Egyptian Journal of Aquatic Biology & Fisheries
Zoology Department, Faculty of Science,
Ain Shams University, Cairo, Egypt.
ISSN 1110 – 6131
Vol. 25(3): 739 – 758 (2021)
www.ejabf.journals.ekb.eg

Assessment of nitrogen pollution of groundwater in the Maamora Gharb aquifer, Morocco

Mourad BOUITA [1,*], Youssef EL MADHI[2], Hanane SBAI[2], Imane BOUITA[4], Ahmed El BAKOURI[3], El Mehdi IBRAHIMI[1], El Mahjoub CHAKIR[1]

1. Department of Physics, Laboratory of Materials Physics and Subatomic, University Ibn Tofail. Faculty of Sciences, Kenitra, Morocco
2. Regional Center for Education and Training. Rabat, Morocco
3. Laboratory of Natural Resources & Sustainable Development, University Ibn Tofail. Faculty of Sciences. Kenitra, Morocco.
4. Department of Biology, University Ibn Tofail. Faculty of Sciences. Kenitra, Morocco

[*]**Corresponding Author: mourad.bouita@gmail.com**

ARTICLE INFO

Article History:
Received: Feb. 26, 2021
Accepted: March 30, 2021
Online: June 28, 2021

Keywords:
Gharb Plain,
Tablecloth,
Nitrate,
Pollution,
Kenitra,
Morocco

ABSTRACT

The present study was conducted to assess the impact of agricultural intensification and the spreading of untreated wastewater on the physical and chemical quality of groundwater in Kénitra (Gharb, Morocco). The physico-chemical parameters monitored were: T°C, pH, EC, NH_4^+, NO_2^-, NO_3^-, Cl^-, SO_4^{2-}, HCO_3, and the total hardness (TH) of raw water from boreholes on the Maâmora aquifer. The groundwater of the kenitra water table showed the following mean values: Temperature (20 ° C), pH (6.47), Electrical Conductivity (785.1 µs / cm), Nitrite (0.0093 mg / L), Nitrate (84.22 mg / L), Ammonia (0.093 mg / L), Chlorides (141 mg / L), HCO_3^- (5 meq / L), Total Hardness (13.9 meq / L), and Sulphates (17.7 mg / L). More specifically, the current study notified high concentrations of nitrates in some wells (up to 2692 mg / L). Hence, the effects of polluted groundwater should be highly concerned due to their serious health consequences. For sustainable use, policymakers must protect the aquifer from the uncontrolled development of agriculture and the spraying of unreasonable masses of pesticides, nitrogen and phosphorus fertilizers.

INTRODUCTION

Since the appearance of water in the planet Earth, its volume and quality have continued to deteriorate. In Morocco, the situation is more serious because in addition to water, water resources are facing strong pressures from climate changes and galloping human demography.

Furthermore, according to the United Nations World Water Resources Development Report, many countries, including Morocco, are already in crisis. With a mobilizable water rate of 650 m3/year **(MIPA 2019),** Morocco is ranked 155 compared to 180 countries **(FAO, 2002)**. The UNICEF has reported that 2.1 billion people worldwide use untreated sources of drinking water such as wells, springs and unprotected surface water **(WHO-UNICEF, 2017).**

Globally, in many parts of the world, especially in arid and semi-arid climates (such as Morocco), groundwaters are a vital source of drinking, agricultural and industrial water supply especially in areas where surface water sources are limited or polluted **(Howard *et al.*, 2006)**. One third of the world's population depends on groundwater and about 40% of the world's food production uses groundwater. In areas with low annual rainfall and a long dry season, underground reservoirs play a major role in satisfying the supply of drinking water **(Li *et al.*, 2018; Naser *et al.*, 2018).**

Water quality is an essential environmental issue for the agricultural sector **(Ayers & Westcot, 1985).** It is also important for all agricultural uses, from irrigation to watering livestock and domestic needs. Any surface or underground water can be contaminated. Certain improper agricultural practices can result in biological, chemical or physical contamination of a water source. Water resources are also subject to pollution mainly due to the discharge of solid and liquid waste represented in leachate, domestic and industrial wastewaters.

For example, in India, each year, around 37.7 million children have water-borne illnesses, causing more than 1.5 million deaths, mostly in children under 5 years old. About 75% of the rural and tribal population do not have adequate sanitation facilities and most of them depend on contaminated water from dangerous sources, thus exposed to water-borne diseases **(WHO, 2020).**

Physico-chemical characterization of groundwaters in different environments has been carried out in many regions of the world to assess the state of groundwater quality using certain physic-chemical indicators and geochemical indices, such as electrical conductivity (EC), rate of sodium adsorption (SAR), percentage of soluble sodium (SSP), concentrations of sulfates and nitrates and presence of toxic heavy metals **(Rodier *et al.*, 2005; Rodier and Legube, 2009; Belkhiri et al., 2012 ; Sarath Prasanth, 2012 ; Belghyti et al., 2013 ; Akter *et al.*, 2016; Alemad *et al.*, 2016 ; Li and *et al.*, 2016 ; Al-Qawati *et al.*, 2018 ; Abbasnia *et al.*, 2019; Lotfi *et al.*, 2020).**

In the Gharb area, which encompasses one of Morocco's largest irrigated areas, agricultural activities are considered among the potential sectors that can contribute to the degradation of water and soil quality. Domestic and industrial discharges are also sources of contamination of surface water. These, in return, can infiltrate to contaminate the quality of groundwater. Agricultural activities are nowadays recognized as an important source of potential pollution degrading the quality of water and contributing to the eutrophication of lakes and reservoirs (nitrogen, phosphate) and to the contamination of groundwater (nitrates).

For the aforementioned multiple reasons, it was of great interest to study the physic-chemical quality of groundwater from the Maâmora aquifer used by a large population of the Gharb region. In the present work, it was proposed to describe the physico-chemistry and its evolution after several decades of exploitation of the Maâmora aquifer, and examine the impact of agriculture on water nitrification as well.

MATERIALS AND METHODS

The present research addressed the physico-chemical pollution of groundwater in the Gharb Chrarda Beni Hssen region to describe the evolution of nitrification of the waters of the Maâmora water tablecloth.

The private boreholes and wells are located in the towns and Douars of Kénitra, Mehdia, Sidi Tayebi, Oulad Berjal, Mnassra, Sidi Slimane, Sidi Allal Tazi and Mograne. To complete the comparisons, other samples were taken by ONEP (National Office for Drinking Water), ORMVAG (Regional Office for Agricultural Development of Gharb) and RAK (Autonomous Authority of water and electricity distribution in Kénitra).

RESULTS

Analysis of nitrate concentrations in the 20 wells at Sidi Slimane showed variations between a minimum of 14.26 mg / L and a maximum of 386.88 mg / L. The recorded average was 99.46 ±94.11 mg/L (Table 1& Fig. 1).

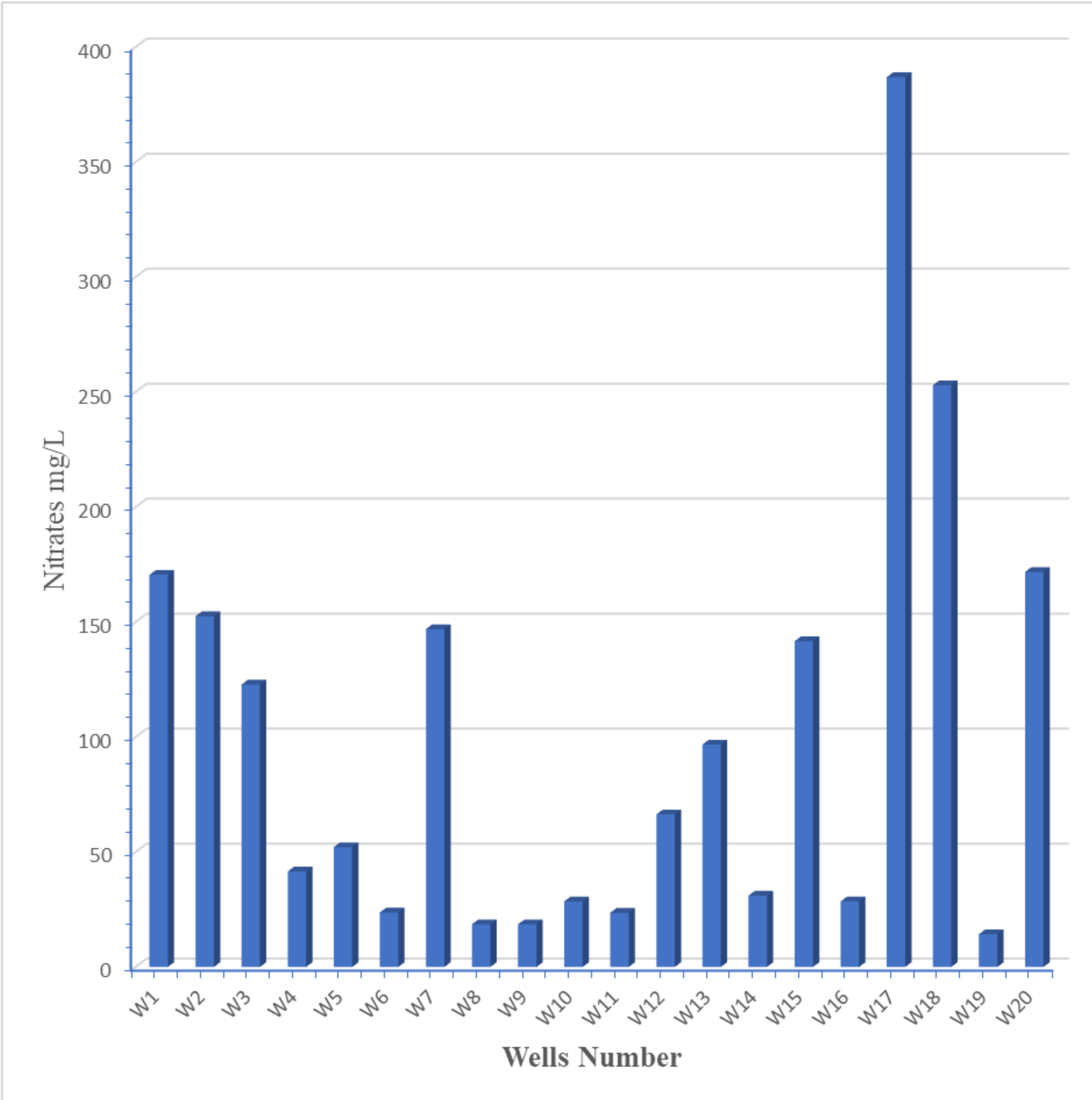

Fig. 1: Spatial variations in nitrate levels in Sidi Slimane groundwater.

Table 1: Sidi Slimane groundwater physic-chemistry results.

Wells	Depth (m)	pH	HCO_3^-	NO_3^-
W1	12	7.50	591.70	170.50
W2	5.5	7.31	591.70	152.50
W3	30	7.01	346.50	122.80
W4	24	7.19	145.20	41.50
W5	12	6.74	486.80	52.10
W6	10	7.06	356.20	23.70
W7	10	7.09	484.30	146.90
W8	50	7.15	208.60	18.60
W9	20	7.85	418.50	18.60
W10	5	7.04	488.00	28.50
W11	15	7.31	400.16	23.56
W12	13	7.63	311.10	66.34
W13	12	7.14	500.20	96.72
W14	65	7.71	368.44	31.00
W15	45	7.36	556.32	141.63
W16	4	7.47	478.24	28.52
W17	24	7.38	653.92	386.88
W18	8	7.60	799.10	252.96
W19	10	7.17	677.10	14.26
W20	30	7.62	370.88	171.74

Analysis of nitrate concentrations in the 54 wells at Sidi Allal Tazi showed variations between a minimum of 4.71 mg / L and a maximum of 527.74 mg / L. The average was recorded at avalue of 110.95 ±87.62 mg/L (Tables 2,3& Fig. 2).

The level of contamination by nitrates was higher in Sidi Allal Tazi (>527 mg/L) than in Sidi Slimane (< 400 mg/L). But those values remain at levels higher than the authorized standards (<50 mg / L).

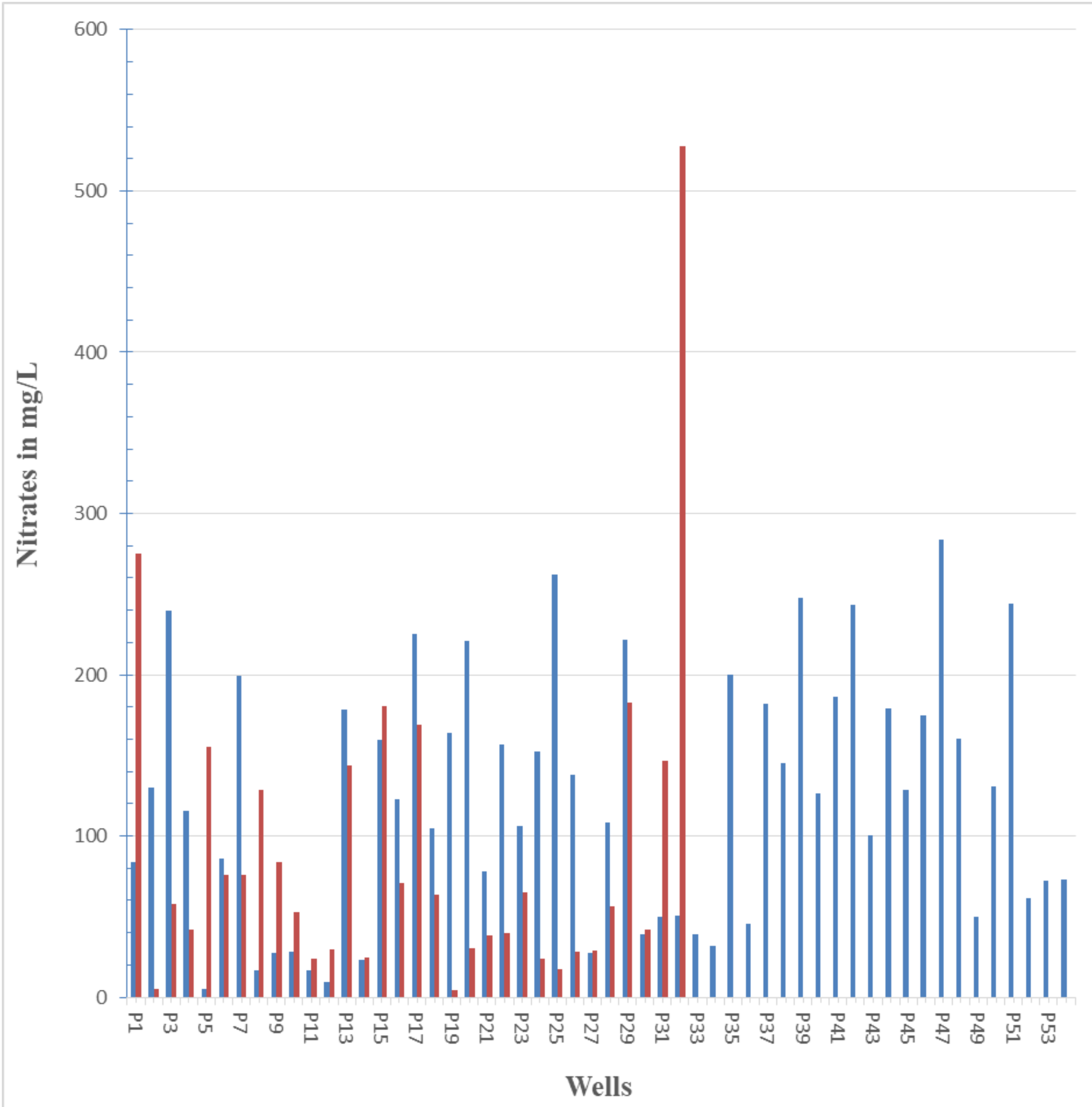

Fig. 2: Spatial variations in nitrate levels in Sidi Allal Tazi groundwater.

Table 2: Sidi Allal Tazi groundwater physic- chemistry results.

Wells	pH	C.E.(dS/m)	Nitrates (ppm)
T1	7.25	1.88	275.40
T2	7.46	0.86	5.08
T3	7.80	0.97	58.03
T4	7.70	1.52	41.66
T5	7.68	10.50	155.49
T6	7.62	1.05	75.51
T7	7.54	0.82	75.51
T8	7.62	1.04	128.46
T9	7.60	0.79	83.57
T10	7.80	1.01	52.95
T11	7.46	1.07	23.81
T12	7.25	1.64	29.51
T13	7.54	0.92	143.71
T16	7.31	1.94	24.30
T17	7.33	2.60	180.66
T18	7.36	1.65	70.93
T19	7.28	1.59	168.76
T20	7.25	2.57	63.48
T21	7.00	2.41	4.71
T22	7.91	1.64	30.50
T23	7.60	0.54	38.56
T24	7.45	2.95	39.55
T25	7.38	1.32	64.97
T27	7.53	1.45	24.05
T28	7.66	1.09	17.36
T29	7.56	1.46	28.15
T30	7.36	1.22	28.89
T31	7.65	0.63	56.54
T33	7.68	0.93	183.02
T34	7.72	0.64	41.91
T35	7.42	1.18	146.56
T36	8.13	15.61	527.74

Table 2: Continuous

NO_3^-			
Wells	**mg/L**	**Wells**	**mg/L**
P1	84.07	P28	108.62
P2	129.95	P29	221.46
P3	239.44	P30	38.81
P4	115.44	P31	50.10
P5	5.46	P32	50.47
P6	86.30	P33	39.06
P7	199.14	P34	31.74
P8	16.49	P35	200.38
P9	27.78	P36	45.26
P10	28.15	P37	182.28
P11	16.74	P38	144.96
P12	9.42	P39	247.88
P13	178.06	P40	126.73
P14	22.94	P41	186.00
P15	159.96	P42	243.04
P16	122.64	P43	100.69
P17	225.56	P44	178.93
P18	104.41	P45	128.71
P19	163.68	P46	174.59
P20	220.72	P47	284.08
P21	78.37	P48	160.08
P22	156.61	P49	50.10
P23	106.39	P50	130.94
P24	152.27	P51	243.78
P25	261.76	P52	61.13
P26	137.76	P53	72.42
P27	27.78	P54	72.79

The dosages of nitrates in the locality of Ouelad Berjal show that the concentrations reach alarming levels (2692 mg / L) in the well number B10. In this region of the Gharb plain, the average nitrate concentration is around 160.41 mg/L (±434.63 mg / L).

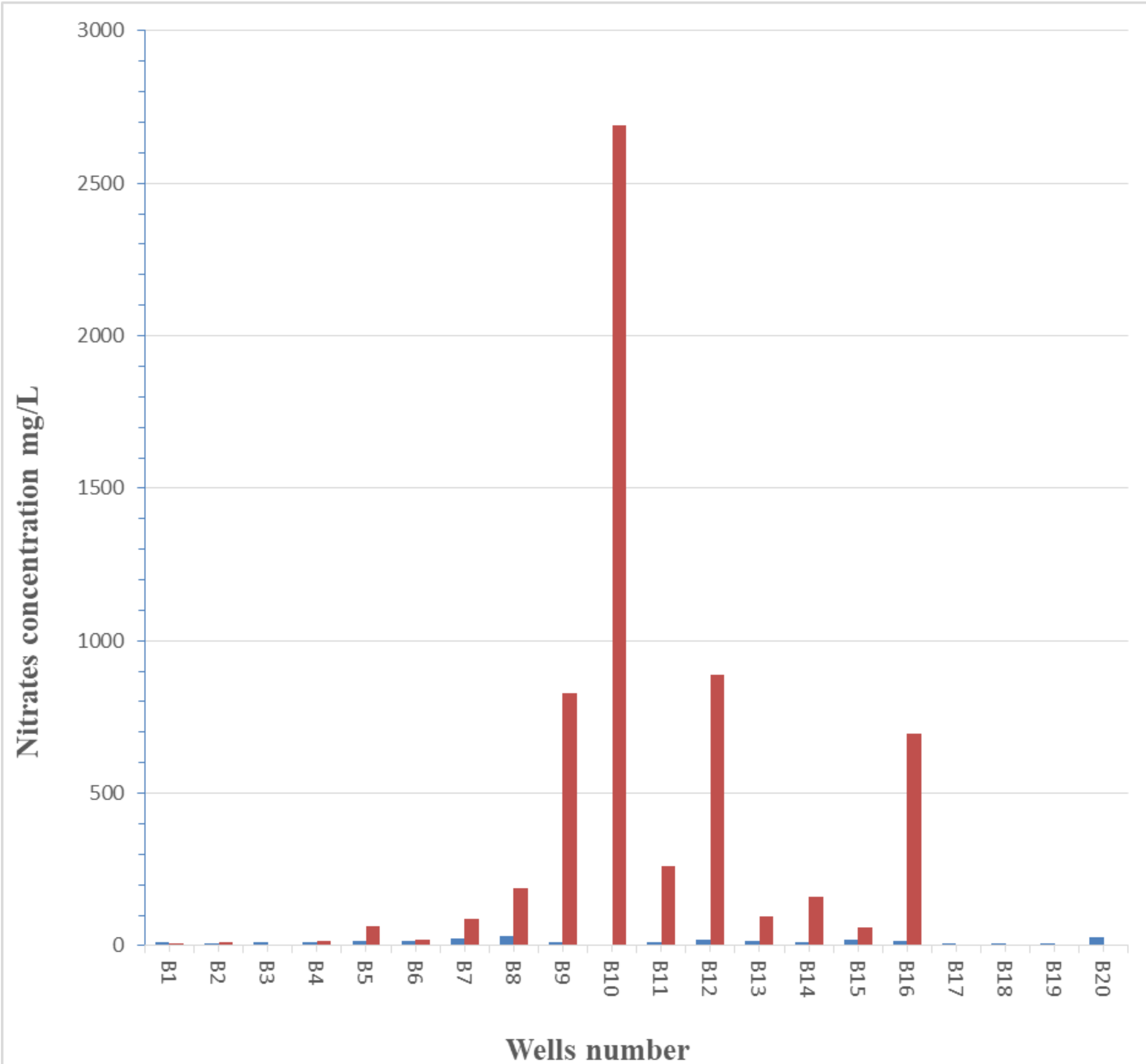

Fig. 3: Spatial variations in nitrate levels in Ouelad Berjal groundwater.

Table 3: Evolution of the physico-chemistry of the waters of Ouelad Berjal.

2010			**2011**		
N° Puits	**pH**	**NO_3^- mg/L**	**Puits**	**pH**	**NO_3^- mg/L**
1	8.62	9.3	**1**	8.07	13.02
2	8.65	10.42	**2**	8.06	6.82
3	8.39	0.24	**3**	7.99	11.16
4	8.46	17.11	**4**	8.1	11.78
5	8	63.36	**5**	8.3	14.88
6	8.12	20.58	**6**	7.76	14.26
7	8.69	86.92	**7**	7.65	23.56
8	8.33	188.6	**8**	8.24	32.86
9	8.49	827.9	**9**	7.85	11.16
10	8.24	2692	**10**	8.11	3.72
11	8.40	260.8	**11**	7.96	13.64
12	8.31	886.9	**12**	7.85	18.6
13	8.77	94.6	**13**	7.75	14.26
14	8.21	162.2	**14**	7.89	12.4
15	8.73	59.9	**15**	7.67	18.6
16	8.33	693.8	**16**	7.96	16.12
			17	7.8	6.82
			18	7.79	8.06
			19	7.9	9.3
			20	7.71	27.9

Analysis of nitrate concentrations in the 90 wells at Mnassra showed variations between a minimum of 4.34 mg / L and a maximum of 275.30 mg / L. The average was recorded at 48.71 ±53.05 mg/L (Table 4& Fig. 4).

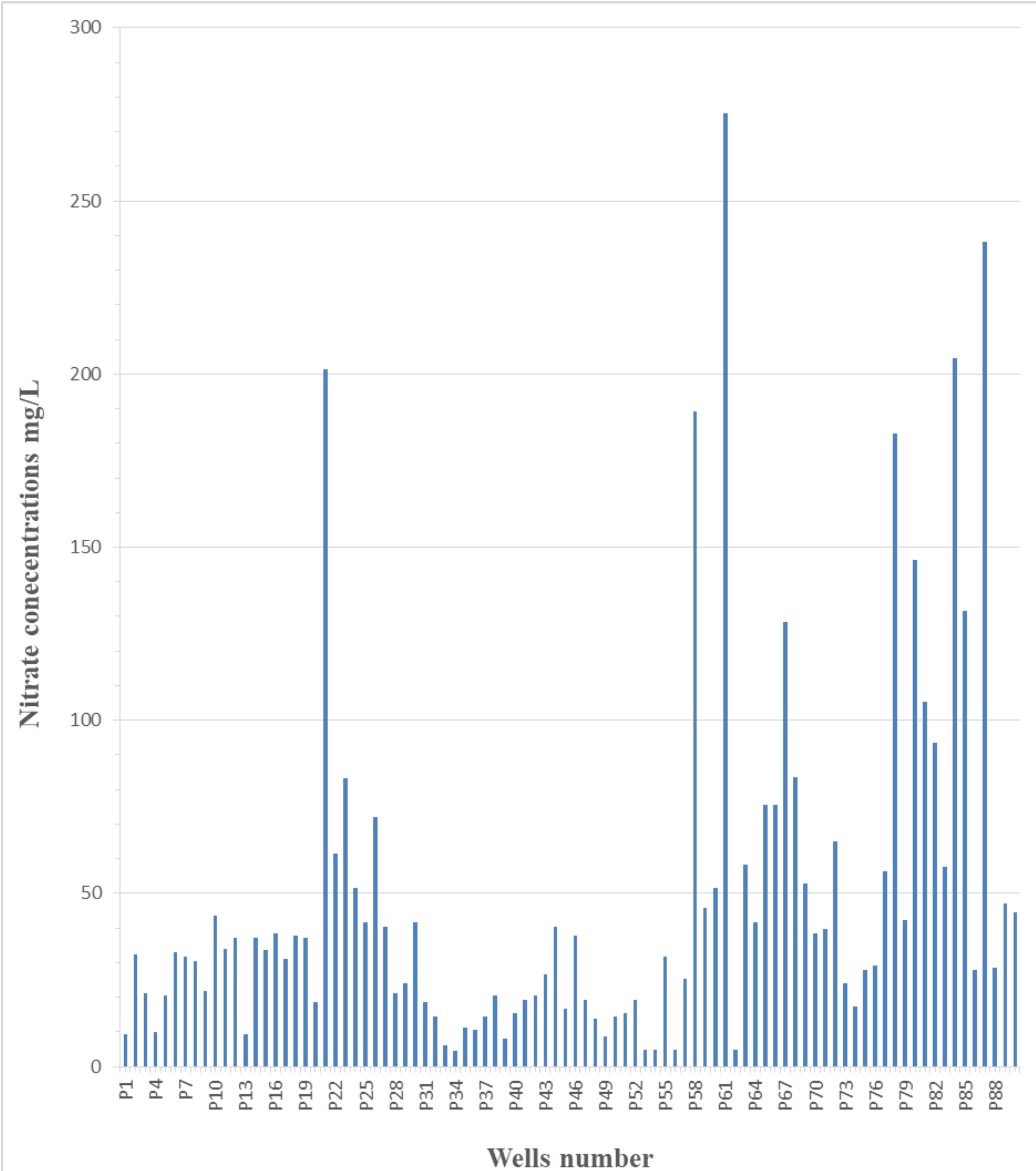

Fig. 4: Spatial variations in nitrate levels in Mnassra groundwater.

Table 4: Evolution of the physico-chemistry of water in Mnassra

Wells	pH	NO3- mg/L	Wells	pH	NO3- mg/L	Wells	pH	NO3- mg/L
P1	7.3	9.301	P31	7.4	18.6	P61	7.25	275.3
P2	7.6	32.24	P32	8.5	14.26	P62	7.46	4.96
P3	7.7	21.08	P33	8	6.2	P63	7.8	58.28
P4	7.6	9.921	P34	8.1	4.34	P64	7.7	41.54
P5	7.9	20.46	P35	8	11.16	P65	7.62	75.65
P6	7.8	32.86	P36	7.9	10.54	P66	7.54	75.65
P7	7.6	31.62	P37	8	14.26	P67	7.62	128.4
P8	7.6	30.38	P38	7.9	20.46	P68	7.6	83.71
P9	7.7	21.7	P39	8.3	8.061	P69	7.8	52.7
P10	7.6	43.4	P40	8.5	15.5	P70	7.6	38.44
P11	7.9	34.1	P41	7.6	19.22	P71	7.45	39.68
P12	7.9	37.2	P42	7.7	20.46	P72	7.38	65.11
P13	9.3	9.301	P43	7.8	26.66	P73	7.53	24.18
P14	7.7	37.2	P44	7.9	40.3	P74	7.66	17.36
P15	7.7	33.48	P45	7.9	16.74	P75	7.56	27.9
P16	7.6	38.44	P46	8.1	37.82	P76	7.36	29.14
P17	7.7	31	P47	8.4	19.22	P77	7.65	56.42
P18	7.8	37.82	P48	8.2	13.64	P78	7.68	182.9
P19	7.7	37.2	P49	7.9	8.681	P79	7.72	42.16
P20	7.9	18.6	P50	7.7	14.26	P80	7.42	146.3
P21	8	201.5	P51	8	15.5	P81	7.4	105.4
P22	7.8	61.38	P52	8	19.22	P82	7.6	93.63
P23	7.8	83.09	P53	7.5	4.96	P83	7.6	57.66
P24	7.7	51.46	P54	7.7	4.96	P84	7.5	204.6
P25	8	41.54	P55	8	31.62	P85	7.55	131.5
P26	7.7	71.93	P56	7.7	4.96	P86	7.4	27.9
P27	7.9	40.3	P57	7.5	25.42	P87	6.4	238.1
P28	7.9	21.08	P58	8	189.1	P88	7.65	28.52
P29	8	24.18	P59	7.9	45.88	P89	7.59	47.12
P30	8	41.54	P60	8	51.46	P90	7.94	44.64

Physico-chemical analysis of groundwater from wells located inside the urban perimeter of Kenitra (Table 5& Fig. 5), showed relatively low nitrate values compared to other localities in Gharb. However, those values are even relatively high compared to the usual standards found in clean tablecloths.

The maximum reached value was of the order of 51.6 mg/L in the Sidi Taibi locality. The minimum recorded was 1.25 mg / L at the well of Aïn Arris. The calculated mean value was 20.95 mg / L (±18.80 mg/L).

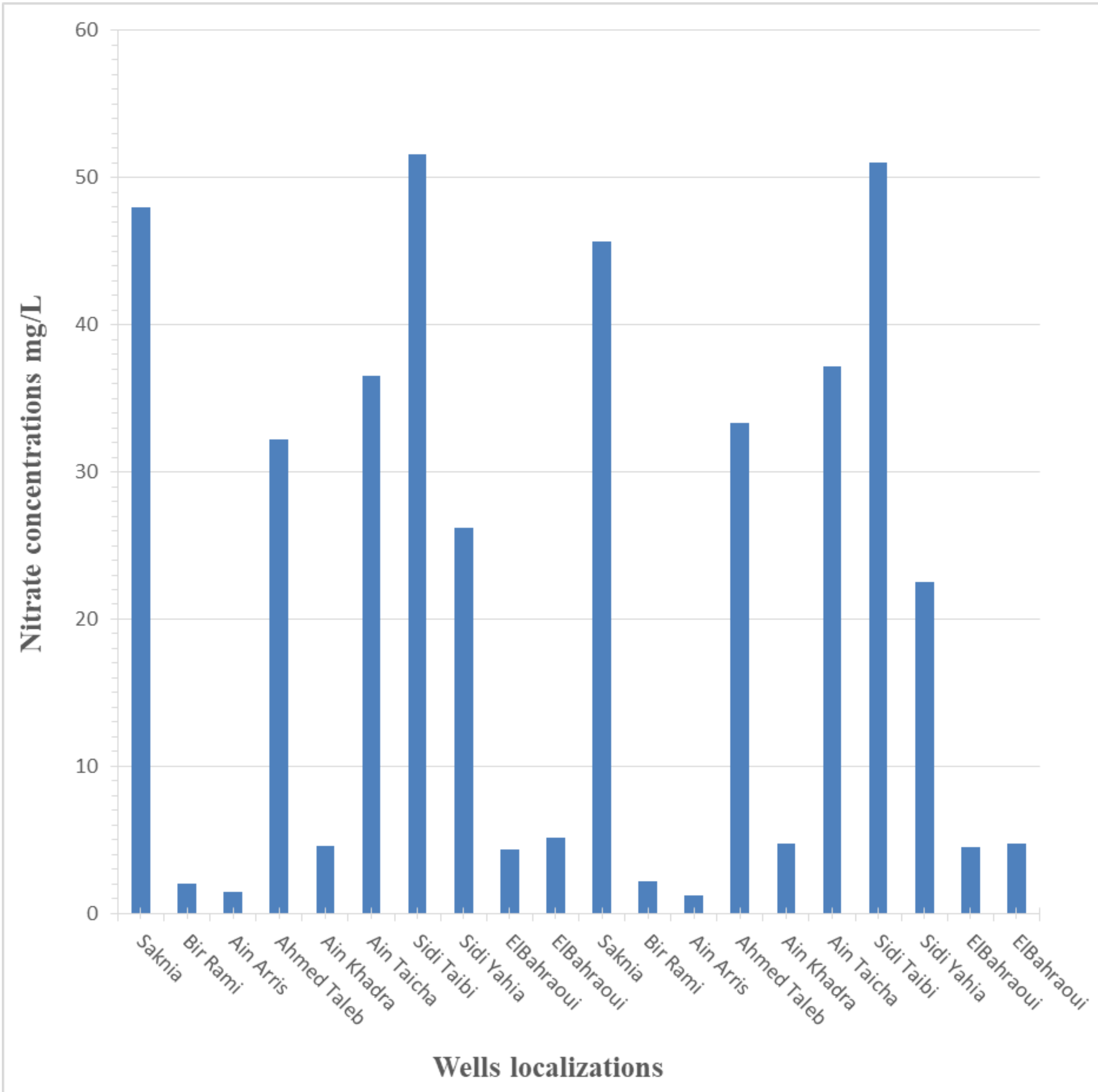

Fig. 5: Geographical distribution of intra-urban pollution of the Maâmora aquifer.

Table 5: Evolution of the physico-chemistry in the urban area of Kénitra.

Wells area	**NO_3^-**
Saknia	48
Bir Rami	2.02
Ain Arris	1.46
Ahmed Taleb	32.2
Ain Khadra	4.56
Ain Taicha	36.5
Sidi Taibi	51.6
Sidi Yahia	26.2
ElBahraoui	4.34
ElBahraoui	5.13
Saknia	45.7
Bir Rami	2.21
Ain Arris	1.25
Ahmed Taleb	33.3
Ain Khadra	4.73
Ain Taicha	37.2
Sidi Taibi	51
Sidi Yahia	22.5
ElBahraoui	4.54
ElBahraoui	4.73

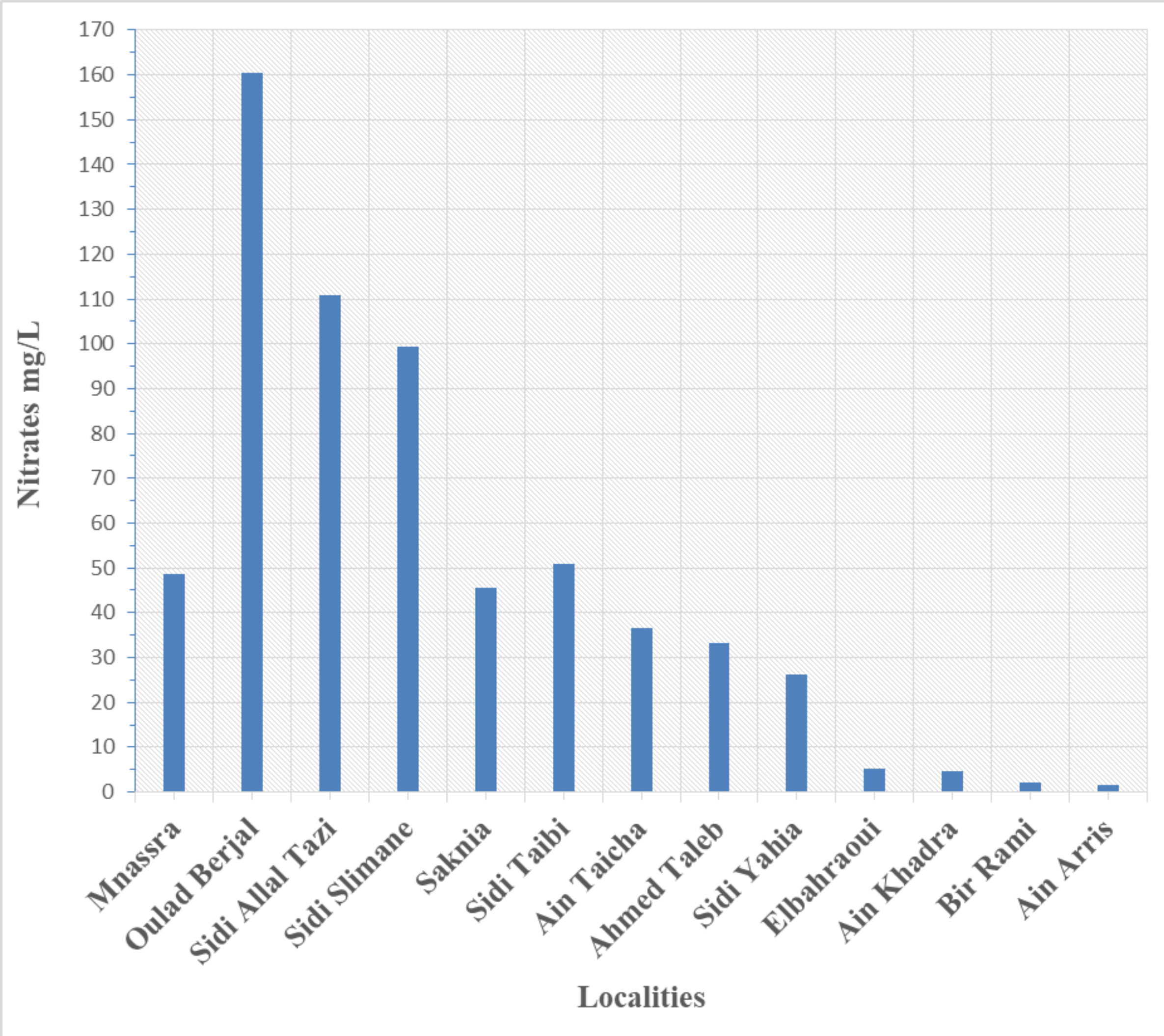

Fig. 6: Representation of the geographic variation of nitrate pollution of the Maâmora aquifer.

DISCUSSION

Domestic and urban discharges locally contribute to nitrate contamination of aquifers **(ONU, 2017).** On the other hand, fertilization by applying chemical or organic nitrogen fertilizers and intensive breeding (animal waste) are the main cause.

The excess nitrates in the soil are pushed a little deeper each year mainly by winter rains. The rate of migration of nitrates to aquifers is slow with average from 1 to 2 m / year and varies according to the nature of the subsoil.

The excess nitrogen spread over the surface therefore records an average of 10 to 20 years to reach a water table 20 m deep **(Edmunds & Gaye, 1994; Seiler & Lindner, 1995; WHO, 2011).**

Concentrations of NO_3^- in the samples ranged from 0.24 to 2692 mg / L with an average of 90.25 (Tables 2,3 & Fig. 3). It has been observed that the highest concentrations were recorded in areas with intensive agricultural activities with a high load of organic nitrogen due to animal effluents, those of heavily fertilized large crops and those with shallow water resources.

The high concentrations of nitrates in the groundwater in the study area endanger the health of infants and the elderly.

The contribution of different sources to nutrient fluxes carried by surface and groundwater has been the subject of several studies (Manczaz and Floczyk, 1971; Balland and Varet, 1979; Harms *et al.*, 1981; Carl *et al.*, 1985).

Nutrients are found in fertilizers, manure and crop residues. They are present in those sources in organic and inorganic forms. Subsequently, nutrients in organic form can change to inorganic matter, but this can take several months.

If fertilizer or manure is applied excessively, excess nutrients can be introduced into the water. Many inorganic nutrients readily dissolve in soil water and can pass quickly to ground or surface water through leaching or runoff. Organic nutrients can be carried into surface water by runoff and sooner or later they will be transformed into inorganic matter and will be used by aquatic plants and algae.

Nutrients composed of nitrogen and phosphorus, are often considered as two limiting factors. The development capacity of plants (terrestrial and aquatic) depends on the amount of bioavailable nitrogen and phosphorus. If there is excess nitrogen and little phosphorus, phosphorus will be limiting and will prevent the development of plants. Conversely, if there is a lot of phosphorus and little nitrogen, the latter will be limiting. When the two elements are present in sufficient quantity, the plants are developing normally.

Nitrogen and phosphorus exist in soil in many forms. Nitrogen transfer takes place above all in the form of soluble nitrates. Phosphorus strongly bound to the soil is transferred by erosion and runoff. Agricultural practices influence the forms and quantities transferred and the conditions of transfer to water.

Over-fertilization is often responsible for the degradation of water quality **(Gouy *et al.*,1998**). Nutrients can enter surface waters in different forms depending on the availability for aquatic vegetation.

Chemical fertilizers containing nitrates and phosphates used in agriculture alter the quality of the groundwater to which they are dragged **(Gouy *et al.*, 1998)**. Nutrient intake is widely regarded as the most serious effect of agriculture on water quality and the two most damaging nutrients in this regard are nitrogen and phosphorus.

Organic nitrogen or ammoniacal forms after application can be carried by runoff. However, most of the flow comes from the leaching of very soluble nitrates. The leached nitrogen reaches surface water by hypodermic flow favoured by soil work or by drainage to the water tables themselves which replenish rivers. Organic waste containing nitrogen (from proteins) is mineralized under the action of bacteria in ammonia or ammonium ions which will be oxidized underground and in the presence of microorganisms in nitrite ions, then its directly assimilable by the plant **(Hatier, 1993).**

Nitrate and ammonium ions present in the soil have three modes of formation: the synthesis of fertilizers, the transformation by legumes and the formation in thunderstorms. Bacteria allow the transformation of ammonium ions into nitrate ions (oxidation), while on the other hand, permit the transformation of nitrate ions (denitrification) or ammonium into dinitrogen in the air.

Nitrates (NO_3^-) are chemical compounds made up of nitrogen and oxygen. They result from the nitrogen cycle which is a nutrient essential for plant life. Oxidation by microorganisms in plants, soil or water makes nitrogen available to plants in the form of nitrates. Thus all sources of nitrogen are potentially capable of being found in the form of nitrate.

Nitrogen is an essential nutrient for plant life. It penetrates the soil in many ways: for example in the form of slurry, manure, compost or artificial mineral fertilizer but also through fragments of rotting plants. However, it is rare for plants to completely absorb the amount of nitrates available in the soil. Since nitrates are extremely soluble in water, the remainder carried by precipitation therefore infiltrates the water table **(Gascuel, 2001).**

In water, the nitrates in excess are one of the causes, along with phosphates, of the eutrophication of aquatic environments (development of algae in rivers, lakes and in coastal areas… etc) and disrupt their use. Ammoniacal discharges by oxidizing to nitrates contribute to lowering the oxygen content sometimes to a lethal level. The nitrate-nitrite pair disturbs the acid-base balance favouring one species over the other **(Capblancq & Décamps, 2002**).

Concentrations of nitrates in groundwater in high quantities pose health problems for human populations who obtain their supplies directly from this water without treatment. Ingestion of a high content of nitrates can cause serious and sometimes fatal illnesses, especially in young children. Their transformation into nitrites and nitroso compounds (nitrosamines and nitrosamides) can cause carcinogenic diseases in the digestive system in adults **(Foreman *et al.*, 1985)**.

CONCLUSION

The assessment of nitrogen pollution of groundwater in the Maamora Gharb aquifer, showed very high concentrations of NO_3^- with a maximum of 2692 mg / L and an average of 90.25 mg/L. It was found that the highest concentrations are correlated with intense agricultural activities generating a high load of organic nitrogen due to animal effluent and fertilizers.

REFERENCES

El Yemli, A.; Berrid, N.; Idrissi, A.I.; Hussein, A.K.; Al-Nahmi, F. and Ghazi, A. (2020). Study of the physico-chemical quality of the Groundwater in the Sidi Taibi, Kenitra, Morocco. Egypt. Aquat. Biol. Fish., ISSN 1110 –6131: 24 (3): 109 –124.

Abbas, A.; Yousefi, N.; Mahvi, A.H.; Nabizadeh, R.; Radfard, M.; Yousefi, M. and Alimohammadi, M. (2019). Evaluation of groundwater quality using water quality index and its suitability for assessing water for drinking and irrigation purposes: Case study of Sistan and Baluchistan province. Iran. Hum. Ecol. Risk Assess.,ISSN 1080-7039 :25 (4): 988–1005.

Alemad, A. K.; Saadaoui, H.; Ait said, N;. Najy, M.; Daifi, H.; Yahya, S.; Outhman, A;. Marc, I.; Aboubaker, B;. Belhaili, I.; Idrissi Azami, Y.; El kharrim, K. and Belghyti, D. (2016). No te about the causes of the deterioration of groundwater quality in aquifer of Sanaa, Yemen. Environ. Sci., 7 (1): 161–169.

Tahera, A.; Tuz Jhohura, F.; Akter, F.; Chowdhury, T.R.; Mistry, S.K.; Digbijoy Dey, Barua, M.K.; Md Islam, A. and Rahman, M. (2016). Water Quality Index for measuring drinking water quality in rural, Bangladesh. *J. Heal. Popul. Nutr.*, 35 (1): 4.

Al-Qawati, M.; Naser, R.S.M.; Hamdaoui, F.; Achhar, A.; EL Kharrim, K.; Achaouch, A. and Belghyti, D. (2018). Hydro-chemical monitoring of Groundwater Quality for Irrigation in Sidi Allal Tazi area, Kenitra, Morocco. *Res. J. Chem. Environ.*, 22 (4): 36–44.

Ayers R.S. and Westcot D.W. (1985). Water Quality for Agriculture, FAO Irrigation and Drainage, Food and Agriculture Organization of the United Nations, Rome. (29) 1–117 .

Balland, P. and Varet, G. (1979). Application des relations concentration débit à l'estimation quantitative des apports en éléments fertilisants par le réseau hydrographique superficiel des lacs d'Annecy et du Bourget. La Technique de l'eau et de l'Assainissement. no. 385: 17-31.

Belghyti, D. ; EL Guamri, Y. ; Ztit, G. ; Ouahidi, My.L. ; Joti My.B. ; Harchrass, A. ; Amghar, H. ; Bouchouata, O. ; EL Kharrim, K. et Bounouira, H. (2009). Caractérisation physico-chimique des eaux usées d'abattoir en vue de la mise en oeuvre d'un traitement adéquat, Kénitra, Maroc. Afrique Science., 05 (2) : 199 – 216.

Belghyti, D. ; Daifi, H. ; Alemad, A. ; Elkharrim, K.; Elmarkhi, M.; Souidi, Y.; Benelharkati, F.; Joti, B.; Elmoukrifi, Z.; Ibeda, A.; Azami-Idrissi, Y.; Baroud, S.; Elkhayyat, F.; Elrhaouat, O.; Sadeq, S.; Taboz, Y.; Sbai, H.; Naser, R.; Chigger, H. and Derwich, N. (2013). Groundwater management for sustainable production of drinking water quality in Maâmora," *WIT Trans. Ecol. Environ.*, 178 (3) : 241–254.

Belkhiri, L.; Mouni, L. and Boudoukha, A. (2012). Geochemical evolution of groundwater in an alluvial aquifer: Case of El Eulma aquifer, East Algeria. *J. African Earth Sci.*, (66–67): 46–55.

Capblancq, J. and Décamps, H. (2002). L'eutrophisation des eaux continentales : questions à propos d'un processus complexe towards a sustainable control of eutrophication of continental waters. Nature Sciences Sociétés. 10(2): 6-17.

Edmunds, W.M. and Gaye, C.B. (1994). Estimating the spatial variability of groundwater recharge in the Sahel using chloride. *J. Hydrol.*, 156 (1–4): pp. 47–59.

Edmunds, W.M. and Smedley, P.L. (2000). Residence time indicators in groundwater: The East Midlands Triassic sandstone aquifer. *Appl. Geochemistry*, 15(6): 737–752, 2000.

FAO, 2019. AQUASTAT - FAO's Global Information System on Water and Agriculture. FAO. pp. 2–5.

Gouy, V. Gril, J. J. Lacas, J. G. Boivin, A. and Carluer, N. (1998). Contamination des eaux de surfaces par les pesticides et rôle des zones tampons pour en limiter le transfert : Etat des connaissances et conséquences pour l'action. Ingénierie N° spécial.

Howard, G. Bartram, J. Pedley, S. Schmoll, O. Chorus, I. and Berger, P. (2006). World Health Organization. Protecting Groundwater for Health: Managing the Quality of Drinking-water Sources. Edited by O. Schmoll, G. Howard, J. Chilton and I. Chorus. ISBN: 1843390795. Published by IWA Publishing, London, UK,

Jenkins, S.H. (1982). Standard Methods for the Examination of Water and Wastewater. *Water Res.*16(10): 1495–1496.

Li, P.; Wu, J. and Qian, H. (2016). Hydrochemical appraisal of groundwater quality for drinking and irrigation purposes and the major influencing factors: a case study in and around Hua County, China. *Arab. J. Geosci.*, 9(1): 1–17.

Li, P. ; He, S. ; Yang, N. and Xiang, G. (2018). Groundwater quality assessment for domestic and agricultural purposes in Yan'an City, northwest China: implications to sustainable groundwater quality management on the Loess Plateau," *Environ Earth Sci.*, 77(23).

Manczak, H. & Florczyk, H. (1971). Interpretation of results from the studies of pollution of surface flowing waters. Wat. Res. 5: 575-584.

Naser, R.; El Bakkali, M.; Darwesh, N.; El Kharrim, K. and Belghyti, D. (2018). Assessment of groundwater quality in the Al- Burayhi and Hedran sub-basin, Taiz, Yemen - A GIS approach," in *E3S Web of Conferences*, 37: 1–6.

ONU, 2017. l'organisation des Nations Unies, Les eaux usées une ressource inexploitée. L'Organisation des Nations Unies pour l'éducation, la science et la culture (UNESCO) 7 place de Fontenoy, 75352 Paris 07-SP (2017).

Reza, R. and Singh, G. (2010). Assessment of Ground Water Quality Status by Using Water Quality Index Method in Orissa, India. World Appl. Sci. J., 9(12): pp.1392-1397 .

Rice, E. W.; Baird, R. B. and Eaton, A. D. (2017): *Standard Methods for the Examination of Water and Wastewater, 23.*

Richards, L. A. (1954). Diagnosis and Improving of Saline and Alkali Soils. United States Department of Agriculture, Washington, USA (1954).

Rodier, J. (1996). Analyse de l'eau : eaux naturelles, eaux résiduaires et eau de mer. 8ème édition, DUNOD, Paris, France, 340pp.

Rodier, J. ; Bazin, C. ; Broutin, J.-P. and Chambon, P. (2005). L'analyse de l'eau: Eaux naturelles, eaux résiduaires, eaux de mer. Dunod Edition, 8 édition, 1 (XLVII-1383 pp.).

Rodier, J. and Legube, B. (2009). L'analyse de l'eau. Ed. Dunod.

Sarath Prasanth, S.V.; Magesh, N.S.; Jitheshlal, K.V.; Chandrasekar, N. and Gangadhar, K. (2012). Evaluation of groundwater quality and its suitability for drinking and agricultural use in the coastal stretch of Alappuzha District, Kerala, India. *Appl. Water Sci.*, 2(3): 165–175.

Seiler, K. P. and Lindner, W. (1995). Near-surface and deep groundwaters. *J. Hydrol.*, 165(1–4): 33–44.

Tricker, R. and Preussmann, R. (1991). Carcinogenic N-nitrosamines in the diet: occurrence, formation, mechanisms and carcinogenic potential Mutat Res. Mar-Apr 1991;259(3-4):277-89. doi: 10.1016/0165-1218(91)90123-4.

WHO, 2011: Guidelines for drinking-water quality. F. Edition, *WHO Chron.*, 38(4): 104–108.

WHO-UNICEF, (2015). Progress on sanitation and drinking water-2015 update and MDG assessment. Geneva: World Health Organization Press.

WHO, (2015). Progress on Sanitation and Drinking Water : 2015 Update and MDG Assessment - World Health Organization - Google Livres." [Online]. Available: https://books.google.co.ma/books?hl=fr&lr=&id=KFA0DgAAQBAJ&oi=fnd&pg=PA1&dq=UNICEF+reported+that+663+million+people+across+theworld+used+unimproved+