoring of some parameters such as EC, Cl^-, and NO_3^- was carried out in seven wells. The data were collected from the Hydraulic Basin Moulouya Agency for the period 2000 to 2012 and we completed the monitoring for the period 2013 to 2014.
Bacteriological analysis was conducted in the same groundwater wells in the study area in June and November 2013 and March and July 2014. All measurements were conducted on the same day in the quality control laboratory (University of Mohammed Premier, Morocco). Pathogens analyzed in this study include total coliforms (TC), fecal coliforms (FC), and fecal streptococci (FS: Intestinal Enterococci). Water samples of 100 ml were filtered (pore size: 0.45 µm) and were transferred onto triphenyl-tetrazolium chloride (TTC) and

tergicol lactose agar [19], which were used as selective media for FC. The FC and TC were counted after 24 h incubation at 44 ± 1 °C. For FS, the selective medium of Slanetz and Bartley was used. The FS were counted after incubation at 37 °C for 24 h. The total number of bacteria was determined as colony-forming units per 100 ml (CFU/100 ml).

4 Results and discussion

4.1 Groundwater bacteriological quality

Figures 2, 3, and 4 show the abundance of FC, TC, and FS in groundwater sampled in June and November 2013 and March and July 2014. The results that show the contamination of groundwater affects almost the whole region. Generally, the highest numbers of these bacteria groups were recorded in June 2013 and July 2014 (dry period). One well (no. 17) shows no contamination during the June 2013 period, and four wells (nos. 16, 30, 33, and 36) show no contamination in the July 2014 period. Otherwise, in the humid period (November and March 2013) there are three uncontaminated wells (wells 8, 30, and 33), and in March 2014 there are four uncontaminated wells (nos 6, 11, 24 and 26); additionally, the abundance of bacteria is lower than in the dry period (June and July). The highest numbers of bacteria were recorded in Madarh region (Figure 1). The fecal contamination is due to the injection of fecal organic matter in septic tanks. Therefore, the abundance of bacteria depends on the richness of nutrients from human waste and animals [6].

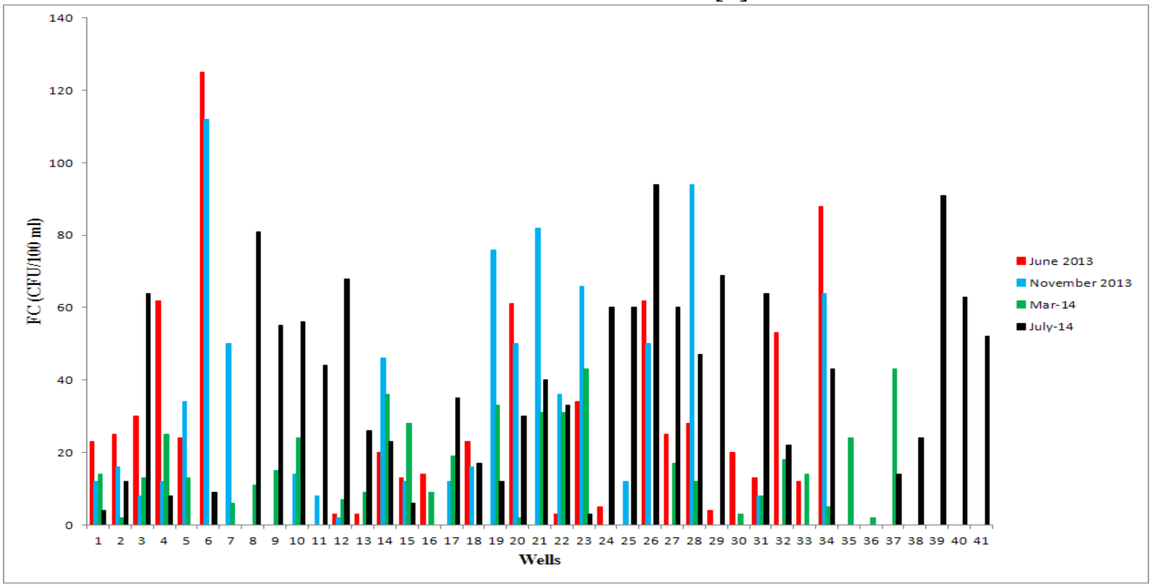

Figure 2: Abundance of FC in groundwater sampled in June and November 2013 and March and June 2014.

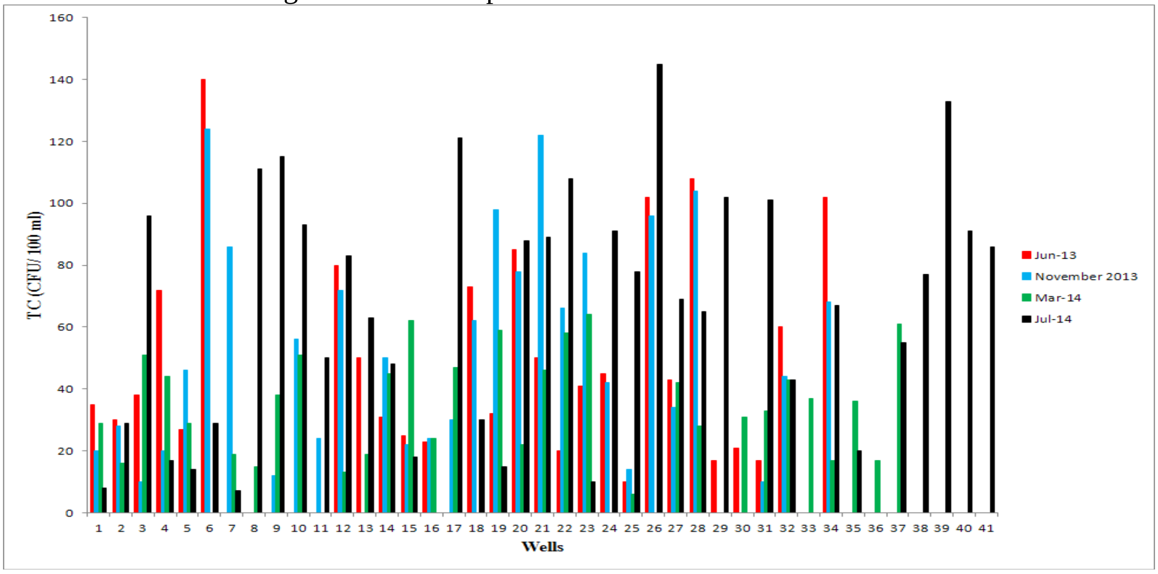

Figure 3: Abundance of TC in groundwater sampled in June and November 2013 and March and June 2014.

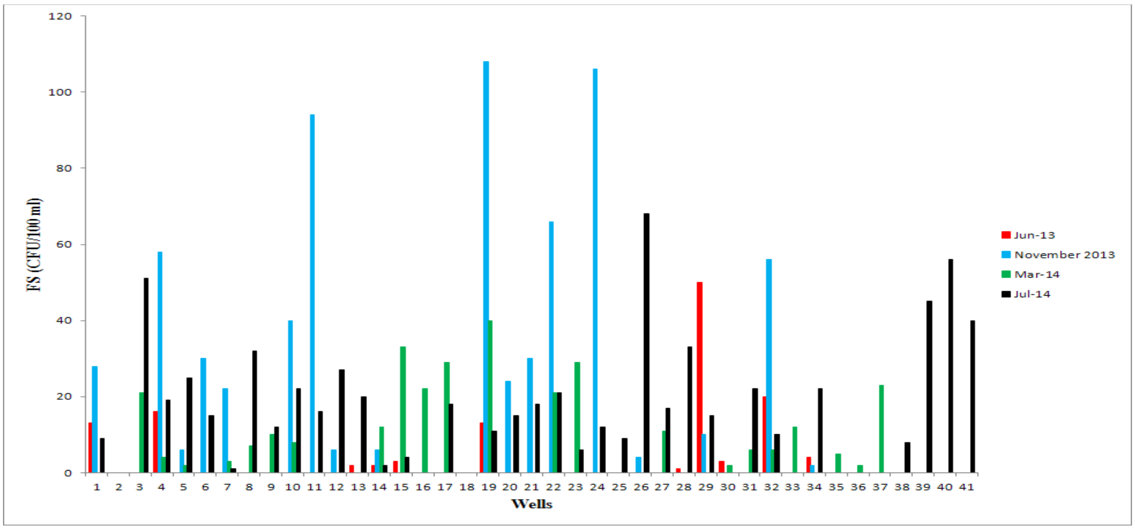

Figure 4: Abundance of FS in groundwater sampled in June and November 2013 and March and June 2014.

4.2 Hydrochemistry of groundwater and global quality

The hydrogeochemical facies of groundwater and the relationship between different dissolved ions can be understood by plotting geochemical data on a Piper diagram and using Aquachem software, which indicates that most waters are Na-K-Cl and Ca-Mg-Cl-SO4 types (Figure 5 and Table 1). The Piper diagram and Table 1 show the evolution of major ions for different periods. Generally, there is no significantly variation in groundwater facies between periods.

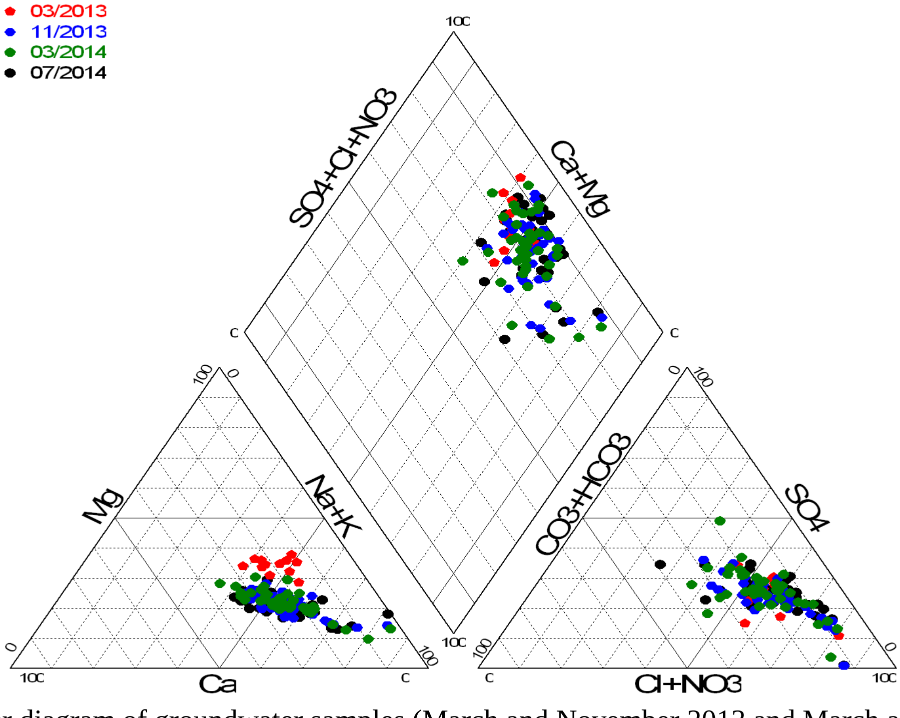

Figure 5: Piper diagram of groundwater samples (March and November 2013 and March and June 2014).

The EC values of groundwater samples range from 740 to 5380 µS/Cm in March 2013, from 1170 to 4120 µS/Cm in June 2013, from 1590 to 7340 µS/Cm in November 2013, from 1954 to 7130 µS/Cm in March 2014, and from 1475 to 6330 µS/Cm in July 2014. The highest EC is recorded in the western part of the study area. The concentrations of NO_3^- are in the range of 31.6–135.7, 10.5–212.9, 1.7–168.3, 7.22–269.78, and 4.38–267.36 mg/l, while those of Cl^- are in the range of 329.4–1666.4, 113.6–1480.3, 159.3–1806.2, 213.79–2001.55, and 197.79-1582.2 mg/l in March, June, and November 2013 and March and July 2014 respectively. NH_4^+ is lower than 0.37, 1.12, and 0.8 mg/l, with the exception of well no. 18, where it is 5.79, 3.15, and 5.85 mg/l in November 2013 and March and July 2014 respectively.

Table 1: Water type.

Samples 11/2013	Samples 04/2014	Samples 07/2014	Water Type
-	10	-	Na-Ca-Cl-HCO3
32	12, 14 and 32	20	Na-Ca-Cl-HCO3-SO4
9, 10, 15, 20 and 26	11, 15	13	Na-Ca-Cl-SO4
12	9 and 20	32	Na-Ca-Cl-SO4-HCO3
16, 25 and 33	16, 25 and 26	16	Na-Ca-Mg-Cl
	37	37	Na-Ca-Mg-Cl-HCO3-SO4
2, 5-8, 11, 14, 21, 22 and 24	5-8, 13, 21, 22 and 12bis	5, 7, 8, 10, 14, 15, 21,22, 25, 26 and 33	Na-Ca-Mg-Cl-SO4
-	36 and 41	9, 11, 12, 35, 36 and 41	Na-Ca-Mg-Cl-SO4-HCO3
28	28 and 35	28	Na-Ca-Mg-SO4-Cl-HCO3
18	18	18	Na-Cl
30	17 and 30	30	Na-Cl-HCO3-SO4
3 and 4	34, 39 and 40	4, 39 and 40	Na-Cl-SO4
27 and 34	4 and 27	27, 34 and 38	Na-Cl-SO4-HCO3
	1 and 33	1 and 31	Na-Mg-Ca-Cl
1 and 19	2, 19 and 24	2, 6 and 24	Na-Mg-Ca-Cl-SO4
-	38		Na-Mg-Ca-Cl-SO4-HCO3
23 and 31	23 and 31		Na-Mg-Cl
-	3	3, 19 and 23	Na-Mg-Cl-SO4
-	-	29	Na-Ca-Mg-Cl-HCO3
-	-	17	Na-HCO3-Cl-SO4
17	-	-	Na-HCO3-SO4-Cl
29	-	-	Na-Ca-Mg-HCO3-Cl-SO4

To evaluate the quality of groundwater in Triffa plain, the monitoring of some parameters such as EC, Cl-, and NO3- was carried out in seven wells. These wells (nos. 2, 14, 15, 20, 22, 23, and 30) are distributed in the study area (Figure 6, Figure 7, and Figure 78).

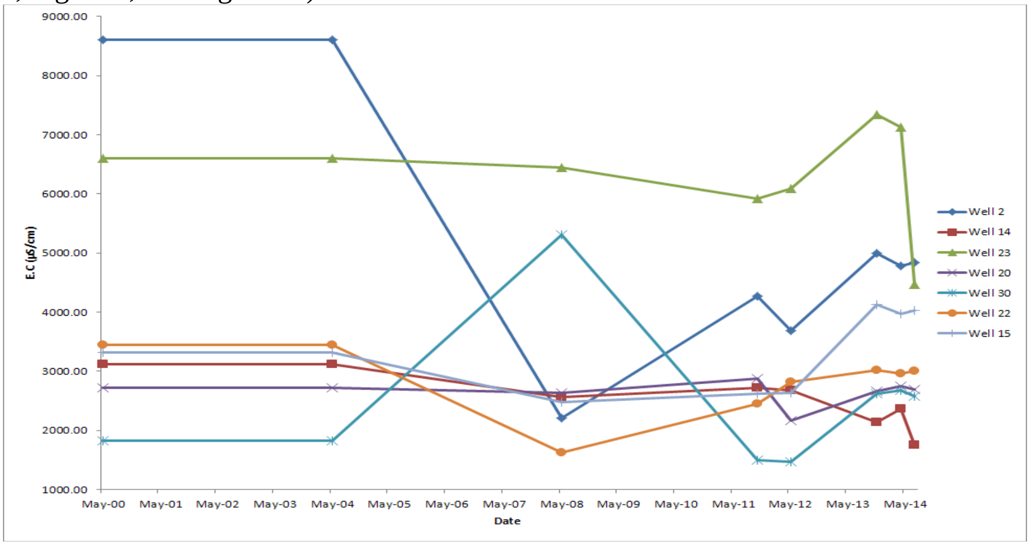

Figure 6: Evolution of electric conductivity (EC in µS/cm) in seven wells.

Thus, the global quality of the groundwater was evaluated according to six parameters [20]: EC, Cl-, NO3-, NH4+, OM (organic matter), and FC (Table 2). The global quality is the most degraded quality of six parameters. The GIS is used to obtain different maps and to show the distribution of groundwater quality classes. The results show that the monitoring of EC increased after 2008 in all wells. The graphic (Figure 7) of Cl- shows some stabilization of concentration in wells 15, 20, 22, and 23, while in the rest of the wells there are increases in the concentration after May 2012. The linear correlation of NO3- shows an increase in concentration in all of the wells.

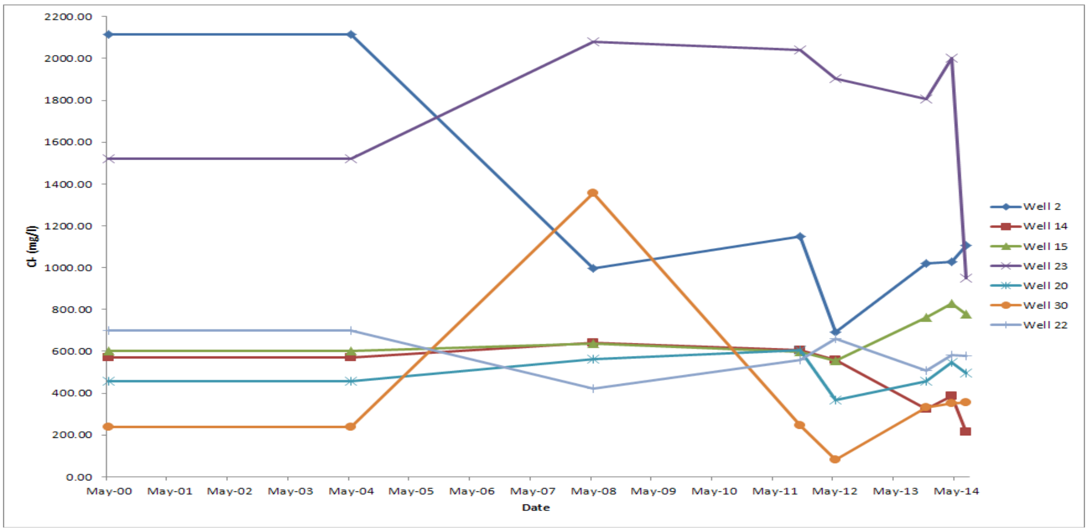

Figure 7: Evolution of concentration of Cl- (mg/l) in seven wells.

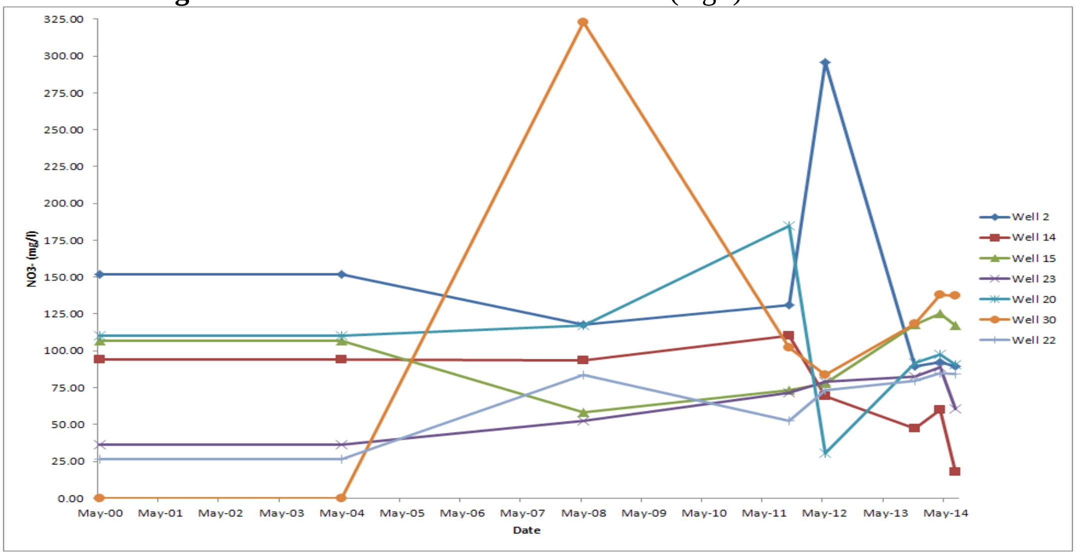

Figure 8: Evolution of concentration of NO3- (mg/l) in seven wells.

Table 2: Simplified grid to evaluate the global quality of groundwater [20]: OM (Organic matter).

Parameters	E.C (µS/cm)	Cl- (mg/l)	NO3- (mg/l)	NH4+ (mg/l)	OM (mg/l)	FC (CFU/100 ml)
Excellent	< 400	< 200	< 5	≤ 0.1	< 3	≤ 20
Good	400 - 1300	200 - 300	5 - 25	0.1 – 0.5	3 - 5	20 - 2000
Moderate	1300 - 2700	300 - 750	25 - 50	0.5 - 2	5 - 8	2000 - 20000
Poor	2700 - 3000	750 - 1000	50 - 100	2 – 8	> 8	> 20000
Very Poor	> 3000	> 1000	> 100	> 8	-	-

To evaluate the global quality we considered five parameters: EC, Cl^-, NO_3^-, NH_4^+, and FC for the period of November 2013 and March and July 2014, four parameters (EC, Cl^-, NO_3^-, and FC) for June 2013, and three parameters (EC, Cl^-, and NO_3^-) for March 2013.The global quality of different periods shows four classes of quality (Figure 9, 10, 11, 12, and 13) : good, moderate, poor, and very poor, of which the last two classes predominate in the study area. The comparison between periods shows a deterioration of groundwater quality (increasing number of wells with low quality water). In detail, the first element responsible for this degradation is EC and the second is NO_3^-. The high concentrations of NO_3^- result from the presence of cultivation zones, where ammonium nitrate is used as a chemical fertilizer, and the wastewater comes from the septic tanks. This observation is similar to those made by other studies carried out in the Triffa plain [1, 5]. The increases in other anions and cations occur due to the concentration of these ions by recycling the groundwater as irrigation water [6].

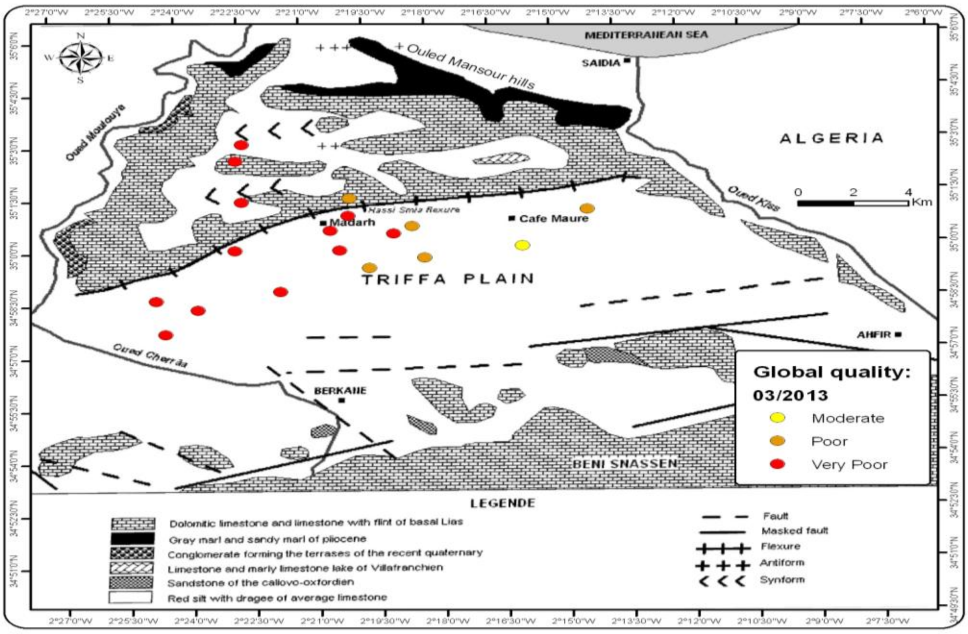

Figure 9: Global quality of groundwater in 03/2013.

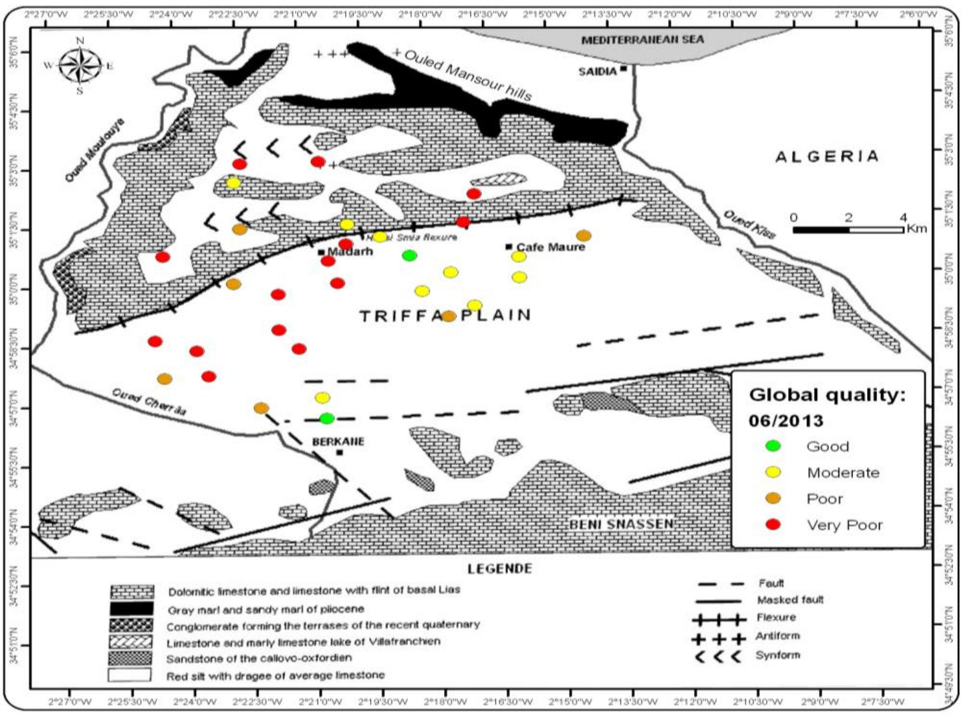

Figure 10: Global quality of groundwater in 06/2013.

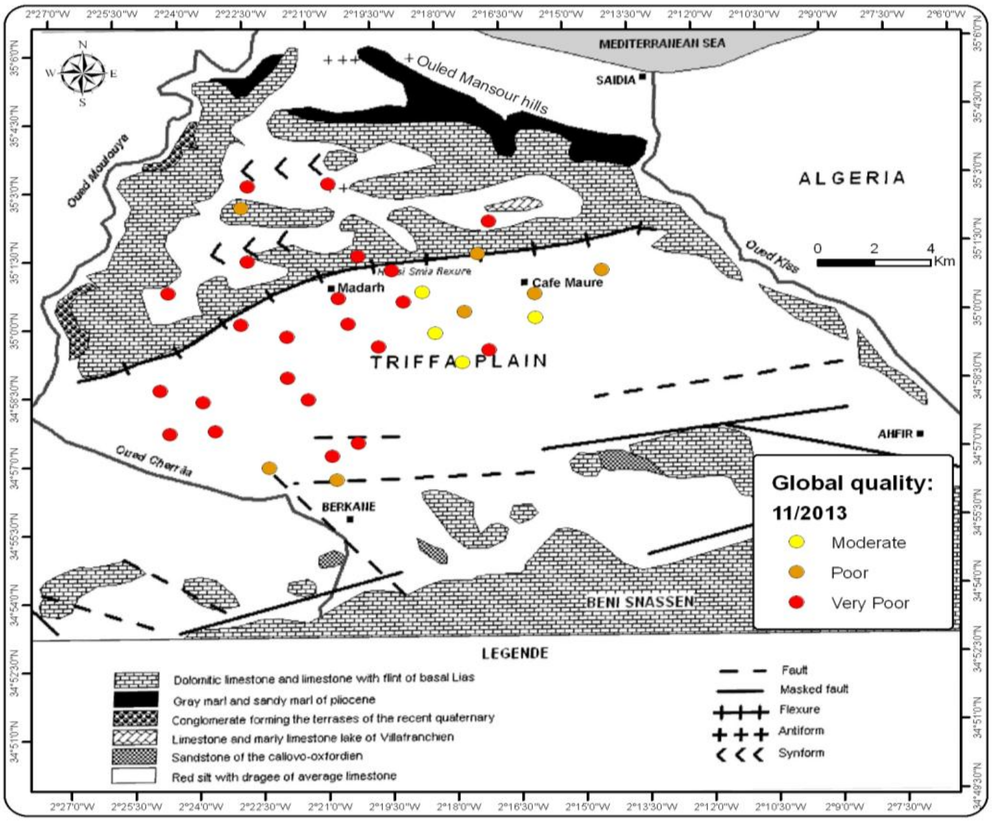

Figure 11: Global quality of groundwater in 11/2013.

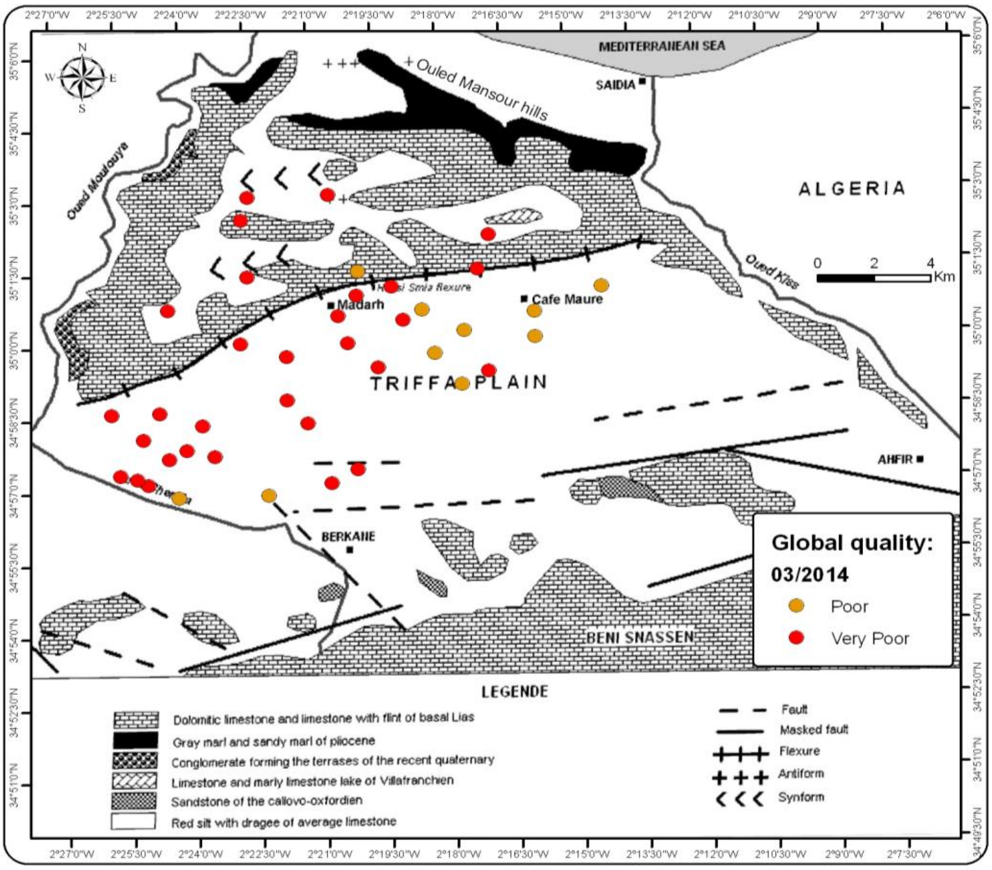

Figure 12: Global quality of groundwater in 03/2014.

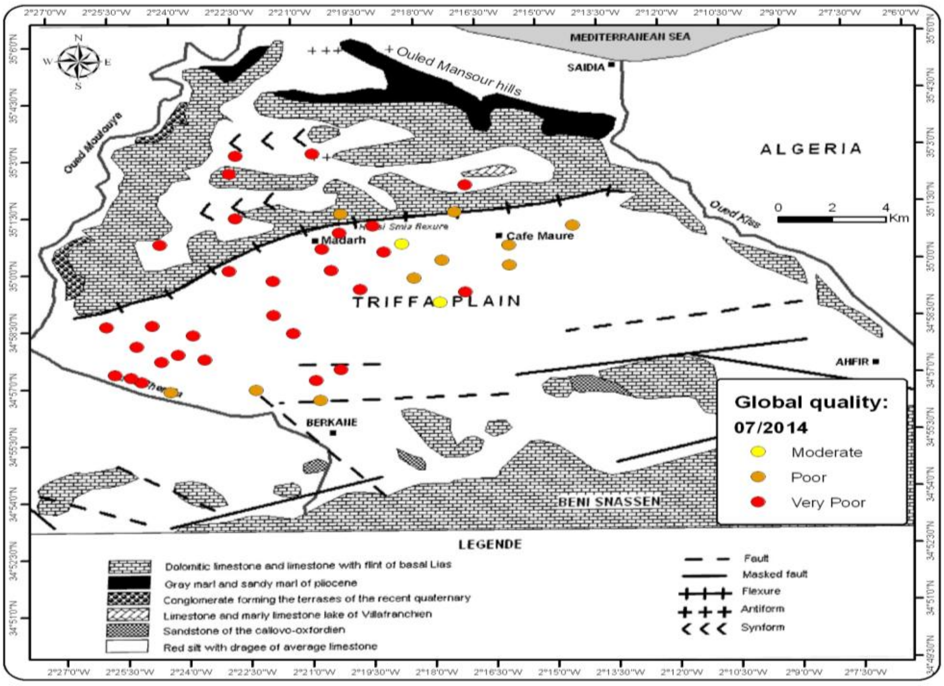

Figure 13: Global quality of groundwater in 07/2014.

Conclusion

The results obtained show that the groundwater quality has deteriorated, and the general quality present is poor and very poor. Two parameters are used to evaluate the global quality of groundwater in Triffa plain: EC and NO_3^-. High concentrations of nitrates and EC are recorded in the western part of Triffa plain and more than 95% of wells tested exceed the standard level (50 mg/l) for drinking water set by [21]. The bacteriological data (TC, FC, and FS) show that almost all of the samples are contaminated. The contamination comes from the septic tanks and the wastewater rejected in the Charaa wadi. Therefore, this contamination is dangerous for human life. Thus, the groundwater of Triffa plain is recommended for irrigation and domestic use.

References

1. Fekkoul A., Zarhloule Y., Boughriba M., Barkaoui A., Jilali A., Salem B., *Arab J Geosc*. 6 (2013) 12.
2. Lamrani Alaoui, H., K. Oufdou, and N. Mezrioui., *Environ Monito Assess*. 145 (2008) 1-3.
3. Douagui A.G., Kouassi I.K., Mangoua O., J M., Savane I., *J Hydro-environ Resea*. 6 (2012) 3.
4. Saber M.,Abdelshafy M., Faragallah M.A., Abd-alla M., *Arab J Geosc*. (2013).
5. Fetouani S., Sbaa M., Vanclooster M., Bendra B., *Agri W Manag*. 95 (2008) 2.
6. Bahri, F. and H. Saibi, *Arab J Geosc*. 5(2012) 6.
7. Wang, R., J.-M. Bian, and Y. Gao, *Arab J Geosc*. 7 (2014) 14.
8. Marko, K., N. Al-Amri, and A.M. Elfeki, *Arab J Geosc*. 7 (2014) 12.
9. Ben Brahim, F., S. Bouri, and H. Khanfir, *Arab J Geosc*. 6 (2013) 6.
10. Jilali, A., Abbas M., Amar M., Zarhloule Y., *Nat Environ Poll Techn*. 14 (2015) 2.
11. ElMandour, A., *Univ Med 1er, FSO*. (1998).
12. Benkaddour, R., *Univ Med 1er, FSO*. (1997).
13. Chettouani, B. and S. Damou., *IAV Rabat*. (1993).
14. DGH., *Rap Inedit*. (1997).
15. El Idrysy, E. and F. Smedt., *Hydrog J*. 14 (2006) 7.
16. El Idrysy, E. and F. Smedt., Hydrog J. 15 (2007) 3.
17. MEMEE., (2001).
18. Rodier, J., *7th ed, ISBN: 2-04-015615-1 Paris*. (1984).
19. AFNOR., *ISBN: 2-12-214311-8, Paris.* (1998).
20. MATEE., *Roy Maroc, Mini Amé Ter, Eau Environ.* (2003).
21. WHO., *UNICEF, OMS.* (2000).