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Impact of Anthropic Activities on the Quality of Groundwater in the Central Rif (North Morocco)

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ABSTRACT

The present study aimed to evaluate the effects of human anthropic activities on the physicochemical and biological properties as well as the quantity of the groundwater in the central Rif of Morocco. Series of analyses were carried out on the water resources of this area. The interpretation of analytical data and the distribution of groundwater into groups were treated using multivariate statistical methods including Principal Component Analysis (PCA) and the Ascending Hierarchical Classification (CHA). The results of the present study showed strong mineralization of the investigated area waters. This study also indicated the impact of anthropogenic activities and their influences on the quality of groundwater in the central Rif, with the presence of total coliforms, fecal Escherichia coli type, and fecal streptococci intestinal enterococcal type, suggesting that the contamination of this groundwater was induced by human pollution. In addition, the infiltration of groundwater by wastewater from septic tanks, the use of wastewater for irrigation purposes, the increased use of fertilizers and pesticides in agriculture, and irregular rainfall in the region constitute the main factors of anthropogenic contamination of groundwater in the study area.

Keywords: anthropogenic activity, groundwater, mineralization, PCA, pollution, Central Rif, Morocco

INTRODUCTION

Groundwater represents about 97% of the world's liquid freshwater (Bosca, 2002; Schmoll et al., 2006). Indeed, it offers regularity, quality and protection properties that are often much superior to those of surface water, which is more vulnerable (Dole-Olivier et al., 2005). In addition, they have an important socio-economic value as an inestimable natural resource either for agricultural, industrial and domestic needs in developed countries and undoubtedly even more in developing countries (Danielopol et al., 2003; Li et al., 2015). The high population growth, the improvement of the living standard, the industrial development and the extension of irrigated agriculture observed recently in the Mediterranean basin, qualified as a poor region in terms of water, have led to a overexploitation of this natural resource which therefore ranks this geographic area as the most affected by the risk of scarcity (Margat, 2008). These pressures induced by humans on the water resources lead to both their overexploitation and the increasing degradation of their quality. In the context of the availability of water, Morocco became one of the countries that are the most exposed to the negative effects of climate change and suffering from water scarcity (Dahan, 2017).

In Morocco, groundwater constitutes an important part of the country's hydraulic heritage (MATEE, 2015). Morocco, like all the riparian countries of the Mediterranean region, has experienced periods of drought over the past two decades and despite the efforts of governments, the problems of the management, exploitation and sustainable use of groundwater resources are still persistent. Moreover, several basins of the Central Rif are characterized by qualitative disturbances and a high density of wells, leading to the over-exploitation of the aquifer, such as the Ghis-Nekor basin (Chafouq et al., 2018), which is also the case of the Bokoya plain.

Thus, the aim of the present study was to investigate the quality and the quantity of the groundwater in the Rif Central area by performing several sampling campaigns as well as analysis of water withdrawals from one water source and several wells and under-flows at the level of the two plains, notably Bokoya and Ghis-Nekor.

MATERIALS AND METHODS

Study zone

Geographic location

The study area is located at the North of Morocco in the Central Rif region (Figure 1). It covers the area from the Bokoya Plain in the west to the Ghis-Nekor Plain in the east.

The Ghis-Nekor plain is located on the edge of the Mediterranean, about 12 km southeast of the Al-Hoceima city. It is crossed by two rivers with temporary flow: the Ghis in its north-western part and the Nekor in its central part. The triangular shaped Ghis-Nekor aquifer is the most important alluvial aquifer in the study area. On the other side, the Bokoya plain located to the southwest of the city along the Mediterranean coast is crossed by two rivers, Bades in its north-western part and Bousicour in its central part. More than

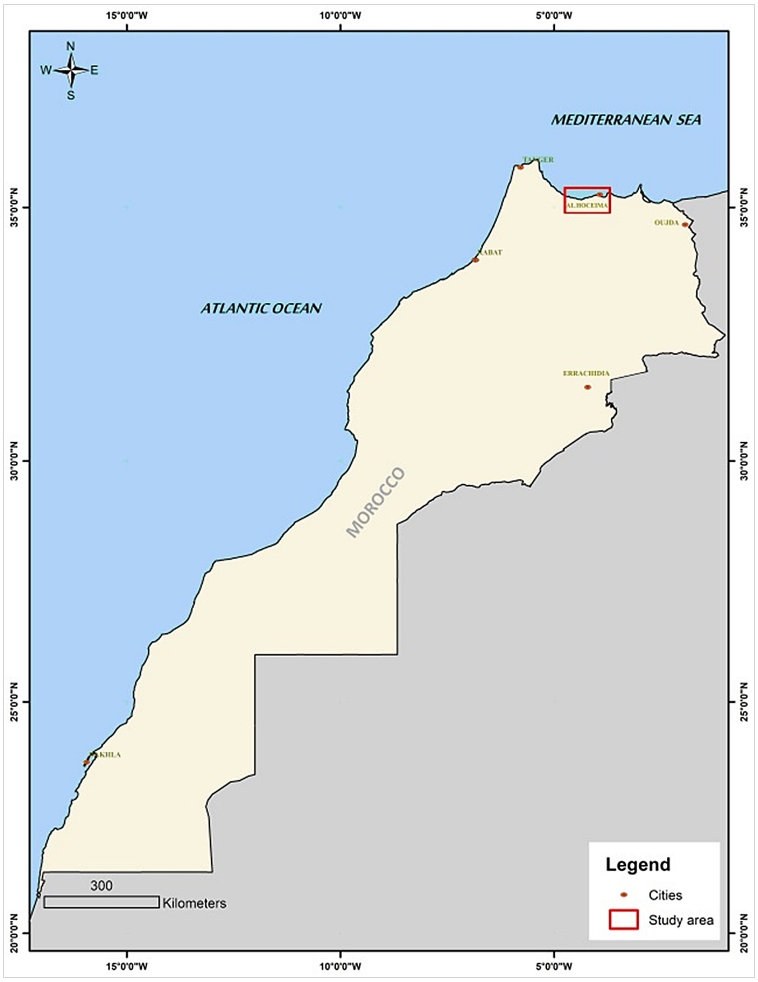

Figure 1. Geographical location of the study area

50 sites, representing wells, one source and three rivers sub-flows were prospected. These sites are located near urban areas, in the places where human activity is intense, in coastal areas and in the places where there is no source of contamination. The climate of the study area is in general characterized by a transition from semi-arid to humid, with an alternation of seasons distinguished by a cool and humid winter (October to April) as well as a hot and dry summer (June to September). The average annual rainfall exceeds 300 mm on the coast and 1000 mm at the highest altitudes. As for the temperature, it varies from 10°C to 30°C (HCP, 2017).

Geological setting

The north of Morocco is dominated by the peaks of the Rif chain, the highest point of which, Jbel Tidirhine (2456 m) is located on the limestone units. Covering an area of approximately 32000 km^2, the Rif chain (in Amazigh "Arrif" which means "shore, edge") is an alpine chain of 300 km long and 100 km wide located in the northern region of Morocco (Poujol, 2014). The Rif's domain extends from the Atlantic Ocean to Oued Nekor which is part of the Mediterranean territory of the country. The Rif is subdivided into three main areas from the North to the South, either from the inside to the outside of the arc, and going up the stratigraphic series: the internal zones, the aquifers of flysch and the external zones (Flinch, 1993; El Ouahabi et al., 2014). As for the study area (Rif Central), it is one of three areas starting from the Bokoya massif in the west (internal domain) to the Temsamane unit in the east (external domain) and in the south by the flush aquifers of Tisirène (Figure 2).

The Bokoya massif, located to the west of Al-Hoceima, is dominated by limestone scales which stretch out in the form of a narrow band 10 km wide separating the Alboran Sea in the north from the Tisirene sheet in the south which are essentially made up of Cenomanian flyshsshisto-sandstone (Salhi, 2008). It is made up of Triassic-Liassic carbonate rocks, condensed Jurassic series and paleogene marl levels (Andrieux, 1971). On the other hand, the Ghis-nekor plain is filled with heterogeneous alluvium ranging from the Pliocene to the present day. The recent Quaternary covers most of the plain. It is materialized by the presence of conglomerates, sandstones and plateaus silts from the Ghis and Imzoren rivers. Moreover, Oued Nekor is occupied by gray silt, current alluvium and modern coastal dune sands, sometimes consolidated (Salhi, 2008).

Situation of the study area

The studied sites are spread over two large hydraulic basins: the Ghis-Nekor basin and the Bokoya basin. Thus, 51 wells, 3 underflow sites of the Ghis and Nekor rivers and one water source were located (Figure 3).

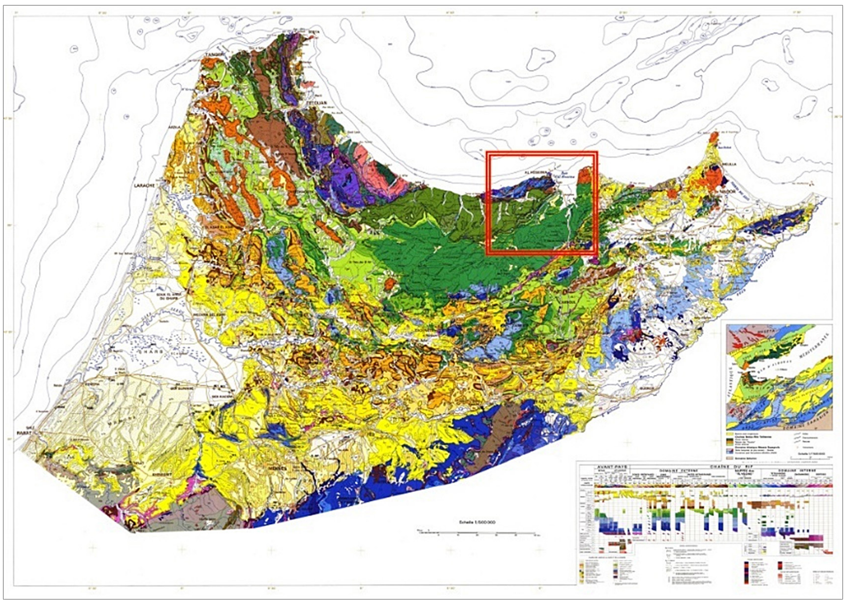

Figure 2. Geological setting of the study area (Suter, 1980)

Physicochemical analyses

The physico-chemical factors of the water: temperature, pH, turbidity, salinity, conductivity and dissolved oxygen were measured in the field using WTW portable meters. The indicator ions of organic pollution, the calcium and magnesium hardness, as well as the sodium, potassium, sulfate and chloride ion contents were analyzed in the laboratory, in accordance with AFNOR standards and the methods recommended by Rodier (2009).

Bacteriological analyses

The water from the wells was collected, stored and transported to the laboratory to undergo the analyzes in question, in less than four hours, using the Most Probable Number (MPN) counting method (Rodier, 2009).

Coliforms

The culture medium used for the presumptive test is Tryptose Sulfate Lauryl Broth. The inoculated tubes are incubated at 37°C for total coliforms and 44°C for fecal coliforms. After 48 hours incubation, the tubes are considered positive when they are turbid with gas production. The results were confirmed by inoculating the positive tubes using a Pasteur pipette in brilliant green lactose broth for total coliforms and EC medium for fecal coliforms. The incubation was carried out at 37°C and 44°C for 48 hours respectively. Only turbid tubes with gas production are considered positive and are counted using the Mac-Grady table (Rodier, 2009).

Faecal streptococci

The inoculation of the water samples was done in the same way as for coliforms while the culture medium used for enterococci is sodium azide glucose broth. Incubation was done at 37°C during 48 hours. Cloudy and depositing tubes are considered as positives. These were later inoculated using a loop in petri dishes of esculin azide bile agar (BEA). The incubation was done at 44°C for 4 hours. The darkening of the medium confirms the presence of intestinal enterococci after a negative catalase test. Moreover, the Mac-Grady table was used for counting the intestinal enterococci (Rodier, 2009).

Statistical analysis

Principal Component Analyses (PCA) were carried out based on the physico-chemical data obtained (average values of monthly measurements) in the study area (Table 1). Data processing was performed by using SPSS 10.0.5 software. These analyses were completed by a hierarchical classification which permits to subdivide the groups of stations and thus obtain their typologies.

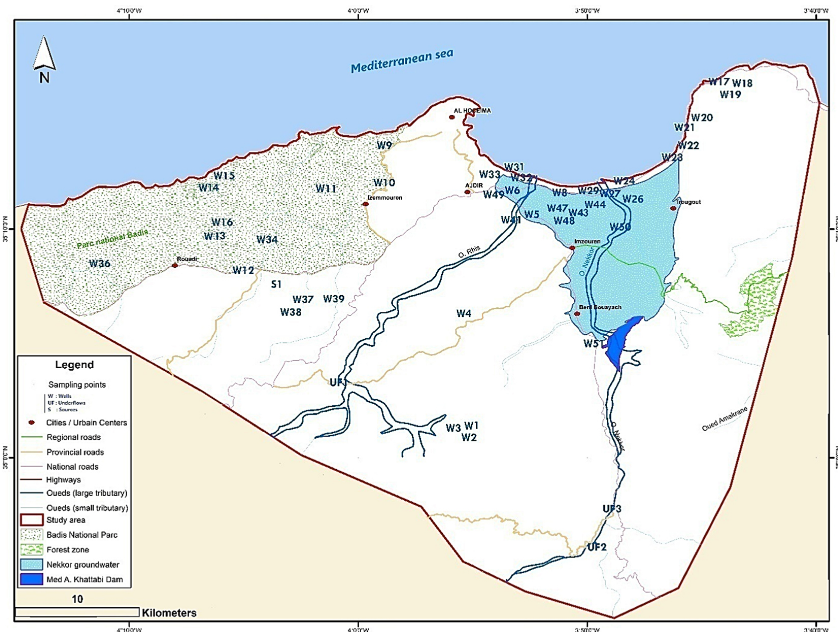

Figure 3. Geographical location of the studied wells

Table 1. Average values of physicochemical variables in groundwater in the study area.

ID	T	pH	CE	O_2	NO_3^-	NH_4^+	PO_4^{3-}	Pt_i^*	SO_4^{2-}	Cl^-	Ca^{2+}	Mg^{2+}	K^+	Na^+	Salinity	Turbidity
Unit	°C		$\mu S.cm^{-1}$	$mg.l^{-1}$											$g.l^{-1}$	NTU
W1	18.06	6.7	1934	7.9	26.91	0.16	4.02	1.31	776.29	142	318.36	97.2	2.3	135.5	1.92	0.23
W2	16.57	7.37	1022	2.29	13.86	0.01	3.98	1.3	50.47	88.75	88.17	60	1.6	153.5	0.5	1.81
W3	19.19	7.02	1217	6.12	10.1	2.2	2.6	0.85	78.01	195.25	92.18	50.4	0.9	233	0.63	0.66
W4	18.26	7.5	3694	3.57	4.07	0.12	4.24	1.38	424.47	985.5	88.17	91.2	4.6	623.5	3.73	0.36
W5	19.61	6.65	2170	3.83	22.34	0.1	4.3	1.4	741.87	710	256.51	139.2	8	394	2.18	2.32
W6	20.16	7.02	1762	3.78	8.16	0.1	4.34	1.42	726.57	426	248.49	148.2	12.2	339	0.9	1.51
W7	18.76	7.17	4142	4.22	2.99	0.1	4.28	1.39	1231.35	1029.5	328.65	201.6	5.7	560.5	2.01	2.67
W8	19.03	7.12	3640	6.59	6.66	0.13	4.19	1.37	944.55	674.5	264.52	158.4	4.5	452.5	2.25	2.19
W9	15.02	8.32	872	4.19	14.82	0.13	4.18	1.36	56.97	147	56.112	16.8	0.4	133	0.43	1.82
W10	17.66	7.15	1263	3.87	50.48	0.12	4.21	1.37	48.56	213	120.24	24	2.8	102	0.63	1.7
W11	19.09	7.6	1276	3.71	86.54	1	4.49	1.47	35.9	213	64.13	19.2	3.6	258.5	0.47	1.15
W12	18.22	7.31	7153	3.8	2.67	0.9	4.56	1.49	503.61	2047.5	208.84	151.2	18.3	789	2.18	3.08
W13	17.53	7.22	854	3.77	41.15	0.17	4.36	1.42	38.44	112	72.14	62.4	5	68.5	0.45	1.3
W14	18.25	7.24	3192	3.8	13.94	0.05	4.46	1.46	104.01	603.5	144.28	67.2	8.9	372.5	1.69	2.08
W15	17.85	7.31	3015	3.86	56.32	0.11	4.45	1.45	140.72	497	112.22	62.4	4.2	384.5	1.59	2.66
W16	18.04	7.53	1302	4.28	34.8	0.09	4.27	1.39	27.11	177.5	80.16	48	4.1	141	0.65	1.34
W17	20.99	7.77	6618	2.64	9.38	0.18	2.66	0.86	598.86	1473.25	152.3	91.2	29	680.5	3.63	15.2
W18	21.32	7.2	3736	2.58	2.6	0.09	1.55	0.5	924.39	497	296.5	129.6	7.8	308.5	1.97	0.72
W19	21.15	7.05	3795	2.67	3.38	0.04	1.55	0.5	842.47	426	304.6	144	10.3	314	2.01	1.42
W20	25.44	7.41	2437	2.75	6.52	0.05	1.93	0.63	83.39	390.5	128.25	81.6	9.6	217.5	1.25	1.33
W21	26.67	7.06	2608	2.58	5.6	0.05	1.8	0.58	103.18	461.5	136.27	81.6	8.6	229	1.32	0.4
W22	21.35	7.44	10210	2.83	70.85	0.12	2.19	0.71	458.89	2432.5	49.7	216	33.1	785.5	3.54	1.72
W23	20.62	7.83	12400	5.52	4.16	2.5	2.4	0.78	623.11	3150	48.09	292.8	54.9	884	7.13	41.9
W24	21.03	7.79	2039	2.67	1.79	0.04	0.8	0.26	709.92	532.5	208.41	129.6	1.9	394.5	1.04	8.53
W25	21.52	6.88	5440	2.82	3.2	0.15	1.1	0.36	704.18	887.5	280.56	153.6	5.7	501	2.29	1.95
W26	21.8	7.04	2347	2.8	0.86	0.05	1.08	0.35	473.32	639	216.43	120	5.8	441	1.19	5.5
W27	20.88	7.16	6472	2.62	0.89	0.04	0.99	0.32	1571.62	1065	360.72	235.2	6.1	596.5	2.2	13.6
W28	23.03	7.56	5594	2.56	1.26	0.1	0.97	0.31	1108.85	852	344.68	182.4	7.8	467.5	3.04	4.19
W29	21.75	7.28	3568	2.62	9.59	0.06	0.72	0.23	618.01	461.5	248.49	115.2	5.6	324.5	1.88	2.15
W30	21.1	7.34	2586	3.05	0.36	0.06	0.95	0.31	455.24	355	184.36	100.8	6.1	247	1.41	4.32
W31	21.63	7.57	1632	2.67	0.85	0.07	1.53	0.5	523.32	390.5	224.44	110.4	6.9	286	0.82	2.39
W32	19.66	7.23	3508	3.03	0.84	0.07	0.84	0.27	608.43	781	232.46	129.6	4.7	308.5	1.85	1.86
W33	21.45	7.8	4389	2.93	33.33	0.04	1.08	0.35	382.9	852	96.19	86.4	39.2	501.5	2.32	3.95
W34	19.03	7.57	1312	4.29	40.23	0.04	0.95	0.31	42.33	213	80.16	24	6.3	157	0.66	9.91
W35	20.68	7.74	3411	2.8	10.59	0.05	1.31	0.42	173.36	674.5	128.25	81.6	17.7	365	1.79	16.1
W36	18.94	7.6	1931	2.86	4.86	0.03	1.19	0.38	89.46	390.5	128.25	48	6.9	249	0.97	2.74
W37	20.33	7.26	7513	2.54	128.45	0.07	1.69	0.55	232.05	1904	228.45	189.6	23.9	605	4.29	16.2
W38	19.59	8.89	2675	2.59	115.4	0.09	1.06	0.34	133.96	603.5	56.11	57.6	26.6	436.5	1.11	0.81
W39	22.13	7.32	10240	2.45	18.3	0.13	1.33	0.43	504.18	2804.5	408.81	259.2	20.2	657.5	5.75	6.02
W40	21.1	7.17	1498	2.87	8.78	0.03	0.8	0.26	402.05	461.5	256.51	81.6	3.4	258.5	0.75	5.43
W41	22.2	7.4	3212	2.63	3.7	0.04	0.72	0.23	471.2	532.5	26.43	124.8	5	300	1.68	7.75
W42	21.26	7.45	3684	2.58	20.98	0.04	1.45	0.47	654.18	532.5	248.49	172.8	8.6	357.5	1.53	11.9
W43	20.27	7.35	3299	2.62	10.79	0.17	1.62	0.53	522.26	532.5	232.46	115.2	3.3	309.5	1.22	46
W44	20.77	7.18	3467	2.59	12.39	0.09	1.25	0.41	541.41	568	256.51	120	3.2	316	1.83	16.5
W45	20.75	6.74	6254	2.54	29.04	2.1	1.62	0.52	1156.72	923	360.72	230.4	6.7	512	3.42	5.54
W46	21.01	6.97	5739	2.54	24.49	0.04	1.87	0.61	976.52	958.5	328.65	216	4.7	470	3.12	32.6
W47	22.08	7.11	2983	2.52	23.8	0.07	1.69	0.55	1029.71	958.5	336.67	201.6	4.6	474.5	1.56	14
W48	21.26	8.78	4335	4.37	10.19	0.05	1.34	0.43	586.09	781	152.3	105.6	6.2	419	2.31	6.03
W49	21.42	7.26	6746	4.42	180.88	0.03	2.26	0.73	525.45	1278	168.33	148.8	18.5	603	3.7	9.95
W50	22.13	7.15	2477	2.87	18.37	0.09	1.39	0.45	905.24	710	352.7	177.6	4	384	1.28	18
W51	22.79	6.96	6264	2.55	26.97	0.04	1.66	0.54	557.37	1349	240.48	148.8	8.7	544.5	3.42	2.38
UF1	23.15	7.63	2087	4.95	0.54	0.05	0.97	0.31	381.34	248.5	176.35	91.2	2.8	148	1.07	2.84
UF2	25.53	7.25	2424	5.76	2.04	0.03	1.25	0.4	576.52	177.5	240.48	100.8	4	136	1.25	3.49
UF3	22.41	7.23	1604	7.46	3.54	0.11	1.13	0.36	568.01	355	336.67	38.4	5.6	256.5	0.81	1.95
S1	21.21	7.06	3292	2.54	34.56	0	1.35	0.44	335.03	1627.5	240.48	124.8	12.9	563	1.73	1.21

*Total dissolved inorganic phosphorus

RESULTS AND DISCUSSION

Water physicochemistry

The Principal Component Analyses (PCA) carried out on the physicochemical data (Table 1), show that axis 1, expressing 34.62% of the total inertia (Fig. 4) is essentially well correlated with the following variables: electrical conductivity (EC), chlorides (Cl^-), sodium (Na^+), salinity, potassium (K^+), turbidity and to a lesser degree with magnesium (Mg^{2+}).

The axis 2, with 22.29% of the total inertia of the cloud opposes the Ca^{2+}, SO_4^{2-} ions to the alkalinity and to the nitrogenous ions of NO_3^- as well as phosphates of orthophosphates (PO_4^{3-}) which contribute negatively to the expression of this axis. The typology of water stations resulting from the analysis of physico-chemical data by hierarchical classification has led to subdivision of the stations studied into four groups (Figure 4).

Group G1: this group consists of a single station (W23) located near the sea where it receives debris from plants and other bodies with very high turbidity. It is the most mineralized group compared to the others, since it is rich in Cl^-, Na^+, SO_4^{2-}, Mg^{2+}, and K^+ with high salinity and a conductivity of 12.400 µS/cm. However, the results show that this group is low in Ca^{2+} (48.09 mg.L^{-1}) which could be explained by the arrival of sea water via the marine intrusion phenomenon. **Group G2**: it includes the stations situated outside of the wastewater spreading area. These stations, which are characterized by their high salinity, are located downstream from the Wadis. The waters of these stations are characterized by strong mineralization with very high values in electrical conductivity, and very high nitrate contents. These wells are characterized by a low piezometric level during the period samples collection. **Group G3**: includes all the stations located away from pollution. Thus, most of the stations

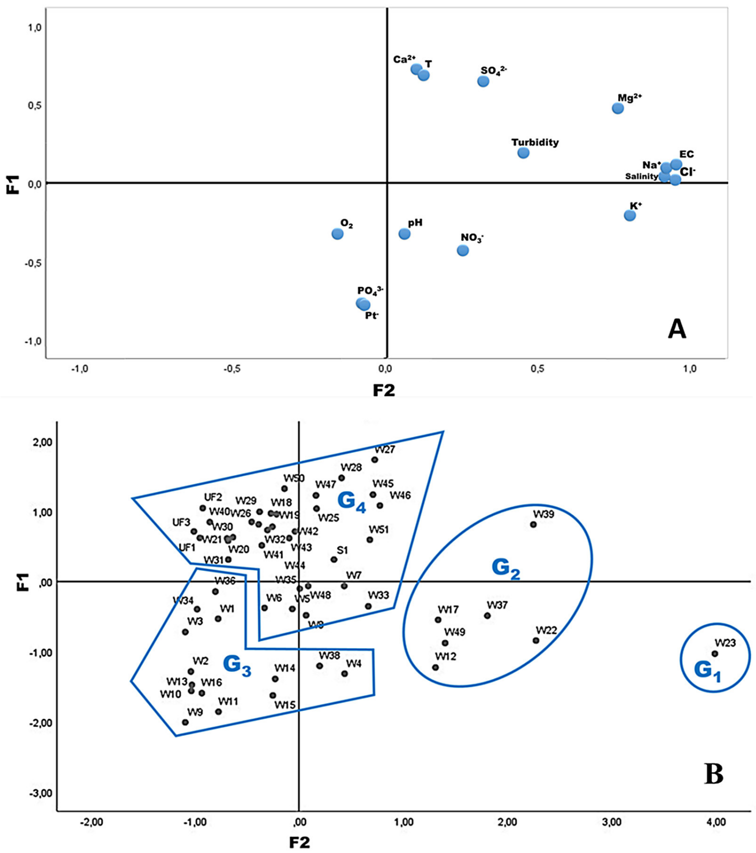

Figure 4. Projection of the physico-chemical variables of water indicated in table 1 (A) and the groups of stations studied in the study area (B) on the plane of the two factorial axes F1 and F2 of the PCA. T: temperature; pH: hydrogen potential; EC: electrical conductivity; O_2: dissolved oxygen; NO_3^-: nitrates; PO_4^{3-}: orthophosphates; Pti: inorganic total phosphate; K^+: potassium; Na^+: sodium; SO_4^{2-}: sulphates; Cl^-: chlorides; Ca^{2+}: calcium; Mg^{2+}: magnesium.

in this group have water with an optimal physico-chemical quality and a high mineralization. The wells belonging to this group are well protected and negatively correlated with axis 2. **Group G4**: this group which is composed of a considerable number of the sampled wells is characterized by high Ca^{2+} and SO_4^{2-} quantities as well as a strong mineralization. These stations occupy the areas where human activity is intense and project to the median of the two factor axes, with weak negative coordinates. The waters belonging to this group are characterized by a very high alkalinity and fairly high sodium contents.

Bacteriology of water

In the water sampled, the germs of faecal contamination vary depending on the site (Table 2). The concentration of total coliforms in the designated study sites reached over 1100 $MPN.100ml^{-1}$ in the W6 well and the concentration of intestinal enterococci reached 75 $MPN.100ml^{-1}$ in W4 and W16. In turn, the rate of Escherichia coli bacteria is zero in most sites with the exception of W1 and W7, which show the contents of 9 and 460 $MPN.100ml^{-1}$, respectively.

The physico-chemical results were analyzed and discussed with reference to the water quality standards proposed by the World Health Organization (WHO, 2011). The physico-chemical properties of the water from the studied wells are in agreement with those of previous studies (Salhi, 2008; Ait Benichou et al., 2017; Gharibi et al., 2017; Chafouq et al., 2018). The majority of the wells studied are well oxygenated, at neutral pH and at a relatively stable temperature. In this study area, the pH and oxygenation of the water are within the drinking standards recommended by WHO (2011) and what is necessary for the protection of aquatic life (DeZuane, 1997). The conductivity values often exceed 10 $\mu S.cm^{-1}$ reflecting highly mineralized water due to the carbonate nature of one part of the bedrock (El Azzouzi et al., 1999). However, other studies at the national scale revealed divergences in terms of mineralization level, which was sometimes very weak, especially at the level of the groundwater of the Ourika valley comparatively to high values in the north of Marrakech city as well as in other wadis situated in the Atlas of Marrakech (Ait Boughrous et al., 2007). The distribution of the electrical conductivity shows very irregular patterns even for closed wells. This can be explained by the dilution by infiltration of fresh water flowing along the rivers (Nekor and Ghis rivers) and the dam from Al Khattabi. Moreover, the heterogeneity in the salinity content observed in neighboring wells at the level of the coastline could be due to the infiltration of rainwater and sometimes to the presence of layers of impermeable clay serving as a protective barrier against the intrusion of sea water. Moreover, this irregularity may be due to the presence of different levels of impermeability, which create sub-aquifers in which the water is not mixed (Salhi, 2008).

Table 2. Microbiological data of groundwater in the study area

Well	Total coliform ($MPN \cdot ml^{-1}$)	*Escherichia Coli* ($MPN \cdot ml^{-1}$)	*Intestinal Enterococci* ($MPN \cdot ml^{-1}$)
W1	$29 \cdot 10^{-2}$	$9 \cdot 10^{-2}$	$23 \cdot 10^{-2}$
W2	$23 \cdot 10^{-2}$	0	0
W3	$9 \cdot 10^{-2}$	0	0
W4	$23 \cdot 10^{-2}$	0	$75 \cdot 10^{-2}$
W5	3.10^{-2}	0	$3 \cdot 10^{-2}$
W6	>11	0	$43 \cdot 10^{-2}$
W7	4.6	4.6	0
W8	$3 \cdot 10^{-2}$	0	0
W9	0	0	0
W10	0	0	0
W11	11	0	$7 \cdot 10^{-2}$
W12	0	0	0
W13	0	0	0
W14	$23 \cdot 10^{-2}$	0	$21 \cdot 10^{-2}$
W15	0	0	0
W16	$43 \cdot 10^{-2}$	0	$75 \cdot 10^{-2}$

The concentrations of nitrate ions are generally high, which can be explained by the impact of human activities on the water table. Their presence in water is linked to the use of fertilizers and manure and also to the increased existence of defective septic systems (Levallois and Phaneuf, 1994); hence the risk of groundwater contamination becomes more accentuated due to its proximity to the soil surface which favors the arrival of wastewater into the groundwater and on the other hand to the texture of the bedrock which is very coarse, thus causing great vulnerability (Hakkou et al., 2001; Khan and Wen, 2020). The nitrite contents are very low since in exception of a few cases, they do not exceed the limits set by the WHO (2011) and those retained by the Moroccan standards for groundwater (Lyakhloufi et al., 1999). Ammonium, which is toxic for aquatic life even at very low concentrations (McNeely et al., 1979; Bowie et al., 1985) is present in this area with trace values in a few wells which are generally near urban agglomerations and agricultural areas. At this same level, several wells revealed fairly high contents of nitrate and orthophosphate ions. The poor quality of the water in some wells is explained by the contamination of wastewater from the many septic tanks in the area. The concentrations of chloride ions which are toxic to aquatic biodiversity (Ayers and Westcot, 1976) caused by inputs from geochemical origin were found to be higher than the standard values recommended by WHO.

The distribution of the concentration of sulfate ions is very heterogeneous from one well to another while exceeding the average quality values recommended by the Moroccan standard and that of the WHO (2004). Indeed, it is commonly recognized that the main source of these sulfated ions in groundwater is the weathering of sulfur minerals such as gypsum, anhydrite and sulfides as well as industrial and mining wastes (Fianko et al., 2009).

The sodium content of almost all of the samples analyzed exceeds the desirable limit of 200 $mg.l^{-1}$ (WHO, 2004). The high concentration of Na^+ is often the result of weathering of rock-forming minerals such as sodium halite and plagioclase as well as anthropogenic sources, including industrial, household and animal wastes (Freeze and Cherry, 1979). The contents of calcium, magnesium were detected in the majority of samples with values exceeding the standards recommended by the WHO (2004), while the potassium levels were found in all samples much below the threshold dictated by WHO. The high level of calcium may be explained by the alteration of carbonate minerals (calcite, dolomite and aragonite) or the leaching of chemical fertilizers (Prasanna et al., 2011; Khan and Wen, 2020). In addition, the large concentrations of Mg^{2+} ions in groundwater may be linked to the alteration of minerals containing Mg^{2+} and anthropogenic (Marghade et al., 2011).

The results of microbiological analyses either of thermo-tolerant coliforms represented by *Escherichia coli* and intestinal enterococci (faecal streptococci) from the prospected wells water show a high density of bacteria indicative of faecal contamination in some wells and their absence in others (Atherholt et al., 2003). The presence of faecal coliforms is perhaps due to the high levels of organic matter coming from the wastewater of neighboring habitats (Kadaoui et al., 2019; Zouhri et al., 2019) (septic tanks often noticed in the region) and mainly to the inputs of fertilizers, greater than the real needs of the crop, which infiltrate by irrigation water through the soil to the water table and contaminate the groundwater with nitrates. The high load of organic matter reflects the sensitivity of fecal coliforms; however, intestinal enterococci (faecal streptococci) are more resistant. Hence their presence in the water of some wells (Adingra et al., 2012; Touati et al., 2019).

According to the WHO (2000), the microbiological results obtained do not meet the standards relating to drinking water due to the contamination of the quality of these groundwater prospected by pathogenic germs. The presence of this fecal contamination indicates a potential risk to the health of the local population exposed to this natural source.

CONCLUSIONS

The present study showed that the groundwater of the Rif Central is characterized by a strong mineralization of their waters. The high concentration of EC, Cl^-, SO_4^{2-}, NO_3^-, Na^{2+}, etc., in groundwater near sources of pollution degrades its quality for consumption and other domestic purposes. The Standardized Principal Component Analysis of the physico-chemical data allowed differentiating a set of groups according to their quality in the study area. The physicochemical quality of this water varies from one group to another, depending on the nature of the substratum crossed by the water table and the frequency of human activities near the stations studied, such as the infiltration of groundwater by wastewater coming from septic tanks, the use of wastewater for irrigation and the increased use of fertilizers and pesticides in agriculture. Rainfall is a very important factor, when it is regular, in reducing the severity of pollution in the water table.

The results of the microbiological analyses indicating the presence of germs indicative of faecal contamination demonstrate the extent of the threat to the state of health of persons exposed to these waters. This contamination of groundwater may be due to the effect of anthropogenic activities around the prospected sites. All these results reveal the problem of irrational management of groundwater in the study area and this requires limiting its effects in order to fight effectively against pollution.

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