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Contribution Of Hydrochemistry To The Evaluation Of The Physicochemical Quality Of Groundwater Of Ain Al Atti In The Region Of Erfoud (Morocco).

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ABSTRACT
Underground water contamination is one of the environmental problems facing arid to semi-arid lands. To evaluate the physicochemical quality of underground water in the Ain Al Atti region, an hydrochemical study was initiated. Through four water points (spring, well and Oued Ziz), thirteen (13) parameters were determined: the temperature, the Electrical Conductivity (CE), the pH, the Total Alcalimetric Title (TAC), the Total Hardness TH (Hydrothymetrictitle), Cl^-, Na^+, NO_3^-, HCO_3^-, SO_4^{2-}, NH_4^+, Ca^{2+} and Mg^{2+}. Data from these analyses were processed using hydrochemical techniques; Piper diagram. The results obtained show that the waters of Ain Al Atti have a chemical facies mainly of chlorinated sodium type. Based on the analyses performed and the tolerant threshold values of the chemical parameters, the quality of these waters is considered as bad to very bad.
Keywords: Ain Al Atti, underground water, hydrochemistry, chemical facies.

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I. INTRODUCTION

Underground water has an essential role in the development of water resources in arid to semi-arid areas. During the 1980s, Morocco experienced a drought whose effects badly felt in the Errachidia region, so the exhaustion of the alluvial aquifer led to the exploitation of the other reservoirs of the region (Ammary, 2007). Moreover, the exploitation of these aquifers requires their recognition to better characterize the aquifer systems, in this case the infracenomanic aquifer, which includes the artesian source of Ain El Atti.

At the scale of the basin, the strong demand of water for agriculture led to over exploitation of the superficial phreatic underground water inducing the use of the deep artesian aquifer. This situation results in a degradation of water quality (Dakkak, H et al, 2005). The problem targeted by this work revolves around the quality of underground water in the infracenomanian aquifer. These likely cross evaporitic gypsum salt formations. Following these hydrogeological conditions of water circulation, a hydrochemical study was conducted to evaluate the chemical composition of these waters.

Given the fact that it is highly variable, the chemical composition of the underground water depends on the geological nature of the reservoir and also the reactive substances that they may have leached during the flow. The working procedure is based on the measurement of physicochemical parameters through different stations in the field of study (spring, well and Oued), in order to determine the quality of the waters of Ain Al Atti.

II. GEOGRAPHY AND GEOLOGIC FRAME

The study area belongs to the plain of Tafilalt and islocated 60km south of Errachidia and 10km north of the city of Erfoud. It is part of the Cretaceous Errachidia Basin (**Figure 2**). This basin, which presents itself as an a symmetric synclinorium, consists of carbonate deposits of the Turonian (Choubert and Faure-Muret, 1962), sandy-sandstone with intercalation of the Infracenomanian gypsum and clayed sand with evaporate deposits and gypsiferous Senonian formations (Choubert, 1920-1945). The Tafilalet plain is a depression formed by quaternary alluvial sedimentary deposits, which rest directly on the

Infracenomanian in the North and on the Paleozoic in the South (Margat, 1977). It is in the form of two clay-limestone plateaus try fitted and cut by the rivers Ziz and Rhéris, in deep valleys.

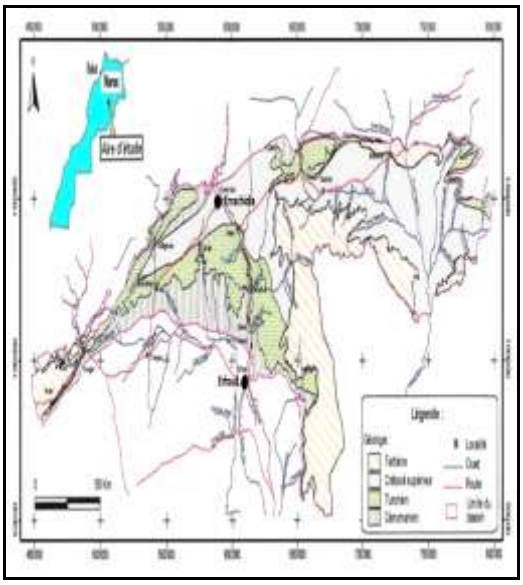

Figure 1: Geologic card of the Cretaceous basin of Errachidia (DRHE, 2007)

III. CLIMATOLOGICALLY CONTEXT, HYDROLOGY AND HYDROGEOLOGY

The climate in this region is arid to semi-arid, which becomes Saharian with strong continental influence to the south with a microclimate characterized by valleys and cultivated areas (palm groves). Temperatures have very significant seasonal variations (48°C during summer and around 15°C during winter), while precipitation (the annual average is 120mm), scare and very irregular, are related to the orographic disturbance responsible for the stormy rains of summer and to the oceanic disturbance, causing winter and spring rains (DRHE, 2009).

Surface waters network, active during winter, is limited to two main rivers (Ziz and Rhéris), coming from the High Atlas and crossing the basin from North to South. Their hydraulic profiles are irregular and have a succession of convex sections. Concerning underground water resources, the Er-Rachidia Basin contains Cretaceous (Senonian, Turonian, and Infracenomanian) and Quaternary aquifers (Margat, 1977). The aquifer of the Infracenomanian consists of continental deposits (coarse sandstone and conglomerates) and lagoon (sands, clays and marl). The Turonian aquifer is composed of fractured limestone formations and dolomite of marine origin, in the form of karst facies. The Senonian aquifer is composed of very heterogeneous sandstone-clayed continental formations, including gypsum and anhydrite. The Quaternary aquifer, south of the basin (Tafilalet nappe), is formed on the base of more or less cemented conglomerates and lacustrine sandstone limestones.

IV. MATERIALS AND METHODS

4.1) Sampling

The sampling covered spring water, surface water (oued) and well water. In the study area, four stations are concerned: the source Ain El Atti (S1), Oued Ziz before the source (S2), Oued Ziz after the source (S3) and the well at 1500 m before the source (S4). A total of eight (8) samples per station were made over a two-month period.

4.2) Experimental procedure

The water samples taken were put in polyethylene bottles, previously washed with nitric acid and then with distilled water. In the field, before filling the bottles, they were washed three times with the water to be taken. The filling of the bottles was done to the brim and then the cap screwed to avoid any gas exchange with the atmosphere. The water samples were then transported to the laboratory for analysis within one hour of collection. During sampling, physical parameters such as temperature, electrical conductivity (EC) and pH were measured in situ.The equipment used in the field consists of a portable thermometer, a conductivity-meter and a pH-meter. The water samples were also subjected to chemical analyses. The parameters measured are the Total Alkalimetric Title (TAC), which represents the alkalinity of the water given by the presence of the HCO_3^- anions or of a CO_3^{2-} and HCO_3^- mixture, the TH Total Hardness (Hydrothymetric Title) indicating the overall content in calcium and magnesium salt. The concentrations of Na^+, NH_4^+, Ca^{2+} and Mg^{2+} and an assay of Cl^-, HCO_3^-, SO_4^{2-} and NO_3^- anions are also determined.

4.3) Results and discussion

The measurements in situ are recorded in **Table 1**. It appears that the temperature values are close together. Surface waters (S2 and S3) are relatively hot, with a temperature that varies around 22°C. The water from the source (S1) displays temperatures ranging from 20°C to 22.1°C, while the water from the well (S4), sees its temperatures lightly lower with an average of 19°C. This variation is probably related to the depth of the water table for source and well water, and to the influence of climatic conditions for surface water (Oued Ziz). The spring waters are slightly acidic

(pH = 6.48) while the waters of the S2, S3 and S4 stations are slightly alkaline, with a maximum value of pH = 7.7 at the S3 station. The electrical conductivity is higher in the four stations with a maximum average value of 8077.5µs/cm recorded at the S3 station (Oued Ziz after the source). The waters are highly mineralized.

Table. 1: Results of the measures in situ of analyzed waters

	T(°C)			pH			CE(µs/cm)		
	Max	Min	average	Max	Min	average	Max	Min	average
S1	22.1	20	21.05	7.39	6.48	6.93	10100	4080	7332.5
S2	22.4	22.3	22.35	7.6	6.63	7.09	10900	3250	7421.25
S3	22.5	22.3	22.4	7.7	6.74	7.32	11010	5000	8077.5
S4	19.1	18.9	19	7.54	6.56	7.12	9730	4010	6897.5

The results of the chemical parameters of the analyzed waters are presented in **Table 2**. The cations studied are Na^+, Ca^{2+}, Mg^{2+} and NH_4^+. Of these, the Na^+ cations are the most important, with an average value of 2247.35 mg/l (S3). The remaining three cations show low concentrations across the four stations, ranging from 2 mg/l to 5.5 mg/l. As for the anions, the most important are Cl^-, with a maximum average concentration of 2103.96 mg/l (S3), followed by HCO_3^- and NO_3^-. SO_4^{2-} anions have relatively low concentrations of not more than 80 mg/l. Total Alcalimetric Titration (TAC) in the water samples analyzed was mainly due to bicarbonate ions (HCO_3^-).

TabLE. 2 : Summary of the measures of the chemical parameters of analyzed waters

	Cl^-	Na^+	HCO_3^-	NO_3^-	SO_4^{2-}	NH_4^+	Ca^{2+}	Mg^{2+}	TAC °F	TH °F
S1	**1953,99**	**1875,56**	**604,51**	**131.13**	**77,39**	**2,04**	**5,36**	**2,82**	**49,55**	**2,01**
S2	**1978,66**	**980,74**	**584,99**	**195.5**	**78,13**	**2,08**	**5,14**	**2,93**	**47,95**	**1,95**
S3	**2103,96**	**2247,35**	**575,53**	**211**	**78,21**	**2,10**	**5,18**	**2,9**	**46,85**	**2,89**
S4	**2001**	**1250,22**	**623,89**	**374.88**	**77,6**	**2,21**	**5,42**	**2,91**	**51,12**	**3,23**

The hydrochemical classification of waters from the triangular diagram of Piper (**Figure 2**) shows that the waters of Ain Al Atti are mainly sodium chlorinated waters. For underground water (S1 and S4) high concentrations of chloride and sodium would be due to the interaction of water with the geological formations of the aquifer.

The increase in the content of these salts is related to the dissolution and leaching of the host (Aoubouazza M et al, 2013) following a long time contact between water and aquifer rock (Ammary, 2007). Contamination and mineralization of surface waters (S3 and S3) are related to the drainage of artesian waters being added of Oued Ziz. In this regard, the work of piezometry and hydrochemistry carried out by Dakkak. H et al, 2005, have also shown that the salinity of the water table is attributed to several parameters including the

evaporating power of the climate and the recharge of the water table by the return of the very salty artesian waters. The latter, added to rivers, make water unusable for irrigation except on sandysoil and for salt-tolerant plant species (Dakkak, H et al, 2005).

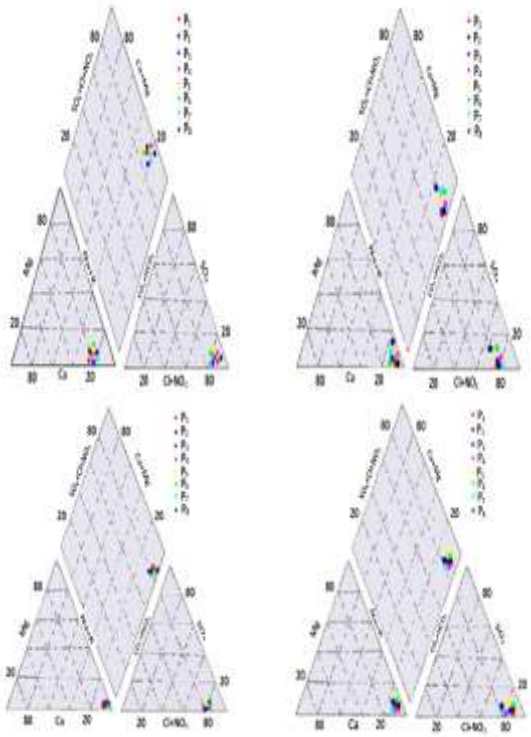

Fig. 2: Piper Diagrams, hydrochemical classification of the analyzed waters

The assessment of the overall quality of the analyzed water is based on the comparison of the results obtained with threshold values of physicochemical parameters. **Table 3** shows the parameters used by the DRHE to determine the water quality in the Er-Rachidia basin, and **Table 4** gives a summary of the results obtained at the four stations. Given these data, the water quality of the Ain Al Atti region is rated as bad to very bad.

Table. 3: Values thresholds of the parameters retained for the appreciation of the global quality of waters (DRH)

Parameters Quality	CE (µs/cm)	Cl^- (mg/l)	NO_3^- (mg/l)	NH_4^+ (mg/l)	SO_4^{2-} (mg/l)
Very good	**<400**	**<200**	**<5**	**<0,1**	**The maximum permissible value 200 mg/l**
good	**400-1300**	**200-300**	**5_25**	**0,1-0,5**	
medium	**1300-2700**	**300-750**	**25_50**	**0,5-2**	
bad	**2700-3000**	**750-1000**	**50_100**	**2_8**	
Very bad	**>3000**	**>1000**	**>100**	**>8**	

Tab. 4: Summary of the results obtained for waters of the various stations (the average value)

	CE (µs/cm)	Cl^- (mg/l)	NO_3^- (mg/l)	NH_4^+ (mg/l)	SO_4^{2-} (mg/l)
S1	**7332.5**	**1953,99**	**131.125**	**2,04**	**111.56**
S2	**7421.25**	**1978,66**	**195.5**	**2,08**	**55.21**
S3	**8077.5**	**2103,96**	**211**	**2,10**	**82.76**
S4	**6897.5**	**2001**	**374.875**	**2,21**	**61.43**

V. CONCLUSION

The hydrochemical analysis made it possible to evaluate the physic-chemical quality of underground water in the Ain Al Atti region. This study has shown that these artesian waters are mainly sodium chlorite facies, following enrichment in chlorine and sodium from contact with the evaporitic formations. The high concentration of its salts is related, in part, to the interactions with the waters of the infra-Cenomanian aquifer which causes the dissolution of these evaporites. The contact between the aquifer and the evaporitic formations is also highlighted by the result of the electromagnetic prospection. Contamination of surface water (Oued Ziz) is the result of drainage of mineralized water that is added to the watercourse. Based on the results obtained for the physico-chemical parameters, the water quality of Ain Al Atti is considered bad to very bad.

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