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HYDROGEOLOGICAL STUDY OF THE SAF-SAF WATERSHED SKIKDA NORTH-EAST ALGERIA

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Abstract: *The control of water resources is a necessity whether superficial or underground, in order to understand the circulation and origin of groundwater in the downstream part of the Saf-Saf watershed located inthe city of Skikda, North-East Algeria. A detailed qualitative and quantitative study was carried out and 15 analyses were carried out. The results were shown from ground water. The generally do not present a risk of alcalinisation, but a moderately high risk of sanilisation due, on the one hand, to marine invasion and, on the other hand, to discharge of wastewater of industrial origin. Soduim chloride facies is the most predominant. The study of the suitability of groundwater for irrigation of agricultural land shows that the majority of water wells have an acceptable quality for irrigation. The analysis of hydro-climatological data allowed an estimate of the water resources of the watershed, thus attributing a Mediterranean climate, characterised by two distinct seasons: one wet and clod and the other dry and hot. The hydrogeological data reveal the existence of two superimposed layers of unequal impotence, the first superficial sandy of the Quaternary and the other of a deep gravel. These two reservoirs present an important resource for exploitation.*

Keywords: *Algeria, Saf-Saf watershed, groundwater, circulation, salinisation, irrigation.*

INTRODUCTION

With the increasing population, water is becoming increasingly scarce, especially since it has not been distributed uniformly. This water scarcity is multiplied by the needs and development of different uses of human activity that directly affects the quality and quantity of water resources and more particularly groundwater. The watershed of the Saf-Saf wadi is one of the coastal sub-basins of Constantine center. It covers an area of 1158 km^2 with a population of about 471 000 inhabitants. This water resource contains a relatively important water potential. It is represented by the groundwater of the alluvial layer of quaternary age and surface water. In recent years, there has been an economic development, particularly in agriculture, which has resulted in an increase in the demand for water on the one hand, and deterioration in the quality of the water on the other. This study focused on hydrogeological study in order to determine the spatial distribution of the groundwater flow and the physicochemical characterization. In this approach, an inventory of 30 wells was carried out for the piezo metric part and a sampling of 15 water points was analysed for the hydro chemical part.

There are six oil exporting harbours in Libya namely; Al Zawia, Al Sidra, Ras Lanuf, Al Breqa, Al Zwitina and Al Hariqa. They may subjected to various levels of oil effects on the components of ecosystem either abiotic such as sea water and beach sediments or biotic components such as micro and macro organisms. At the Al Hariqa harbour, three stations located at coastal part of the Tobruk Gulf, NE Libya (Figure 1) are subjected to sampling for this study. The Al Hariqa Oil harbour, which is located in Tobruk city is crowded with oil tankers, this problem encourage us to investigate and

monitor this active harbour. The coastal water needs close investigation and attention because it is the only marine environments in contact with human activity (swimming, fishing etc.) as well as other biological productivity of marine organisms. This study will draw the attention of the government to oil pollution, and environmental education to people who are not care to this problem.

STUDY AREA SETTINGS

The watershed of the Saf-Saf wadi is part of Skikda province. It is located in the North-Eastern part of Algeria between the longitude 6°65' and 7°08' East and the latitude 36°87' and 36°35' North with an area of about 1158 km^2 [1]. It is one of the sub-basins of the central Constantinian coast. The main watercourse is the Saf-saf wadi with a length of about 55km, which flows into the Mediterranean Sea.
This exoreic basin is limited in the North by the Mediterranean Sea and in the South by Djebel Hadja and Djebel Oucheni, in the West by the massif of Collo and Djebel Boukhalouf and in the East by Djebel Alia and Djebel Tengout [1]. The watershed is located in the small Kabylia, which is part of the alpine chain of maghrebide. The most dominant geological formations are the alluviums and the ancient dunes of Quaternary age [2].
The climate of the region is of Mediterranean type belonging to the Humid to Sub-humid domain whose average annual pluviometry is irregular of the order of 788.762mm. Only 13,80% infiltrates in the water table, the remainder leaving in the form of evaporation (65,64%) and of runoff (20,74%)with an average annual temperature of 19,17°C [3].
The relief is globally diversified with very uneven terrain. The folds of the mountains are generally oriented West-East [4]. The altitudes varied between 1166m at the level of Djebel Hajar and 225m at the level of Djebel Soubouyou [5].

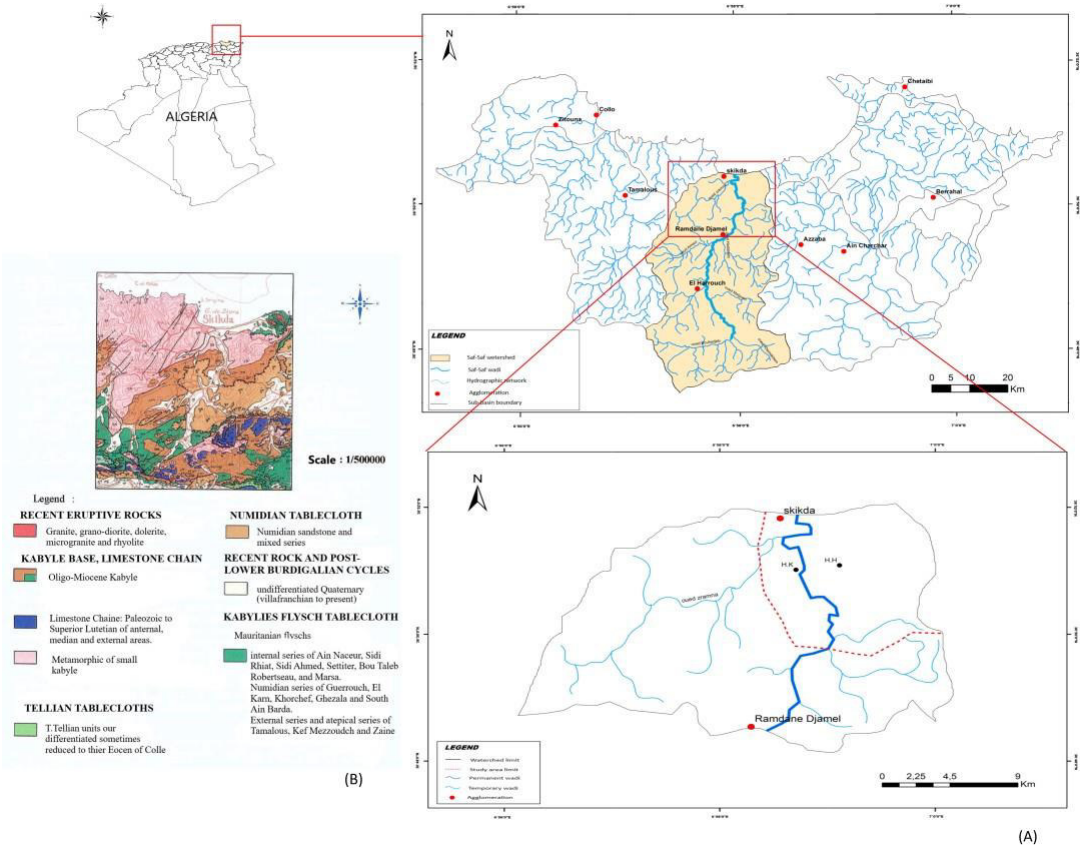

Figure 1. (A) Geographical location of the study area, (B) Geological map (J.M.Vila 1977).

MATERIALS AND METHODS

ESTABLISHMENT OF THE PIEZOMETRIC MAP

The piezometry is a fundamental importance of the analysis and the schematization of the capacitive and conductive functions of the reservoir, as well as the hydrodynamic characteristics of the aquifer [6]. From the data obtained from the direction of hydraulics of Skikda (DHW) and the communal office of hygiene of various commune (Skikda, Hamrouch Hammoudi and Beni Béchir), we measured the piezometry of 30 points of water (wells) during the period of the low waters (September 2020) to specify the evolution of the level of water of the surface water.

These wells are located throughout the surface of the downstream part of the Saf-Saf watershed. The piezometric level was measured with the use of an electric probe. Interpretation of the piezometric map to determine the direction of flow, the main area of groundwater circulation and recharge of the water table and finally to calculate the hydraulic gradient

SAMPLE ANALYSIS

The sampling campaign carried out in September 2020 made it possible to sample 15 water points concerning only the groundwater of the surface water table. For each water point, we measured in situ the physicochemical parameters such as temperature and electrical conductivity of the water. The samples were stored in plastic bottles of 1.5L capacity and transported in a cooler at a temperature of about 4°C until they were analysed. The analysis of chemical elements (Ca^{2+}, Mg^{2+}, Na^{+}, K^{+}, Cl^{-}, SO_4^{2-} and HCO_3^{-}) was carried out at the laboratory of geology and environment at the University of Constantine 1 (Algeria). Conductivity was measured by a Hanna conductivity meter (HI 9035); pH and temperature were determined by a pH-meter E520 Metrohm Herisau.

The TH hardness and the calcium and magnesium ions are determined by the volumetric method with 5 ml of KOH and one pinch of Murexide; titrate with E.D.T.A until the carmine pink color (purple) appears [7]. Chloride ions are determined by the volumetric method with 5 ml of HNO_3 6N, 10 ml of $AgNO_3$, 1 ml of ferric alum and titrate with thiocyanate until the orange-red color appears. Carbonates are determined by the volumetric method with H2SO4 (N/50). The Piper diagram was used torepresent the hydro-chemical facies of the groundwater in the area. The chemical quality of water directly affects the yield of agricultural land and the preservation of soil, to this end and given that, thewatershed of wadi Saf-Saf is agricultural. A chemical study of water for irrigation was conducted to highlight the danger that can present certain chemical elements for plants and soil.

RESULTS AND DISCUSSION

Aquifer System Identification

It was found that the knowledge of aquifer horizons allowing the establishment of relationships between geology and groundwater. The plain of Skikda is characterized by the existence of two superimposed layers of unequal importance [8]. These two layers are separated by a resistant horizon more or less clayey. The first layer of Quaternary age is essentially constituted of finer elements (sand) with a thickness varying between 8 to 30 m [9], rests on an impermeable clayey substratum. It is in relation with the surface. The alimentation of this water table is carried out on the one hand by the abundant atmospheric precipitations of the wet season, which constitute the principal source and onthe other hand of the hydrographic network in particular the wadis of Zremna and Saf-Saf.

The deep water table of the Tertiary is a captive water table, located below the surface water table. It consists of pudding, sandstone and conglomerates [8]. The feeding of the gravelly water table is carried out from the vertical flows coming from the draining of the superficial water table in the semi- permeable areas in the south with the change of facies by clayey-sandy rock, by the effective precipitations on the zone of alimentation and by the hydrographic network such as Saf-Saf wadi and Zramna wadi [9].

Piezometry

The piezometric map of the surface water table is based on data from 30 wells located in the downstream part of the Saf-Saf watershed (Figure 02). The flow of water from the surface is generally

South-North towards the sea with some peculiarity of which the spacing of the piezometric curves increases going from South to North due to the fast flow in the South, which becomes slower in the North.
The piezometric map (Figure 02) shows that the southern part is distinguished by concentric and very tight piezometric curves. This translates a strong hydraulic gradient of 9.10^{-3} hence a low permeability. The direction of flow is generally in all directions with the appearance of an alimentation zone south of Beni Béchir.
Whereas in the northern part, the piezometric curves are spaced, indicating a low hydraulic gradient of $2.4.10^{-3}$. It is a more permeable area whose arrows showing the direction of flow are oriented towards the surface course (Wadi Saf-Saf); this indicates that the wadi drains the water table during the dry period.

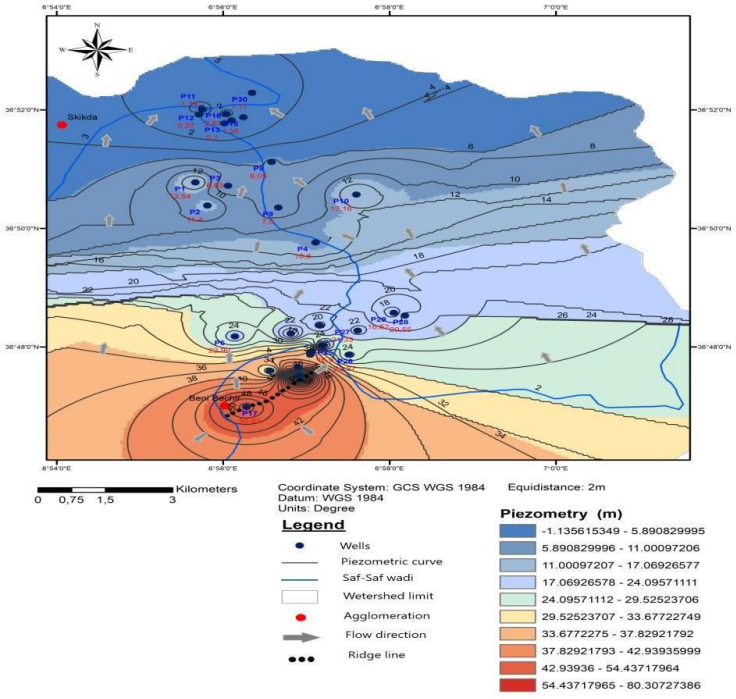

Figure 2. Piezometric map of the lower Saf-Saf valley (September 2020 period)

Sample Analysis

The qualitative study of the groundwater of the surface (Table 1) was revealed by a physicochemical analysis of the water sampled at 15 wells. It appears that the temperature of the water varied between 17°C and 25°C. According to the Algerian standards, the majority of these samples analysed have high conductivity contents ranging from 541µ/cm -5330µ/cm that reflects a strong mineralisation. It is due to the existence of certain chemical elements in high concentration (HCO3-, Cl- and Na+) caused by the dissolving of crossing soils (carbonated rock, saliferous formations, clay) or by marine invasion, notably in the Western North[10]. From a spatial point of view, the distribution of conductivities is heterogeneous, increasing with the direction of flow. The results of the chemical analyses (Table 1) show that the sodium and potassium content varies between 43.47 mg/l and 323.38 mg/l, the high values are represented by the wells (P7, P8, P1, P2) which are located in the NW. Calcium and magnesium contents vary respectively from 6.41mg/l, 154.71 mg/l and 15.36mg/l, 85.68mg/l. The
spatial distribution of these two elements shows that the high contents are located in the northern part. The chloride and bicarbonate contents vary between 23.43 mg/l, 333.7mg/l and 109.8mg/l, 695.4mg/l.

Table 1. Chemical analysis results (September 2020).

N° of Well	T °C	pH	Conductivity (µs/cm)	TAT °F	TH °F	Ca^{++} (mg/l)	Mg^{++} (mg/l)	$Na^{+}+K^{+}$ (mg/l)	$HCO3^{-}$ (mg/l)	$SO4^{-}$ (mg/l)	Cl^{-} (mg/l)	b.e.i
1	21	6,7	1924	15,7	37,6	56,11	56,52	220,34	191,54	238	319,5	-0,06
2	20	6,9	1962	18	53	74,55	82,44	189,06	291,58	242	319,5	0,09
3	19	7	2760	16,1	39,2	60,92	57,48	220,8	196,42	260	312,4	-0,09
4	22	7,4	827	28	30,8	96,19	16,2	43,47	341,6	86	23,43	-1,86
5	21	9,2	1088	30,7	8	6,41	15,36	143,06	374,54	42	28,4	-6,78
6	24	7,5	1743	26,2	46,6	97,8	53,16	171,12	319,64	193	266,2	0,01
7	24	7,3	5330	57	74,4	154,71	85,68	321,08	695,4	386	333,7	-0,49
8	22	7,4	2200	48	30,8	88,98	20,52	232,38	585,6	193	234,3	-1,13
9	25	7,8	1302	9	14,8	32,87	15,84	117,99	109,8	18,5	209,4	0,13
10	21	8,4	2690	21,5	31	58,52	39,24	283,59	262,3	270	305,3	-0,43
11	21	7,5	3180	26,1	54,8	102,6	69,96	221,26	318,42	363	276,9	-0,23
12	21	8,4	1496	12	32	60,92	40,2	80,96	146,4	140	163,3	0,23
13	22	7,6	1292	13	35	78,56	36,84	66,01	158,6	80	198,8	0,49
14	17	7,2	541	14,8	18	36,07	21,55	60,95	180,56	18,5	102,9	0,09
15	21	6,9	4330	39,1	31,4	48,1	46,56	290,03	477,02	80	333,7	-0,34

Explanations: TH: hydrotimetric degree, TAT: total alkalinity titration, b.e.i: Base Exchange index. Source: own study

The majority of the well waters analysed have a Base Exchange index (b.e.i) lower than 0, this is due to the disintegration of the crystallophyllous soils in our area. The rest of the waters have an exchange index higher than 0 because of the lithological nature of the grounds which is sedimentary (sand, sandstone and alluvium). To determine the chemical facies of the groundwater, the data from the chemical analyses of the sampling campaign during the period September 2020 were represented on the piper diagram. The representation of the water points on the triangular diagram allows to identification two main types of chemical facies:

[1] Sodium and potassium chloride waters.

[2] Sodium and potassium bicarbonate waters.

The most dominant facies is the sodium chloride with a rate of 60% of the total samples analysed, which confirms the influence of the lithology on the water chemistry [4].

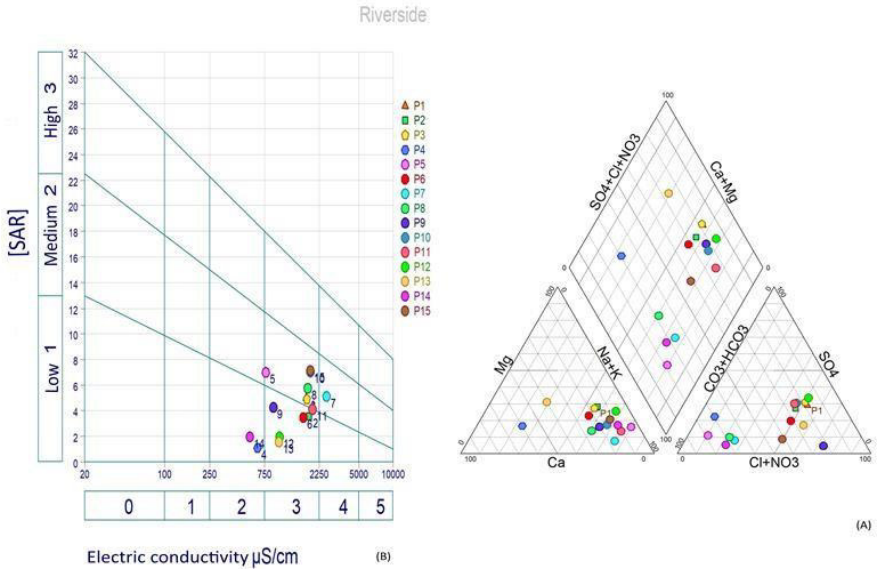

Figure 3. (A) Piper classification, (B) SAR diagram

To define the drinkability of the studied waters, we are going to base on norms that have been

established by the World Health Organization (W.H.O.), the drinkability of the waters of our studyarea is varied between very good (P4, P5, P8, P9, P1) to not potable (P2, P3, P6, P7, P10, P11, P15).
Salt-laden water can pose a risk to irrigation, and this risk is determined using the absorbable sodium value. The representation of the test samples on the Riverside diagram shows three states of use according to the classification of the water by degree of suitability for irrigation by the sodium Absorption Ration method:

- 2 samples (13.34%): in general, water that can be used without control in particular for the irrigation of plants moderately tolerant to salts on soil.
- 12 samples (80%): in general, water suitable for irrigation of salt tolerant crops on well drained soil. However, the evolution of salinity must be monitored.
- 1 sample (6.66%): highly mineralized water that may be suitable for the irrigation of certain salt-tolerant and well-drained species.

The waters of our study area generally present a medium high salinisation due to their proximity to the sea, with a low danger of alkalinisation**.**

CONCLUSIONS

This hydrogeological study deals with the downstream part of the Saf-Saf watershed, which is one of the coastal sub-basins of Constantine, central to the Algerian Northeast. The hydrogeological data have highlighted the existence of two superimposed layers of unequal importance: the first sandy surface of the quaternary, it is in relation with the surface and the other deep gravelly. These two layers are separated by a more or less clayey resistant horizon. The alimentation of this system is generally done either by the atmospheric precipitations of the wet season or by the floods of the wadis.The examination of the piezometric map shows that the Saf-Saf wadi drains the surface water table during the low water period (September 2020) with a flow direction that is generally from south to north. The hydraulic gradient decreases from south to north with a high value of 9.10-3 in the southernpart at the level of Beni Béchir, while the value is low in the north at 2.10-3. The qualitative study of groundwater shows that the most dominant chemical facies in the lower Saf-Saf valley is sodium chloride. The drinkability of these waters is not potable to very good according to WHO standards, which presents a health risk, but they are admissible for irrigation. The chemical analysis of the study area shows that the groundwater has high values of conductivity, due to the existence of certain chemical elements with high findings (HCO3-, Cl- and Na+); this excess is due to the marine invasion.

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