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Assessment of health risks caused by metal pollution of the Maâmora aquifer

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Abstract. Water is a vital commodity for the life of all living beings but despite its importance, its use is not always without danger. Water in these different forms is exposed to various types of pollution that can considerably degrade its quality. Groundwater generally has stable chemical and bacteriological characteristics; however, its properties can degrade depending on the conditions of development, withdrawal, transport, distribution and storage.

The main objective of this work is to assess the health risks due to the conditions of supply and distribution of drinking water through analyzes carried out on fresh water made available to the inhabitants of the city of Kenitra. To do this, we chose to take samples from the Maâmora aquifer and describe the level of its metal pollution.

Analyzes of trace elements or heavy metals Copper, Zinc, Iron, Cadmium, Nickel, Lead, Boron, fluoride in the waters of the Maâmora aquifer were carried out by a flame atomic absorption spectrometer.

Metal analyzes show that the values are still well below the maximum allowed for boron, zinc, fluoride, cadmium, copper and iron. But the concentrations of Lead range from 45.4 to 185.6 µg/L and are very high to the standard of 10 µg/L. The same for Nickel the measured value 78.9 µg/L is much greater than the standard and poses a serious problem for the consumption of raw water from the Maâmora tablecloth.

1-Introduction

The toxicological and ecotoxicological effects of water pollution are multiple. In particular, their role in the destruction of the biodiversity of animal and plant populations and its role in the spread of contagious diseases such as typhoid fever, cholera, amoebic dysentery, and finally its role in the appearance of chronic toxicity (lead poisoning, fluorosis, etc).

This great importance of water has required continuous monitoring of its quality in many countries around the world, in particular, either through direct physico-chemical or metallic monitoring.

The phenomenon of pollution contributes considerably to the limitation of drinking water resources and generates a health risk for the population and compromises the socio-economic development of the country (Rodier, 1996; Berdai, 2003).

Residents of urban areas have access to drinking water which is distributed by ONEP or the Autonomous Authorities; on the other hand, residents of rural areas are forced to exploit untreated groundwater (wells) and are therefore faced with the problem of pollution of drinking and irrigation water.

To respond to this problem, we proposed to study the toxicity of water from wells and boreholes in the Maâmora tablecloth by analyzing their metallic loads (Belghyti et al., 2013).

Our results were compared to those carried out by the Regional Office for Agricultural Development of Gharb (ORMVAG) (Lachhab, 2009), the Laboratory of the National Nuclear Energy Center (CNESTEN) (Bouzidi, 2012) and the laboratory of Ministry of the Environment of Morocco (Bouchouata, 2013).

2- Study zone

The Gharb Chrarda Beni Hssen region covers an area of 7,900 km² or 1.08% of the total area of the country, thus sheltering the Gharb plain (4200 km²). The region includes 3 provinces (Kénitra, Sidi Kacem and Sidi Slimane), 10 urban communities and 53 rural communities. The region is geographically limited to the North by the region of Tanger-Tétouan, to the North East by the region of Taza-El Hoceima-Taounate, to the South-East by the regions of Fez-Boulmane and Meknès-Tafilalet, to the South by the region of Rabat-Salé-Zemmour-Zaer and to the West by the atlantic sea (Figure 1).

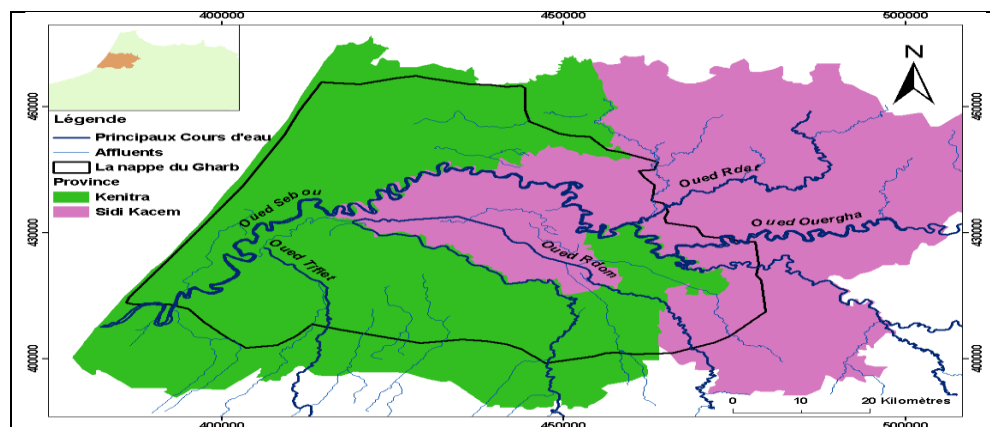


Figure 1: Geographical location of the Gharb plain.

2.1 Maâmora plateau

The Maâmora plateau, which is part of the entire Sebou basin, with an area of 1890 km² is bounded to the south by the Meseta massif, to the north by the Gharb basin. The topography of the region is presented as a succession of hills and valleys lying parallel to the shore, the altitude is relatively low and does not exceed 250 m (Figure 2).

Table 2: Water sampling program for metal determination.

	Fluorine	Boron	Copper	Zinc	Iron	Cadmium	Nickel	Lead
Year	2012	2012	2014					
Months	Février Mars	Février Mars	March, April, May, June, July, August, September, October, November, December.					
Labo	ONEP	ONEP	Faculty of Sciences Kénitra					
Well	Ain Sbai, ElMenzeh, Ain Arris, Ahmed Taleb, Ain Khadra, Ain Taicha, Sidi Taibi, Sidi Yahiya, El Bahraoui, El bahraoui		Bir Rami, El menzeh, Mnassra, Mehdiya, Sidi Taiebi, Bouknadel					



Plate 1: Water analyzes “In situ”

4. Study material:

The determination of heavy metals will be carried out using atomic emission spectrometry coupled to an induced plasma (ICP-AES, Model JOVAN YVAN) (**Plate 2**). The detection limits for different heavy metals are 0.0005; 0.002; 0.004; 0.001 and 0.0008 for Cr, Zn, Cu, Pb and Cd respectively.



Plate 2: Atomic absorption spectrometer (Faculty of Sciences Kénitra).

5. Results and discussion:

Analyzes of trace elements or heavy metals Copper, Zinc, Iron, Cadmium, Nickel, Lead in the waters of the Maâmora aquifer were carried out by a flame atomic absorption spectrometer. The results are reported in (**Tables 2, 3 and 4**).

Lead concentrations vary from 0.0454 to 0.185 mg/L (45.5 to 185 µg/L). The highest values are recorded at Bouknadel (**Table 2 and Figure 3**).

Table 2: Concentration of trace metallic elements in the Maâmora tablecloth.

Zones/Métal	Lead	Zinc	Nikel	Cadmium	Copper	Iron
Well Mnassra P1 (mg/L)	0,0454	0,007	0,0698	<0,0012	0,0385	0,0792
Well Mnassra P2 (mg/L)	0,0634	0,0367	0,055	<0,0012	0,0456	0,0509
Well Bir Rami P3 (mg/L)	0,0557	2,204	0,0772	<0,0012	0,0273	0,0506
Well Mehdia P4 (mg/L)	0,0694	1,427	0,0789	<0,0012	0,0726	0,1001
Well Sidi Tayebi P5 (mg/L)	0,0604	0,02893	0,0701	<0,0012	0,0268	0,0422
Well Bouknadel P6 (mg/L)	0,1856	0,0289	0,0029	<0,0012	0,0306	0,1873
Well Ain Sbai P7 (mg/L)	0,1172	0,5331	0,0197	0,0187	0,0498	0,01116
Well Sidi Yahia P8 (mg/L)	0,0832	0,1187	0,0016	0,0235	0,0573	0,1645
Well Ain Arris P9 mg/L	0,0829	0,0654	0,0069	0,0225	0,0513	0,1188
Average (mg/L)	0.0848	0.49441444	0.04245556	0.00798889	0.04442222	0.08941778
Average (µg/L)	84,80	494,41	42,45	7,98	44,42	98,41
Moroccan Standards (µg/L)	50-25-10	3000	20	3	2000	300

Table 3: Evolution of the concentration of fluorides in the waters of the Maâmora Tablecloth (mg/l)

Drilling	February	March	Average	Standard deviation
F1 : Ain Sbai	0,2	0,21	0,205	0,005
F2 : El Menzeh	0,21	0,23	0,22	0,01
F3 : Ain Arris	0,18	0,19	0,185	0,005
F4 : Ahmed Taleb	0,23	0,24	0,235	0,005
F5 : Ain Khadra	0,2	0,2	0,2	0,00
F6 : Ain Taicha	0,25	0,26	0,255	0,005

Table 4 : Evolution of the concentration of Boron in the waters of the Maâmora Aquifer (mg/l)

Drilling	February	March	Average	Standard Deviation
F1 : Ain Sbai	0,001	0,00	0,0005	0,0005
F2 : El Menzeh	0,002	0,001	0,0015	0,0005
F3: Ain Arris	0,001	0,001	0,001	0,00
F4 : Ahmed Taleb	0,0013	0,0014	0,00135	0,00005
F5 : Ain Khadra	0,00	0,00	0,00	0,00
F6 : Ain Taichà	0,0003	0,0013	0,0008	0,0005
F7 : Sidi Taibi	0,0026	0,0032	0,0029	0,0003
F8 : Sidi Yahia	0,0027	0,0026	0,0265	0,0005
F9 : El Bahraoui	0,0001	0,0001	0,0001	0,00
F10 : El Bahraoui	0,0004	0,0003	0,00035	0,00005

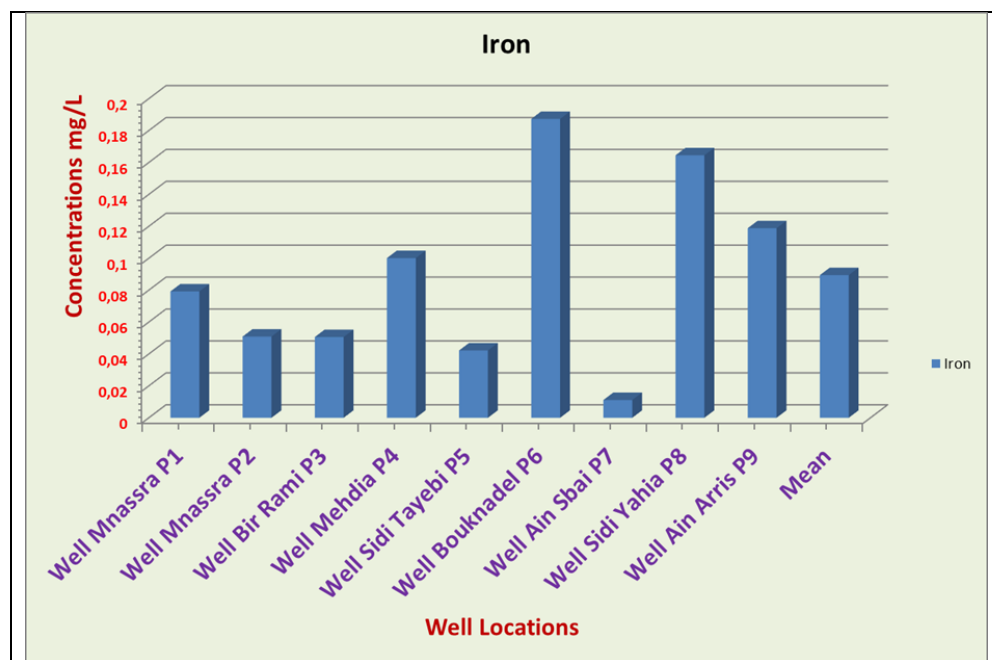


Figure 3: Spatial evolution of the Iron content of the Maâmora aquifer.

Iron concentrations vary from 0.01116 to 0.1873 mg/L (11.16 to 187.3 µg/L). The highest values are recorded at Bouknadel (**Figure 3**).

The standard is set at 0.3 mg/L (VMA) (300 µg/L). All values recorded at the Maâmora aquifer wells remain below the Moroccan standard. In the Maâmora aquifer the average iron is 98.41 µg/L, lower than the standard and does not pose a problem for the consumption of water from the Maâmora aquifer. It should be noted, however, that the concentration of iron in Bouknadel is very high (187.3 µg/L) and can pose a long-term problem due to the cumulative ecotoxicological effect (Bioamplification).

Copper concentrations vary from 0.0268 to 0.0726 mg/L (26.8 to 72.6 µg/L). The highest values are recorded at Mehdi (**Figure 4**). The standard is set at 2 mg/L (VMA) but consumer complaints start from 1 mg/l. All the values recorded at the Maâmora aquifer wells are lower than the Moroccan standard.

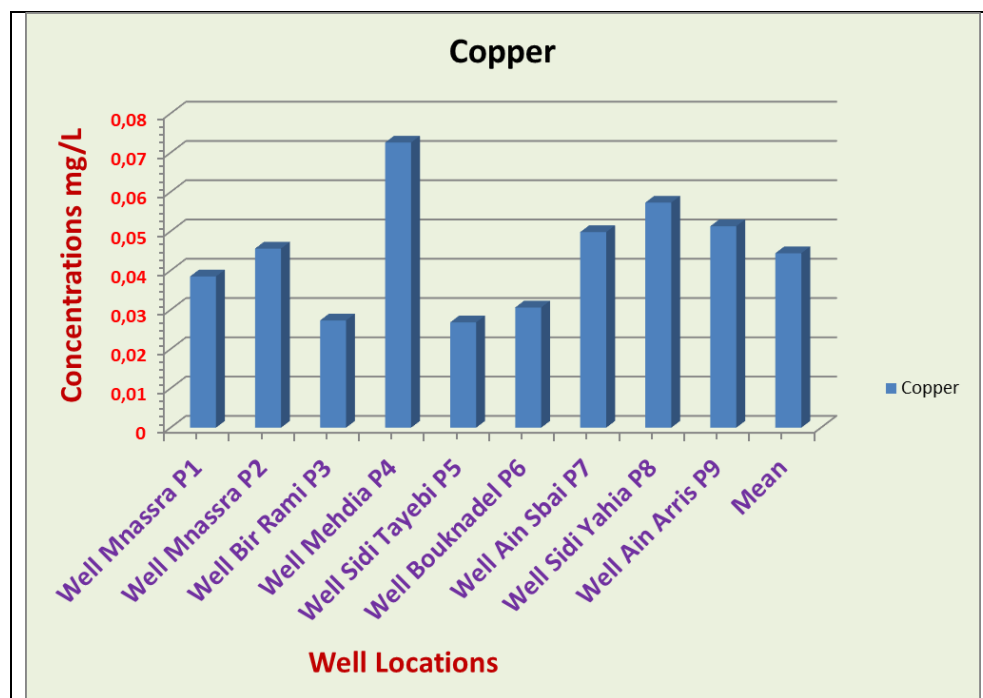


Figure 4: Spatial evolution of the copper content of the Maâmora aquifer.

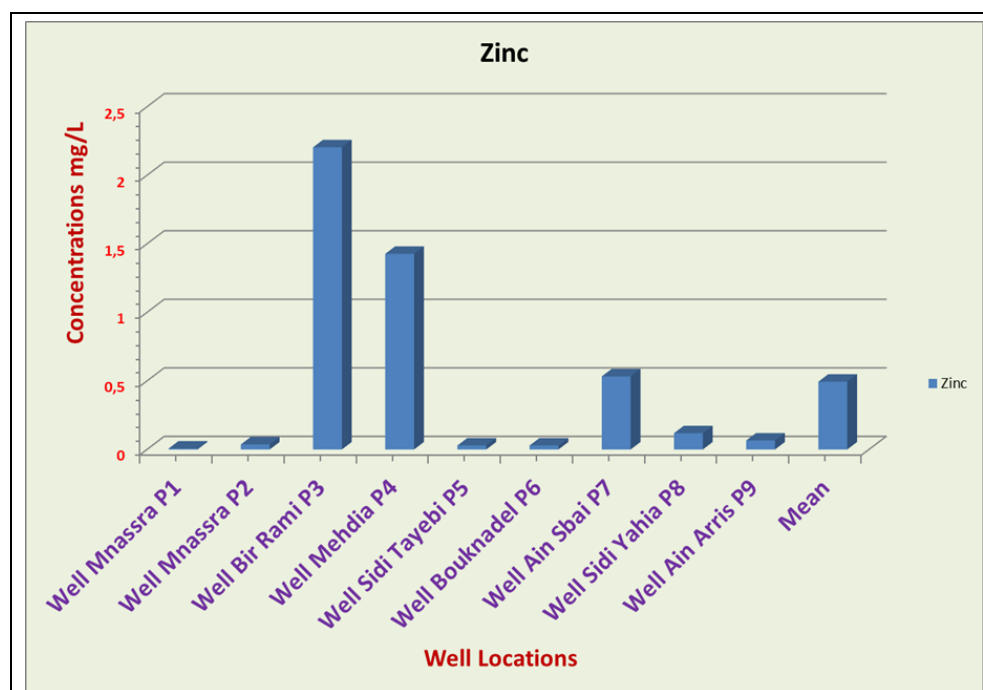


Figure 5: Spatial evolution of zinc contents in the Maâmora aquifer.

Zinc concentrations vary from 0.007 to 2.204 mg/L (7 to 2204 µg/L). The highest values are recorded at Bir Rami and Mehdiya (Figure 5).

The standard is set at 3 mg/L (VMA). All the values recorded at the Maâmora aquifer wells are lower than the Moroccan standard. In the Maâmora aquifer the average of 0.49441 mg/L (494.41 µg/L) remains well below the standard and poses no problem for the consumption of this water.

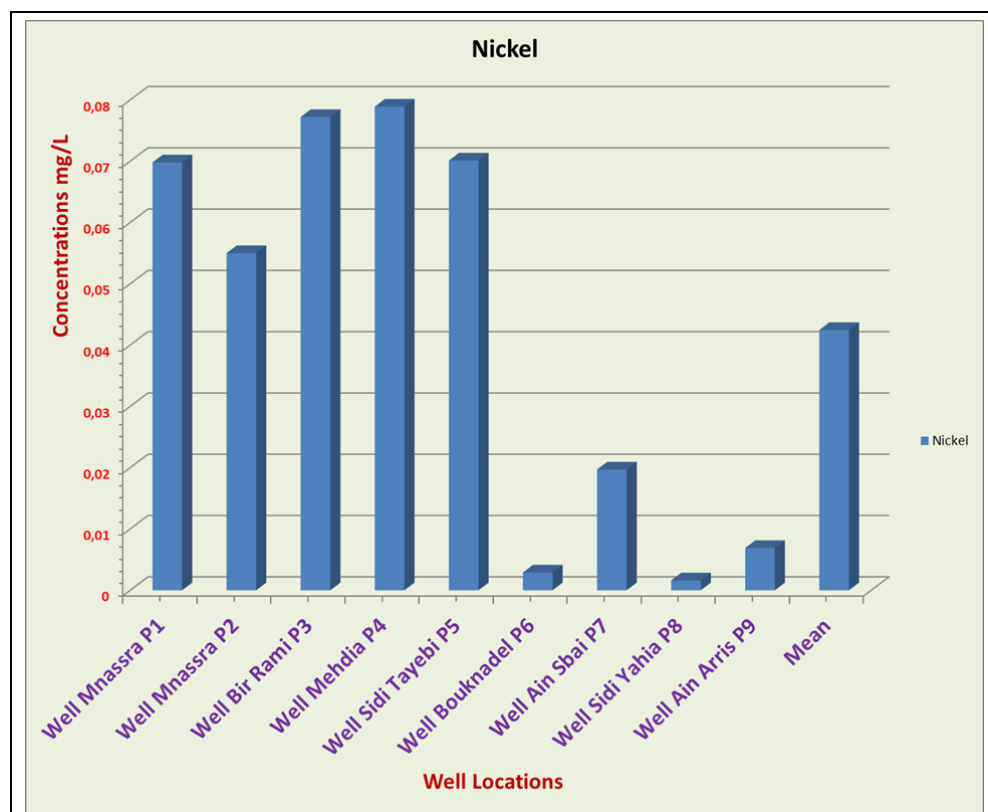


Figure 6: Spatial evolution of the Nickel content of the Maâmora aquifer.

Nickel concentrations vary from 0.0016 to 0.0789 mg/L (1.6 to 78.9 $\mu\text{g/L}$). The lowest values are recorded in Sidi Yahia and Bouknadel (Figure 6).

The standard is set at 20 $\mu\text{g/L}$ (VMA). Almost all the values recorded at the Maâmora aquifer wells exceed the Moroccan standard. In the Maâmora aquifer the average of 42.45 $\mu\text{g/L}$ is much higher than the standard and poses a serious problem for the consumption of untreated water from the Maâmora aquifer.

Cadmium concentrations remain below the flame spectrometer detection limit of 0.0012 mg/L or 1.2 $\mu\text{g/L}$ for 4 wells. But for 3 wells the values exceed the standard set at 3 $\mu\text{g/L}$ (VMA). Therefore the values recorded at the wells of the Maâmora aquifer (18 to 23.5 $\mu\text{g/L}$) exceed the Moroccan standard (Figure 7) and pose a serious problem for the consumption of raw water from the wells of Sidi Yahia, Ain Arris and Ain Sbail.

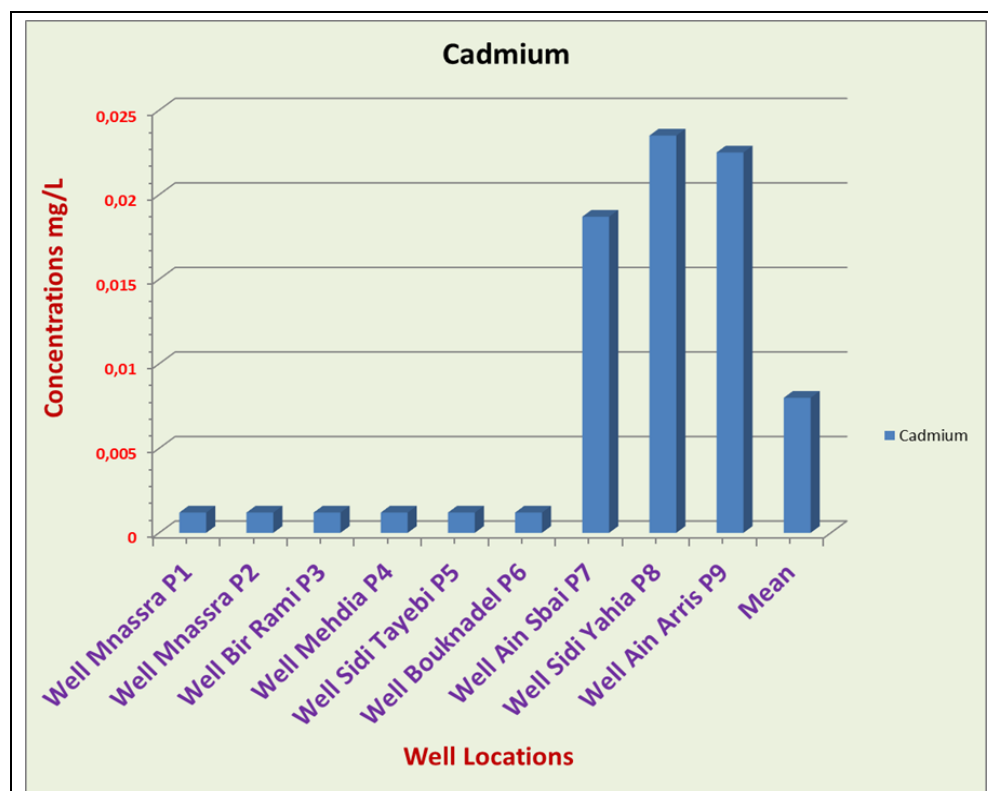


Figure 7: Spatial evolution of the cadmium content of the Maâmora aquifer.

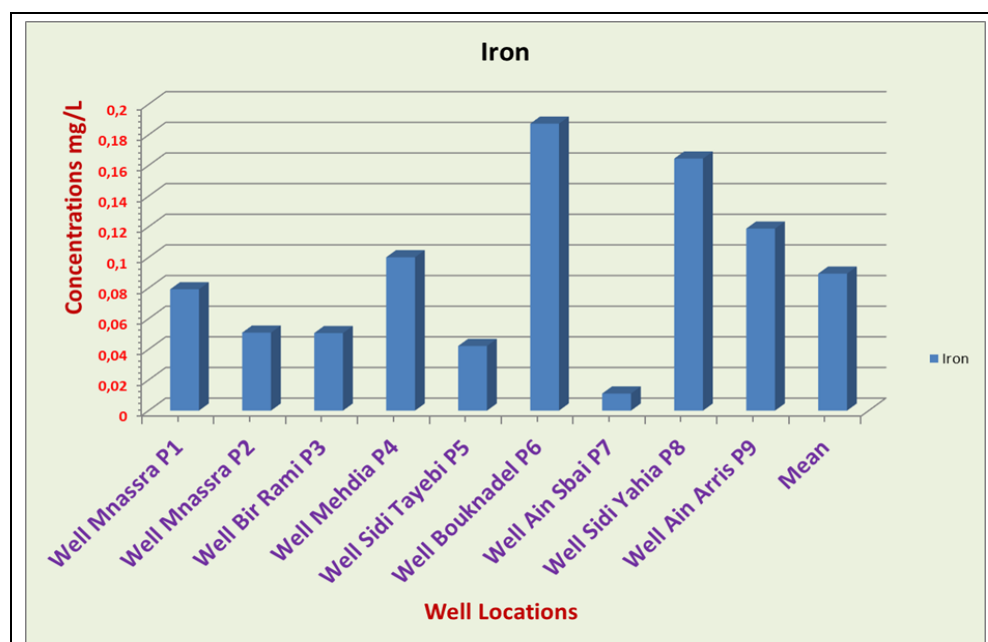


Figure 8: Spatial evolution of the iron content of the Maâmora aquifer.

During our study, the fluoride values (**Table 3; Figure 9**) oscillated between 0.18 and 0.26 mg/l. The maximum admissible value is set at 1.5 mg/l, according to Moroccan water drinking standards.

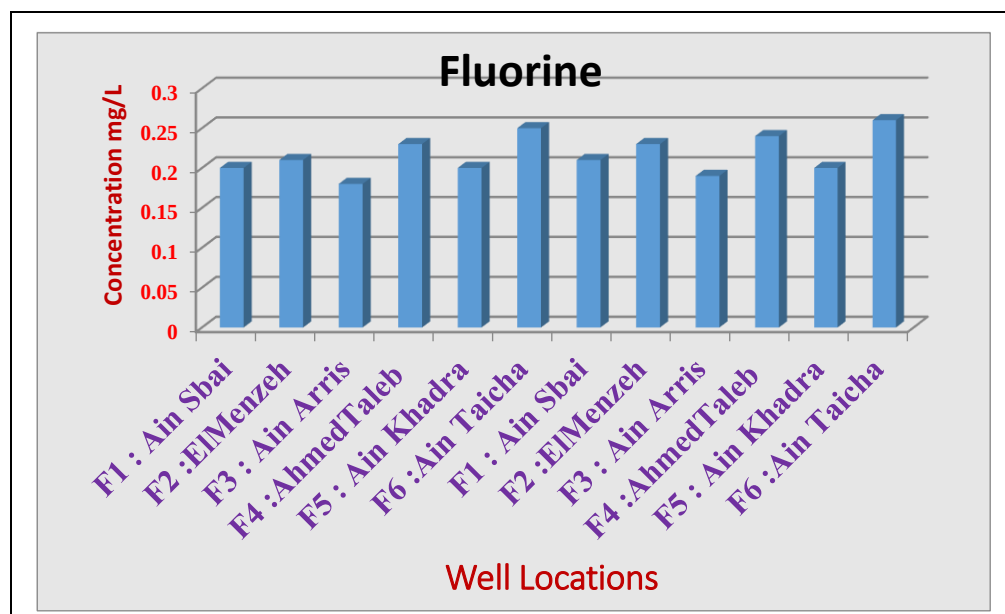


Figure 9: Variations in the concentration of fluoride ions in the Maâmora.

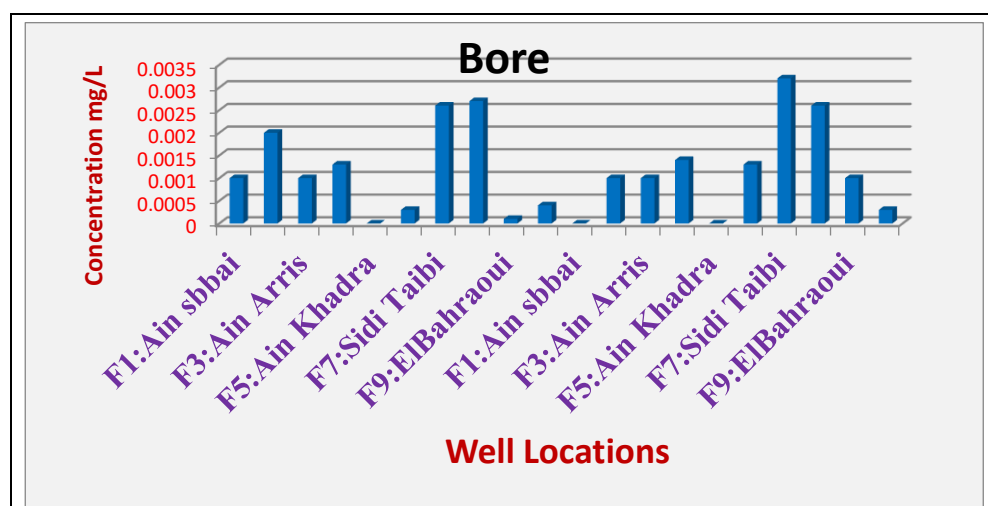


Figure 10: Variations in boron concentration in the Maâmora aquifer.

Boron varies during the study between 0 and 0.0026 mg/l (**Table 4; Figure 10**). These values therefore always remain well below the maximum admissible value set at 0.3 mg/l, according to Moroccan water drinking standards.

6.Discusion:

The comparison of our results with those previously carried out on the wells of the Maâmora aquifer, in particular those carried out by the Ministry of the Environment (**Bouchouata, 2013**) and the National Institute of Hygiene Rabat showed that:

- Copper has levels comparable to those of **Lechhab (2009)** and **Bouchouata (2013)** which remain lower than the Moroccan drinking standards of 2000 µg/L.
- Zinc has contents of 8 to 31 µg/L which are identical to our results. But our values recorded in Mehdiya and Bir Rami El Menzeh of 1427 and 2204 µg/L respectively are unusual.

- Cadmium reaches a maximum of 4.1 µg/L and exceeds the standard of 3 µg/L. Likewise, this excess was recorded in our analyzes by the atomic absorption apparatus of the Faculty of Sciences of Kénitra (18 or 22 or 23.5 µg/L). Our results with an average of 7.98 µg/L are supported by those of Bouchouata but are contradictory with those of (Staessen et al., 1995; Lachheb 2009; Akhiar, 2009).
- Nickel has very low contents of 1.4 to 20 µg/L in Mnassra (Bouchouata, 2013) but very alarming (55 and 69 µg/L) in our analyzes on the Mnassra wells.
- Lead has very low levels of 1.3 to 11 µg/L in Mnassra (Bouchouata, 2013) and 0.77 to 13.55 µg/L (Lechhab, 2009) but very alarming (45 and 63 µg/L) in our analyzes of the two Mnassra wells.
- Iron has very high levels of 42 to 600 µg/L in Mnassra (Bouchouata, 2013). This confirms our results of 50 to 79 µg/L. Likewise, the value of 600 µg/L in Mnassra, comparable to our value of 187.3 µg/L in Bouknadel, shows that changes in iron concentrations must be taken seriously.

7. Conclusion:

Metal analyzes show that the values are still well below the maximum allowed for boron, zinc, fluoride, cadmium, copper and iron. But the concentrations of Lead range from 45.4 to 185.6 µg/L and are very high to the standard of 10 µg/L.

The same for Nickel 78.9 µg/L is much greater than the standard and poses a serious problem for the consumption of water from the Maâmora water table.

We also note that the iron concentration in the Bouknadel boreholes is very high (187.3 µg/L) and the zinc concentration in the Bir Rami boreholes is very high (2204 µg/L) and may pose a problem in the long term due to bioaccumulation in the food chain and directly.

The follow-up of the toxicological study by the analysis of eight metallic trace elements (Boron, Fluorides, Lead, Copper, Cadmium, Nickel, Iron and Zinc) at the wells of the Maâmora aquifer allowed the identification of low levels measured metals.

In light of this work, we can make the following recommendations:

- expand the study area and monitor a significant number of wells to inform us about the quality of the maâmora aquifer;
- study other metallic elements which can be the cause of contamination of the water table such as Selenium, Mercury, Chromium, etc.;
- Monitor the levels of nitrate contamination, especially in regions with intense agricultural activity or nearby areas such as Bouknadel and Mnassra, and study their impact on health;
- Monitor the levels of pesticide contamination, especially in regions with intense agricultural activity such as Bouknadel, El Bahraoui and Mnassra, and study their impact on health.

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