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Health Risk of Maâmora's Groundwater Pollution in Morocco

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Abstract

The problem of pollution affects the whole world groundwater. The purpose of our present study is to evaluate the impact of contamination from residues of industry and agriculture, and discharge of untreated domestic wastewaters on the physical, chemical, metal and bacteriological water quality of Maâmora's tablecloth (Sebou bassin, Kenitra, Morocco). The physicochemical parameters followed are: T ˚C, pH, EC, NH_4^+, NO_2^-, NO_3^-, Cl^-, F^-, HCO_3^-, CO_3^{2-}, SiO_2, SO_4^{2-}, Na^+, Ca^{2+}, Mg^{2+}, K^+, Pb^{2-}, Cd^{2+}, Fe^{2+}, Cu^{2+}, Zn^{2+}, Ni^{2+}, B^{3+}, Dry Residue, Turbidity, Total Hardness (TH), Dissolved O_2, Oxidisability, total and fecal coliforms, faecal streptococci and total and faecal germs of raw water from the boreholes. The physical, chemical, metal and bacteriological quality shows that the groundwater which is used as drinking water in the city of Kenitra and adjacent towns is generally good. However, high concentrations of nitrates (over 210.8 mg/L) and other metals (185 µg/l for lead; 58.98 for nickel; 187.3 µg/L for iron; 2204 µg/L for zinc) in some wells are worrisome because of the serious health consequences.

Keywords

Groundwater, Physicochemical, Microbiological, Metals, Kenitra, Morocco

1. Introduction

In Morocco, groundwater is an important part of the hydraulic heritage of the country [1]. Groundwater, is in

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principle protected geologically, but unfortunately it can be polluted by agriculture, industry, and urban planning.

In this coastal region, in addition to marine disturbances (seawater intrusion), water resources are increasingly threatened by pollution from urban, agricultural, industrial and artisanal origin. Indeed, this urbanization has led to demands for ever increasing water. Pollution of groundwater is one of the most disturbing aspects and the use of these waters for food is a health hazard. Given the high demand for water for demographic growth and related industrial development, water pollution is increasing day by day [2]. The Reference [3] estimates that 80% of diseases that affect the world's population are directly related to water, which implies the need to treat it.

This work focuses on the study of the quality of the Maâmora's groundwater. The analyses of groundwater in the study area were made in Laboratory of the National Office of Drinking Water (ONEP), Regional Office of Agricultural Development in Gharb (ORMVAG), Autonomous Water and Electricity Authority of Kenitra (RAK) and in the Laboratory of Environment and Renewable Energies of Faculty of Sciences, Kenitra, Morocco.

2. Material and Methods Study

2.1. Area Study

Maâmora, which is a 2300 km^2 basin, is bordered on the north by the tablecloth Tiflete, to the east by the river Beht, and west by the Atlantic sea. North of the study area, the Gharb basin shows a very gentle terrain in its central part. In contrast, in the western and eastern part, its altitude is 20 m. The Maâmora basin has a slope of 6% to the NNW, culminates in the SE at around 250 meters and has more on the outskirts of Gharb, an altitude of 10 to 30 meters. The overall morphology is a succession of hills and valleys parallel to the shore in a mean direction N030˚E and N130˚E locally at 150. Mâamora is characterized by a well developed river system from west to east. The main rivers are Sebou, Fouarate, Semento, Tiflete, Touirza, Tahrest, and Mellah. The Oued Fouarate with a total length of about 40 km, occupies the western valley. The area of its basin is about 285 km^2. In its upper reaches, Fouarate river management has a N150˚E, and then curves to the NW with a mean direction N030˚E in the downstream portion of his career, to finally throw in the Sebou river [4]. The city of Kenitra is located 40 km north of Rabat, the capital of the Kingdom of Morocco. It is bounded by the Sebou river in the north, Lake Fouarat in the east and Forest Maâmora in southwest (**Figures 1-3**). The objective of this work is to take a sample of 10 drillings in March-April 2010 (ONEP), 6 of 21 drillings in March-June 2012 (RAK), 5 wells 2013 (ORMVAG) and 6 wells (EER) from January to October 2014 (**Table 1**).

2.2. Study Methods

For samples of raw water of Maâmora, we conducted bacteriological (fecal coliforms, total coliforms), physical, chemical and metal analyses (T ˚C, pH, EC, NH_4^+, NO_2^-, NO_3^-, Cl^-, F^-, HCO_3^-, CO_3^{2-}, SiO_2, SO_4^{2-}, K^+, Na^+, Ca^{2+}, Mg^{2+}, Pb^{2-}, Cd^{2+}, Cu^{2+}, Zn^{2+}, Ni^{2+}, Fe^{2+}, B^{3+}, Dry Residue, Turbidity, Alcalinity (TAC), Total Hardness (TH), Dissolved O_2, Oxidisability).

The samples at the pumps are made after buckling tap and extended in order to have a permanent water quality pumping. The water samples are collected in 500 ml bottles kept refrigerated cooler (4˚C) until analysis (**Figure 4**). The following physicochemical parameters are performed using the techniques of Rodier [5]. Temperature, potential (pH) and electrical conductivity (EC) were measured "*in situ*" using a portable multiparameter (Consort model 835C). Nitrate (NO_3^-), nitrite (NO_2^-), ammonia nitrogen (NH_4^+), silicate (SiO_2), boron (B^{3+}), fluoride (F^-) and sulfate (SO_4^{2-}) are determined by colorimetric assay using a spectrophotometer (UV/ visible Lampa 2). Hardness (TH) is measured by the volumetric method using EDTA. The oxidisability (oxidizable materials: MO) is determined by temperature oxidation in acidic medium.

Bicarbonates (HCO_3^-) are analyzed by volumetric titration with 0.1 N HCl. Chloride (Cl^-) is determined by the solution of mercuric nitrate ($HgNO_3^-$). The title below the oxygen (O_2) is determined by 0.2 N sodium thiosulfate solution ($Na_2S_2O_3$). The dry residue is determined by evaporation at 105˚C and weighed by balance of precision 10^{-4}. Turbidity (NTU) is measured by a turbidimeter: HACH brand, Model 2100 N. For metal analyzes, atomic spectrometry absorption is used after acidification of samples with nitric acid (**Figure 5**).

The microbiological of Maâmora's groundwater is determined by the method of the most probable number (MPN) Rodier [5]. This method is to inoculate using appropriate decimal sample to analyze a series of tubes

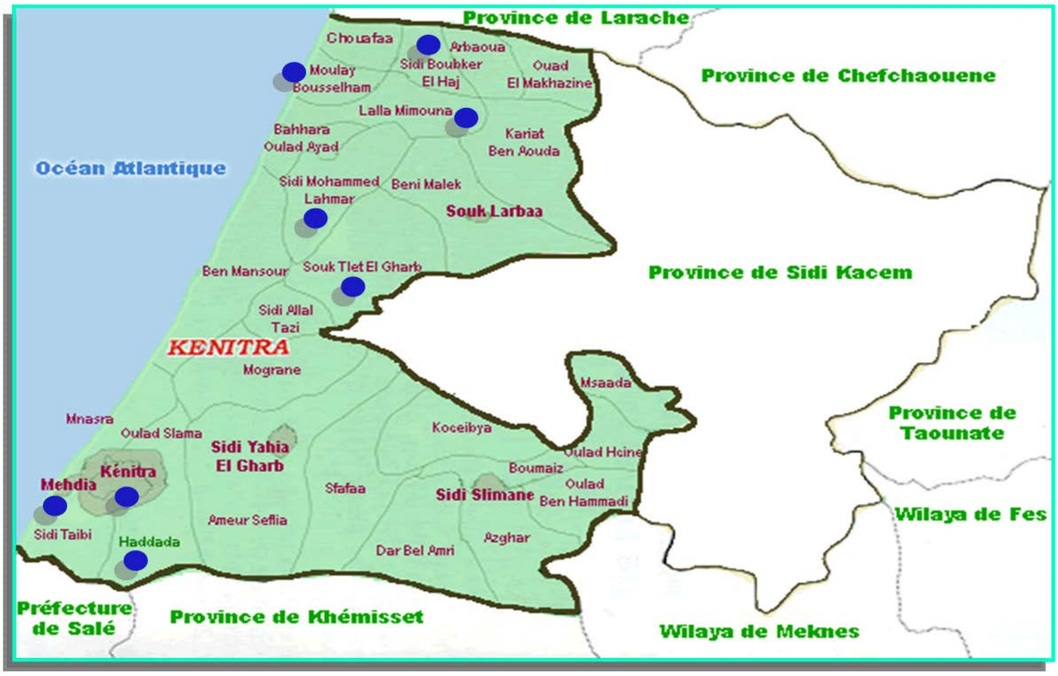

Figure 1. Geographical limits of the Province of Kenitra.

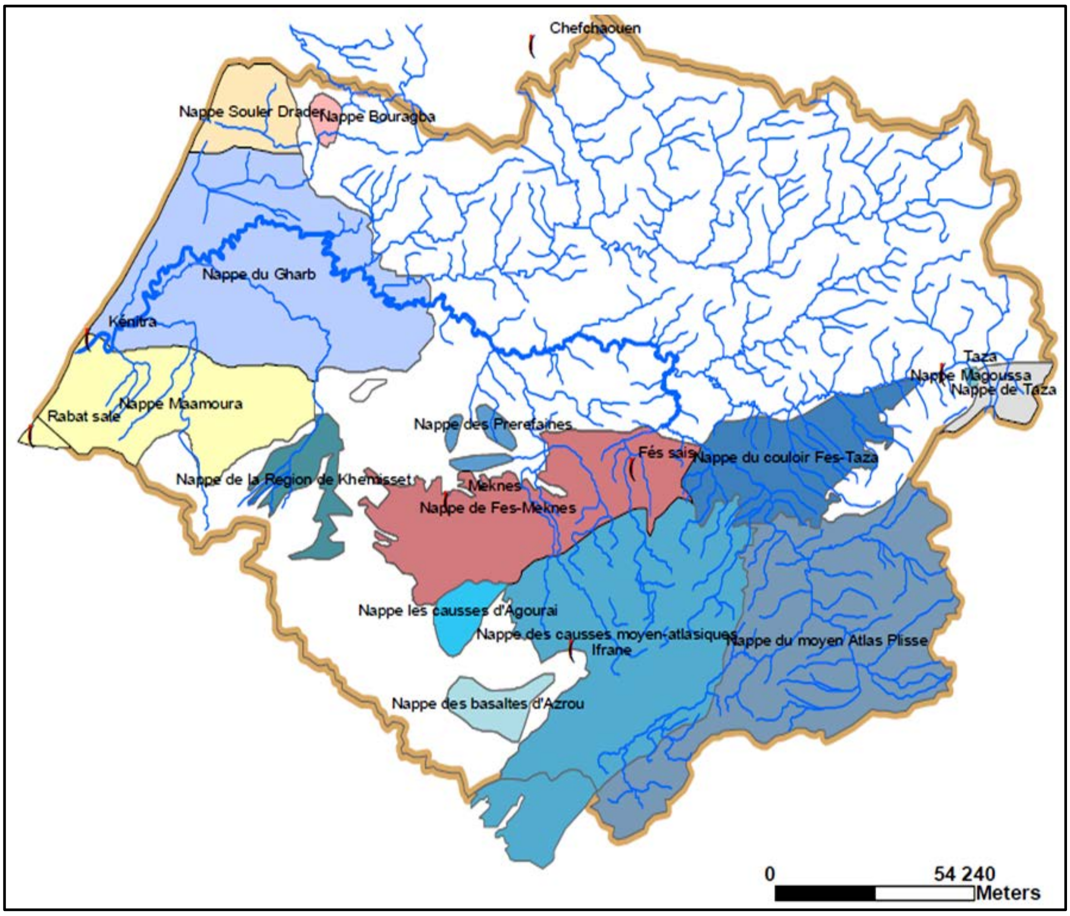

Figure 2. Geographical localization of the study area (Mâamora tablecloth) in Yellow.

Table 1. Characteristics of studied boreholes and drillings.

Laboratories	Wells		
	Number of Wells	Flows	Localization
ONEP	W1	156	Ain Sbai
	W2	50	El Menzeh
	W3	150	Ain Arris
	W4	45	Ahmed Taleb
	W5	40	Ain Khadra
	W6	100	Ain Taicha
	W7	100	Sidi Taibi
	W8	40	Sidi Yahia
	W9	50	ElBahraoui
	W10	50	Road SoukElarbaa
ORMVAG	W11	20	Oulad Berjal
	W12	30	Oulad Berjal
	W13	15	Oulad Berjal
	W14	25	Oulad Berjal
	W15	23	Oulad Berjal
University (EER)	W16	37	Mehdia
	W17	17	Bir Rami
	W18	56	Mnassra
	W19	48	Mnassra
	W20	28	Bouknadel
	W21	22	Sidi Tayebi
RAK	W22	57	Stadium
	W23	50	ElBahraoui
	W24	108	Tayebi
	W25	55	ElBahraoui
	W26	46	ElBahraoui
	W27	45	ElBahraoui

containing nutrient broth medium for searching the total flora dilutions. After incubation for 24 h at 37˚C, the tubes with a disorder are considered positive. The assessment of faecal contamination is achieved by the enumeration of faecal coliforms and faecal streptococci. Total coliforms are counted after incubation for 24 h to 48 h at 37˚C, the tubes contain the medium broth lactose bromocresol purple and are fitted with a Durham (presumptive test). The positive tubes (lactose fermentation and gas production) are transplanted to a confirmatory test in a selective medium containing bile salts, bile brilliant green broth with a Durham tube, and another tube contains peptone water free indole and then incubated for 24 h to 48 h at 44˚C. Gas production in the first and in the second indole is evidenced by the presence of fecal coliforms.

As for streptococci, their research is done on the Rothe medium at 37˚C for 24 h (presumptive test). From tubes positive Rothe, a subculture is performed on middle Litsky at 37˚C for 24 h (confirmatory test). The results are expressed as number of organisms per 100 ml following statistical table Mac Crady. The results are analyzed by a statistical comparison of the mean test of Duncun [6]. From the $p < 0.05$ level, the test is taken as being significant.

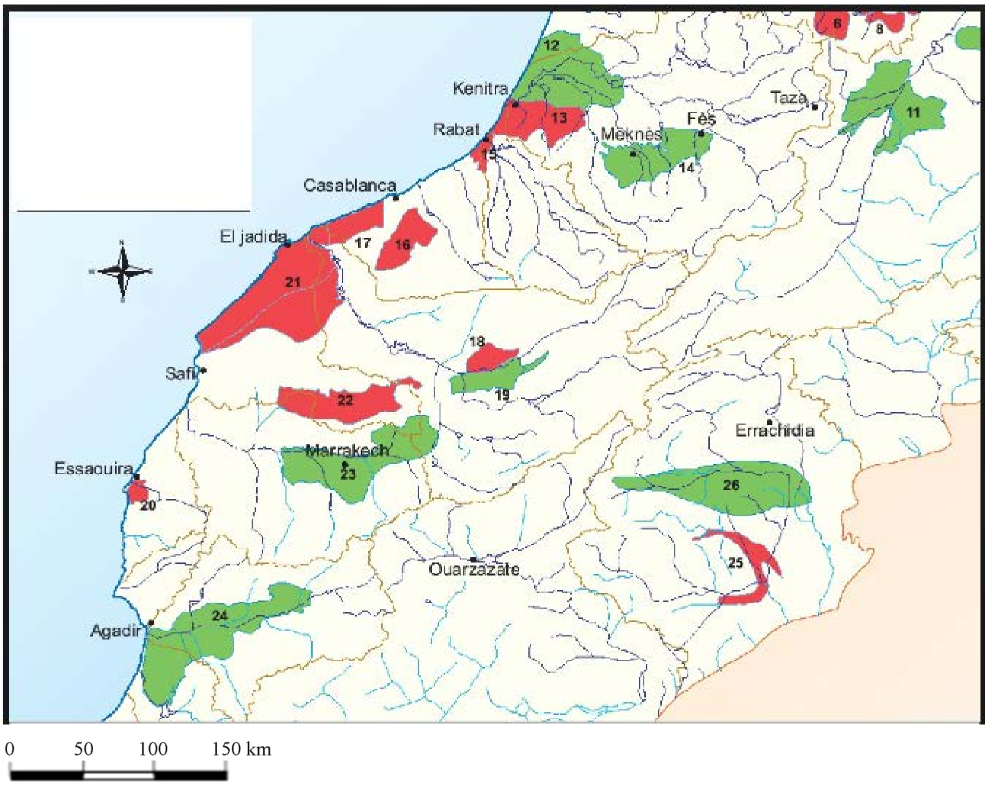

Figure 3. Maâmora's tablecloth (13) and other aquifers of Morocco.

3. Results

The assessment of the physical, chemical (**Tables 2-7**), metal (**Table 8**) and bacteriological (**Table 10**) quality of the Maâmora's water was followed through the analyses of waters collected at the 10 drillings during March-April 2010 (ONEP), 6 drillings on March-June 2012 (RAK), 5 wells 2013 (ORMVAG) and 6 wells (EER-Faculty) from January to October 2014.

3.1. Physical and Chemical Results

3.1.1. Temperature

We note that the temperature values remain almost constant (**Table 9**) and remain about 19.6 and 21.9. This is due to that groundwater is protected from solar radiation and the atmosphere.

3.1.2. pH

The pH of the water varies in the study from 6.65 to 7.96 (**Table 9**). The values obtained are close to neutrality, while referring to the Moroccan standards (6.5 < pH < 8.5) for drinking water, we note that 100% of the analyzed waters conform to human consumption. Indeed, the waters of the Maâmora do not require pH adjustment.

3.1.3. Electrical Conductivity EC

The conductivity values in our study range from 575 to 3220 µS/cm (**Table 9**). The maximum allowable value (MAV) is set to 2700 µS/cm according to Moroccan drinking water standards. These values are still stable and below VMA in almost boreholes. But the high value of this parameter in marine adjacent boreholes like Mnassra (3220 µS/cm) and Mehdia (3020 µS/cm) is explained by the high concentration of sodium chloride (**Table 4** and **Table 5**) attributed to seawater intrusion.

3.1.4. Chloride Cl^-

In nature the chlorides are widespread, generally in the form of sodium salts (NaCl) and potassium (KCl) and

Figure 4. Illustrations of some boreholes and drillings sampled from Kenitra (Mnassra, Bir Rami…).

represent approximately 0.05% of the lithosphere. The chloride contents range from 81 to 787 mg/L (**Tables 3-5**).

3.1.5. Dissolved Oxygen O_2

Dissolved oxygen varies during the study from 3.32 to 6.72 mg/L (**Table 2**). The maximum value is set between $5 < O_2 < 8$ mg O_2/L according to Moroccan standards for drinking water.

Figure 5. Methods of analyses of raw water in Laboratory of Environment (Faculty of Science Kenitra). (a) Conductimeter; (b) pH meter; (c) Spectrophotometer; (d) Multiparameter; (e) Turbidimeter and multiparameter; (f) Atomic absorption spectrometry.

Table 2. Physical and chemical analyses from ONEP drillings (March-April 2010).

Boreholes Localizations	Physical/Chemicals								
	T ˚C	pH	EC µS/cm	TDS	O_2	Ca^{2+}	Mg^{2+}	Na^+	K^+
Saknia-W1[a]	19.7	7.35	671	346	6.72	58	38	62	11
El Menzeh-Bir Rami-W2[a]	20.1	6.86	945	297	6.24	102	24	39.8	5.5
Ain Arris-W3[a]	19.8	7.2	691	418	3.38	60	37	89	14.7
Ahmed Taleb-W4[a]	19.6	7.16	882	387	6.48	98	34	78	12.5
Ain Khadra-W5[a]	20	7.13	736	279	5.67	53	35	67	13
Ain Taicha-W6[a]	19.9	6.8	954	496	4.83	156	27	387	4.5
Sidi Taibi-W7[a]	21.9	6.89	769	407	3.32	58	30	85.6	13.8
Sidi Yahia-W8[a]	20	7.21	754	394	6.5	125	27	77	9.9
ElBahraoui-W9[a]	21.8	7.73	575	376	5.64	130	35	60	15
ElBahraoui-W10[a]	21.4	7.45	825	388	4.88	99	31	89	17
Saknia-W1[b]	20.4	7.2	698	367	6.72	63	25	65	15.1
El Menzeh-Bir Rami-W2[b]	21.2	6.65	878	293	6.24	98	27	34.5	6.7
Ain Arris-W3[b]	20.7	7.21	732	440	3.38	60	33	89	14.8
Ahmed Taleb-W4[b]	20.3	7.2	653	453	6.48	110	32	85	13.8
Ain Khadra-W5[b]	20.6	7.18	820	263	6.35	58	31	48	14.2
Ain Taicha-W6[b]	20.2	6.9	879	514	6.2	160	25	386	7.5
Sidi Taibi6W7[b]	20.4	6.9	765	432	3.32	61	32	91	14.3
Sidi Yahia-W8[b]	20	7.65	745	489	6.5	165	22	125	14.5
ElBahraoui-W9[b]	20.6	7.89	595	449	5.64	159	26	111	11.8
ElBahraoui-W10[b]	20.1	7.33	835	449	4.88	140	28.5	113	15

[a]Sample of water on March 2010; [b]Sample of water on April 2010.

3.1.6. Oxidisability $KMnO_4$

The oxidisability by $KMnO_4$ dissolved varies during the study from 1.0 to 3.2 mg/L O_2 (**Table 2**). The maximum allowable value of O_2 is 5 mg/L by Moroccan standards for drinking water ONEP [7].

3.1.7. Turbidity NTU

Turbidity varies during the study from 0.78 to 3.75 NTU, the maximum value is 5 NTU by Moroccan standards for drinking water. We find that 100% of the analyzed waters have turbidity levels below the maximum value and that are consistent with Moroccan standards as these groundwater have natural filtration in the soil.

3.1.8. Dry Residue

During our study, the dry residues values range from 0.0112 to 0.1246 mg/L. The maximum value is set at 0.5 mg/L according to Moroccan standards of water potability. So these values are still lower than the maximum permissible value.

3.1.9. Alkalinity HCO_3^-

The TAC assay is the ions HO^-, HCO_3^- and CO_3^{2-} present in the water, that is to say all of the basic species present. The alkali strength is a measurement of the water tenure of free carbonate and caustic alkali. TAC water varies during the study from 4 to 6.2 meq/L (**Table 3**). According to Moroccan standards of potability of water

Table 3. Physical and chemical analyzes from ONEP drillings (March-April 2010).

Boreholes Localizations	Physical/Chemicals									
	HCO_3^-	CO_3^{2-}	F^-	Cl^-	SO_4^{2-}	NO_2^-	NO_3^-	SiO_2	NH_4^+	TAC
Saknia-W1[a]	234	0	0.2	81.7	19.7	0	48	22.1	0	4.2
El Menzeh-Bir Rami-W2[a]	258	0	0.21	103	20.1	0	2.02	0.25	0.11	5
Ain Arris-W3[a]	243	0	0.18	195	19.8	0	1.46	0.47	0.01	5.3
Ahmed Taleb-W4[a]	261	0	0.23	153	19.6	0	32.2	0.73	0.31	4
Ain Khadra-W5[a]	239	0	0.2	85.2	20	0	4.56	0.83	0.12	4.3
Ain Taicha-W6[a]	389	0	0.25	213	19.9	0	36.5	0.35	0.23	4.5
Sidi Taibi-W7[a]	250	0	0.19	153	15	0.02	51.6	0.5	0.05	5.4
Sidi Yahia-W8[a]	356	0	0.24	114	13.7	0.02	26.2	0.91	0.04	4.9
ElBahraoui-W9[a]	343	0	0.2	92.3	14.3	0.01	4.34	19.5	0.04	5.4
ElBahraoui-W10[a]	353	0	0.26	135	11.7	0.05	5.13	0.35	0.04	6.2
Saknia-W1[b]	229	0	0.2	107	20.4	0	45.7	21	0.01	4.3
El Menzeh-Bir Rami-W2[b]	245	0	0.21	103	21.2	0	2.21	0.24	0.13	5.4
Ain Arris-W3[b]	247	0	0.18	220	20.7	0	1.25	0.5	0.12	5
Ahmed Taleb-W4[b]	255	0	0.23	206	20.3	0	33.3	0.71	0.01	4.6
Ain Khadra-W5[b]	238	0	0.21	85.2	20.6	0	4.73	0.82	0.1	4.4
Ain Taicha-W6[b]	397	0	0.23	238	20.2	0	37.2	0.36	0.35	5.6
Sidi Taibi-W7[b]	261	0	0.19	167	14.6	0.03	51	0.47	0.04	5.5
Sidi Yahia-W8[b]	380	0	0.24	124	14.3	0.01	22.5	0.93	0.04	4.9
ElBahraoui-W9[b]	395	0	0.2	95.9	15.4	0.01	4.54	19.5	0.04	5.4
ElBahraoui-W10[b]	378	0	0.26	135	11.6	0.06	4.73	0.38	0.04	6

[a]Sample of water on March 2010. [b]Sample of water on April 2010.

Table 4. Physical and chemical analyzes from Lab. ORMVAG (February-June 2013).

Boreholes Localizations	Physical/Chemicals[a]									
	pH	CE	Ca^{2+}	Mg^{2+}	Na^+	K^+	HCO_3^-	NO_3^-	Cl^-	SO_4^{2-}
Borehole **W11** Mnassra	7.67	3220	86	68.64	2336.8	11.31	63.44	18.6	787.39	312
Borehole **W12** Mnassra	7.96	2180	106	49.68	1610.92	5.07	47.58	16.12	541.73	292
Borehole **W13** Bir Rami	7.8	2540	119.2	79.2	1591.6	8.58	56.12	6.82	577.94	398.4
Borehole **W14** Mehdia	7.79	3020	113	65.76	2072.3	9.36	50.02	8.06	669.35	489.6
Borehole **W15** Sidi Tayebi	7.71	2310	115.2	52.08	1644.5	12.09	51.24	27.9	522.56	302.4

[a]Sample of water on February-June 2013.

the maximum value is 50 meq/L. HCO_3^- water varies during the study from 47.58 to 397 mg/L (**Table 9**). HCO_3^- is an indicator of the presence of ions carbonates, bicarbonates, hydroxides hardness of drinking water factor.

3.1.10. Total Hardness TH

The total hardness TH of water varies during the study from 28.5 meq/L to 55 meq/L (**Table 9**). The maximum

Table 5. Physical and chemical analyzes from Lab. EER, University Ibn Tofail (January-October 2014).

Boreholes Localizations	Physical/Chemicals[a]									
	pH	CE	Ca^{2+}	Mg^{2+}	Na^{+}	K^{+}	HCO_3^-	NO_3^-	Cl^-	SO_4^{2-}
Borehole **W16** Mnassra	7.61	2000	122	26.64	358.8	0.39	324.52	4.34	492.1	216.8
Borehole **W17** Mnassra	7.75	1140	71.6	31.2	133.4	15.99	253.76	28.52	210.7	36.4
Borehole **W18** Bir Rami	7.45	990	111.6	27.84	46	7.8	259.86	210.8	172.2	28.4
Borehole **W19** Mehdia	7.63	2410	111.6	12.72	391	1.17	391.62	21.08	620.9	173.6
Borehole **W20** Sidi Tayebi	7.78	1130	63.6	39.12	98.9	15.6	247.66	11.16	256.2	20.8
Borehole **W21** Bouknadel	7.48	1520	187.2	20.16	135.7	1.56	328.18	163.68	298.9	82.4

[a]Sample of water on January-October 2014.

Table 6. Physical and chemical analyzes from Lab. EER, University Ibn Tofail.

Boreholes Localizations	Physical/Chemicals[a]		
	NH_4^+	CO_3^{2-}	TH
Borehole **W16** Mnassra	3.42	0	42
Borehole **W17** Mnassra	4.5	0	31
Borehole **W18** Bir Rami	4.32	0	39
Borehole **W19** Mehdia	5.94	0	45
Borehole **W20** Sidi Tayebi	3.42	0	32
Borehole **W21** Bouknadel	4.68	0	55

[a]Sample of water on January-October 2014.

Table 7. Physical and chemical analyzes from Lab. RAK (March-June 2012).

Boreholes Localizations	Physical/Chemicals[a]							
	pH	EC	NH_4^+	NO_3^-	SO_4^{2-}	CO_3^{2-}	Mg^{2+}	TH
Borehole **W22** Mnassra	6.94	831	0.002	91.09	16.2	0	15.2	36.7
Borehole **W23** Mnassra	6.84	743	0.002	39.81	6.85	0	13.4	33.9
Borehole **W24** Bir Rami	6.99	724	0.002	10.71	6.17	0	20.7	32
Borehole **W25** Mehdia	7	626	0.002	23.95	4.18	0	12.2	28.5
Borehole **W26** Sidi Tayebi	6.96	605	0.002	19.14	2.3	0	13.4	29
Borehole **W27** Bouknadel	7.05	680	0.002	14.05	2.3	0	12.2	31.2

[a]Sample of water on March-June 2012.

for Moroccan standards of potability is the value 50 meq/L. TH is a factor indicating the presence of magnesium and calcium ions. The release by rocks containing divalent metals (Mg^{2+}, Ca^{2+}) is responsible for this hardness.

3.1.11. Nitrates NO_3^-

The nitrate content varies during the study from 1.25 to 210.8 mg/L (**Table 9**). According to Moroccan standards of potability of water ONEP [7], the maximum value is set at 50 mg/l. Although nitrates have no direct toxic effects except at high doses, the fact that they can give birth to nitrites which lead to toxicity. Nitrate levels are high in boreholes W7, W18, W21 and W22 (Mnassra, Sidi Tayebi, Bouknadel, Bir Rami) which exceed the Moroccan standards.

Table 8. Concentration of metalic elements in Maâmora's groundwaters.

Geography	Metals (μg/L)[a]					
	Lead	Zinc	Nickel	Cadmium	Copper	Iron
Borehole **W16** Mnassra	45.4	7	69.8	<1.2	38.5	79.2
Borehole **W17** Mnassra	63.4	36.7	55	<1.2	45.6	50.9
Borehole **W18** Bir Rami	55.7	2204	77.2	<1.2	27.3	50.6
Borehole **W19** Mehdia	69.4	1427	78.9	<1.2	72.6	100.1
Borehole **W20** Sidi Tayebi	60.4	28.93	70.1	<1.2	26.8	42.2
Borehole **W21** Bouknadel	185.6	28.9	2.9	<1.2	30.6	187.3
Mean	79.98	622.1	58.98	<1.2	40.23	85.05
Morocco Standards	50/25/10	3000	20	3	2000	300

[a]Metal analyses were done at Faculty of Sciences Laboratory, Kenitra, Morocco.

Table 9. Statistical of all analyzes of Maâmora's groundwaters.

Parameters	Physical and Chemical Analyses[a]				
	Sample Size	Minima	Maxima	Mean	SD
T ˚C	37	19.60	21.90	20.43	0.48
pH	37	6.65	7.96	7.30	0.36
EC μS/cm	37	575.00	3220.00	1137.05	725.19
NH_4^+ mg/L	37	0.00	5.94	1.09	1.76
NO_3^- mg/L	37	1.25	210.80	30.67	42.91
Cl^- mg/L	37	81.70	787.39	256.65	184.48
SO_4^{2-} mg/L	37	2.30	489.60	74.16	124.97
HCO_3^- mg/L	37	47.58	397.00	258.87	98.51
CO_3^{2-} mg/L	37	0.00	0.00	0.00	0.00
TH ˚F	37	28.50	55.00	36.27	4.33
Ca^{2+} mg/L	37	53.00	187.20	103.87	34.27
Mg^{2+} mg/L	37	12.20	79.20	31.34	15.25
Na^+ mg/L	37	34.50	2336.80	406.51	605.85
K^+ mg/L	37	0.39	17.00	10.76	4.31
TDS mg/L	37	263.00	514.00	396.85	52.95
O_2 mg/L	37	3.32	6.72	5.47	0.89
F^- mg/L	37	0.18	0.26	0.21	0.02
SiO_2 mg/L	37	0.24	22.10	4.54	5.96
TAC	37	4.00	6.20	5.01	0.44

[a]Mean of all samples.

3.1.12. Nitrites NO_2^-

The nitrite content varies during the study from 0.00 to 0.06 mg/L (**Table 3**). The nitrite remains below of VMA set at 0.5 mg/L according to Moroccan standards ONEP [7].

3.1.13. Ammonia NH_4^+

In our study the ammonium values are from 0.00 to 5.94 mg/L (**Table 3** and **Table 6**). The maximum value is set at 0.5 mg/L according to Moroccan standards of potability.

3.1.14. Sulfate SO_4^{2-}

Sulfate varies during the study between 2.3 and 489.6 mg/L (**Table 9**). The maximum value is set at 400 mg/L by Moroccan standards of potability of water. So the values are still well below the maximum allowable value. This can be justified by the presence of very low sulfate levels in the soil and groundwater in the study area ONEP [7].

3.1.15. Silicate SiO_2

In this field survey, the values of silicate range from 0.24 and 22.1 mg/L (**Table 3**). The maximum value is 100 mg/L according to Moroccan standards of potability.

3.2. Metals Results

During our study of fluoride the values range from 0.18 and 0.26 mg/L (**Table 3**). The maximum value is fixed at 1.5 mg/L by Moroccan standards of potability.

3.2.1. Boron B^{3+}

Boron varies during the study between 0.00 and 0.026 mg/L. The maximum value is set at 0.3 mg/L according to Moroccan standards of potability. Therefore these values are still well below the authorized maximum value.

3.2.2. Fluoride F^-

During our study of fluoride the values range from 0.18 and 0.26 mg/L (**Table 3**). The maximum value is fixed at 1.5 mg/L by Moroccan standards of potability.

3.2.3. Lead Pb^{2-}

The concentration of lead ranges from 0.0454 to 0.185 mg/L (45.4 to 185.6 µg/L). The highest values are recorded in Bouknadel (**Table 8**). Called the maximum value of 50 µg/L will be applied until 2010 from that date, the VMA is 25 µg/L and will be taxable until 2015. Beyond 2015, the maximum value allowed to comply will be 10 µg / L.

3.2.4. Zinc Zn^{2+}

The concentrations of zinc vary from 0.007 to 2.204 mg/L (7 to 2204 µg/L). The highest values are recorded in Bir Rami and Mehdia (**Table 8**). The standard is set at 3000 µg/L (VMA). All the values recorded in the Mâamora's wells are lower than Moroccan standard. In Mâamora the average 622 µg/L remains far below the norm and not a problem for the consumption of these waters.

3.2.5. Nickel Ni^{2+}

The nickel concentrations range from 0.0029 to 0.0789 mg/L (2.9 to 78.9 µg/L). The lowest values are recorded in Bouknadel (**Table 8**). The standard is set at 20 µg/L (VMA). Almost all the values stored in the wells of the Mâamora exceed this Moroccan standard. In Mâamora averaging 58.98 µg/L is much greater than the standard and poses a serious problem for the consumption of water from the Mâamora's groundwater.

3.2.6. Cadmium Cd^{2+}

The cadmium concentrations remain below the limit of flame spectrometer detection 0.0012 mg/L (1.2 µg/L). The standard is set at 3 µg/L (VMA). So all values stored in the wells of the tablecloth Mâamora do not exceed the Moroccan standard (**Table 8**) and are not problems for the consumption of these waters.

3.2.7. Copper Cu^{2+}

In the aquifer Mâamora, the concentration of copper ranges from 26.8 to 72.6 µg/L. The highest values are recorded in Mehdia (**Table 8**). The Moroccan standard is set at 2000 µg/L (VMA). The averaging 40.23 µg/L and all the recorded values in the wells of the Mâamora's aquifer are far below the norm and the consumption of these waters poses no problem.

3.2.8. Iron Fe^{2+}

Iron concentrations vary from 0.0422 to 0.1873 mg/L (42.2 to 187.3 µg/L). The highest values are recorded at

Bouknadel (**Table 8**). The standard is set at 0.3 mg/L (VMA) (300 µg/L). All values recorded in the wells of the tablecloth Mâamora remain below the Moroccan standard. In Mâamora's aquifer the Iron average of 85.05 µg/L is below standard and do not pose a problem for the consumption of these waters. We note, however, that the concentration of iron in Bouknal's boreholes is very high (187.3 mg/L) and may pose a long-term problem due to bioaccumulation through the food chain and direct way.

3.3. Bacterial Results

Bacteriological analyses of water from 6 wells (**Table 10**) studied reveal that there is a lack of contamination by total coliforms, faecal coliforms and faecal streptococci. By against contamination is noted by the total germs at 22˚C and 37˚C. This is consistent with the Moroccan standards and guidance of ONEP [7]. The total lack of bacteria contamination is attributed to the fact that the modern boreholes and their catchment areas are protected against traditional wells that are contaminated.

4. Discussion

The piper diagram (**Figure 6**) has allowed us to define the hydrochimic and chemical facies of Maâmora's tablecloth waters. The piper diagram shows that 27 wells in the Maâmora's are very heterogeneous and are classified in the following chemical facies:

- chloride, sulphate, Calcium and magnesium;
- chloride, Sodium and potassium or sodium sulphate;
- bicarbonate calcium and magnesium.

Based on the results, the temperature, pH, nitrite, ammonia nitrogen, sulfates and oxidizable materials recorded values below the recommended standards REEM [1] and also approved by (**Table 11**) the World Health Organization [3]. The electrical conductivity, chloride and bicarbonate (HCO_3^-) recorded respective averages 1137.05 µS/cm, 256.65 mg/L and 258.87 mg/L (6.1 meq/L). We find that these parameters have high values at the wells W6, W11, W14 and W19. The waters of Maâmora are further characterized by a particularly high level of total hardness wells W19 (Mehdia) and W21 (Bouknadel) respectively 42 and 55 meq/L.

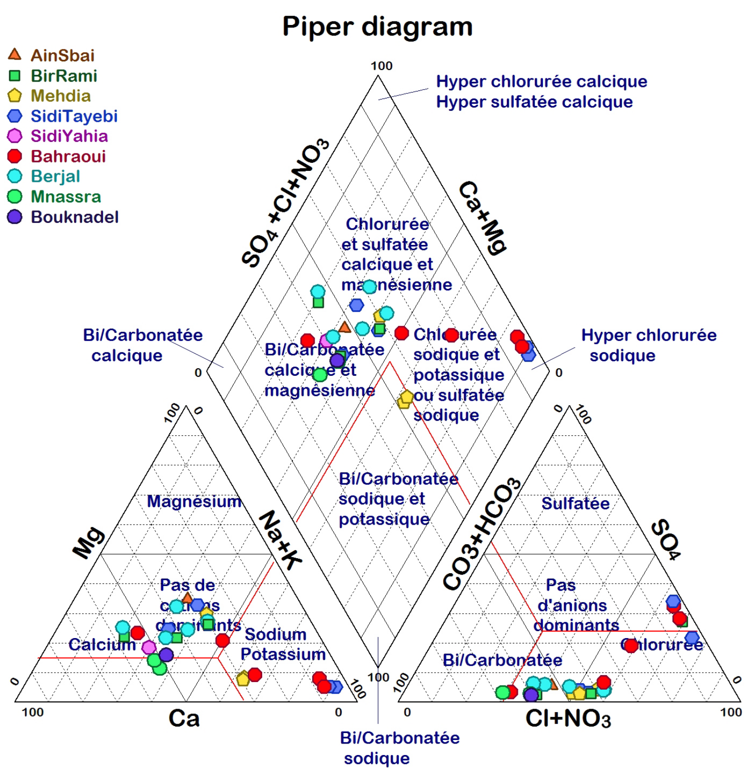

Figure 6. Hydrochemical of Maâmora's groundwater.

Table 10. Bacterial analyzes in Maâmora's groundwaters[a].

Geography	Bacterial (UFC)[b]				
	CT	CF	GT-22˚C	GT-37˚C	SF-37˚C
Borehole **W22** Mnassra	0	0	4	2	0
Borehole **W23** Mnassra	0	0	1	4	0
Borehole **W24** Bir Rami	0	0	13	9	0
Borehole **W25** Mehdia	0	0	3	0	0
Borehole **W26** Sidi Tayebi	0	0	0	0	0
Borehole **W27** Bouknadel	0	0	3	6	0
Mean	0	0	4	3	0
Morocco Standards	0/100ml	0/100ml	100/ml	20/ml	0/100ml

[a]Bacteria analysis at RAK laboratory (2012); [b]CF: Faecal coliforms, CT: total coliforms, GT: total germs, SF: faecal streptococci.

Table 11. Comparison of Maâmora's tablecloth with others quifers and standards.

Parameters	Aquifers Standards					
	Maâmora	Moroccan	WHO 2007	French 1993	Egypt 2005	Tunisia 2003
T˚C	20.43	25	25	25	25	25
pH	7.3	6.5 à 8.5	6.5 à 8.5	6.5 à 8.5	6.5 à 8.5	6.5 à 8.5
EC µS/cm	1137.05	2700	2500	2500	2700	2500
Turbidity NTU	3.75	5	5	5	5	5
TH mg/l	36.27 meq/L	50 meq/L	500	500	200	500
HCO_3^- mg/l	258.87	50 meq	400	400	300	400
NO_3^- mg/l	30.67	50	50	50	50	50
NO_2^- mg/l	0,032	0.5	0.5	0.1	0.2	0.1
SO_4^{2-} mg/l	74.16	400	250	250	250	250
Cl^- mg/l	256.16	750	250	250	250	250
NH_4^+ mg/l	1.09	0.5	0.5	0.5	0.2	0.5
O_2 mg/l	5.47	5 à 8	5 à 8	5 à 8	5 à 8	5 à 8
Oxydisability	3.2	5 meq	5	5	5	5
Boron mg/l	0.026	0.3	0.3	0.01	0.7	0.01
F^- mg/l	0.21	1.5	1.5	1.5	1.5	1.5
SiO_2 mg/l	4.54	100	100	100	100	100
Dry Residue mg/l	0.1246	0.5	0.5	1500	-	1500
Bacteria	4	0/100	0	0	0	0

However, the water is marked Maâmora nitric because the concentration of about 91.09 mg/L (W22; Mnassra), 163.68 mg/L (W21; Bouknadel) and 210.8 mg/L (W18; Bir Rami) far above the standard (50 mg/L) set by the World Health Organization [3]. The nitrate constitutes a threat to the man in the process of consumption [7] [8].

Therefore, the metal analysis shows that values are still well below the authorized maximum for boron, zinc, fluoride, cadmium, cooper, iron. But the concentration of lead ranges from 45.4 to 185.6 µg/L and are very high to the norm of 10 µg/L. The same for nickel 58.98 µg/L is much greater than the standard and poses a serious problem for the consumption of water from the Mâamora's groundwater. We also note that the concentration of iron in Bouknal's boreholes is very high (187.3 mg/L) and the concentration of zinc in Bir Rami's boreholes is very high (2204 mg/L) and may pose a long-term problem due to bioaccumulation through the food chain and direct way.

The operation is based on results of the comparison between the Moroccan standards and data analysis carried out on samples of raw water.

The results of the physicochemical analyses presented in this work show that the pH, temperature, organic matter and sulfates can be considered eligible and have no impact on water quality. Thus, the average pH values (7.3), temperature (20.43˚C) and sulfate (74.16 mg/L) are consistent with the standards of supply waters [1]. These results are in agreement with those obtained on the waters of groundwater Mnassra (Morocco) [9] and Gharb (Belksiri) [10].

Maâmora's waters are highly sought, on the one hand, to supply drinking water Gharb basin, Rabat the capital and economic center of Morocco (Casablanca), on the other hand, to meet the needs of the industrial and agricultural sector. Hence the need to use the tools is necessary to preserve, characterize and quantify the quality of these resources [4]. The analysis and interpretation show piezometric groundwater flow to the Gharb plain and the Atlantic Ocean. The lithology of permeable land consists mainly of sand, sandstone, conglomerate, limestone and clay. Together they form a Plio-Quaternary aquifer based on a Mio-Pliocene bedrock (blue marl) [11].

The variation of the concentration of nitrates found among different wells may be related to the heterogeneity among different physical environments. For Reference [12], the large spatial variability of nitrate at Maâmora study area is due to the surface texture and lithology. However, the proportion of wells nitrate is low, the high proportion of nitrates can be caused by the use of chemical fertilizers in agriculture. The heavy rainfall and lack of vegetation cover contribute to the rapid leaching of nitrates to Maâmora's groundwater [12]-[15]. Similarly, [16] found that the winter period was the critical phase of leaching of excess nitrogen in groundwater in the Rhine valley in France because of the lack of vegetation and the impact of heavy rainfall. Also the high level of nitrates is observed in Europe, Senegal and attributed to intensification of agriculture and its impact [17]-[19].

Moreover, in the Maâmora's water there are no indicators of fecal contamination in protected boreholes, in agreement with those found [20]-[23] for the sheet of Marrakech an d Sidi Kacem (Morocco) and Nouakchett (Mauritania). These results are similar to those of [24] [25] good limit for drinking water.

Physicochemical and bacteriological values of our studies are lower than the Moroccan standards, WHO (2007), France (1993), Egypt (2005) and Tunisia (1993) (**Table 11**). Except that the concentration of nitrate exceeds the standards listed above.

5. Conclusions

The results of physicochemical analyses of drillings studied are consistent with Moroccan standards for drinking water. The results of physicochemical analyses on key parameters measured indicators show a normal temperature in boreholes. The pH values measured are excellent. Comparing the values of the electrical conductivity with the water grid can be inferred that the water of Maâmora are good, and analysis of physicochemical parameters (nitrite, nitrate, ammonium, chloride, fluoride, boron, silicate, sulfate ions,…, etc.) remains stable and consistent with Moroccan standards. However, the exponential growth in demand for water and the significant deterioration experienced by the water resources through various forms of pollution leads to the plan and management of water resources, especially drinking water.

Therefore, the preventive aspect should focus more on regular monitoring of water quality or may be on the production of drinking water as well as the control of sources of pollution threatening the water.

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