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Spatial variation of the water rising and water table salinity in the Basin of Ouargla (Algerian Sahara)

I. Recioui[a,b*], M. Daddi Bouhoun[b], D. Boutoutaou[a], A. Mihoub[c]

[a]*Univ. Ouargla, Lab. Exploitation and valorization of Natural Resources in Arid Zones. P.Box. 511 Ouargla 30 000, Algeria.*

[b]*Univ. Ouargla, Lab. Ecosystem Protection in Arid and Semi Arid Zones P.Box 511 Ouargla 30 000, Algeria.*

[c]*Center of Scientific and Technical Research on Arid Regions (CRSTRA). Biskra 07000, Algeria.*

Abstract

The increase of waters requirements for both the needs of drinking water supply that the needs of industries and agriculture has pushed the services concerned of the hydraulics to develop a number of drilling capturing the aquifers of terminal complex (CT) and the continental intercalary (CI). This exploitation of groundwater has proved to be excessive which has created an imbalance of the water table and subsequently this situation has led and contributes in a direct way to the water table rising in Ouargla basin.

The study shows that the problem of water rising has had serious effects on the physical degradation of soils by the congestion that it causes and the formation of gypseous crusts, compact, as well as the chemical degradation by the salinization of soils. The results of the study also show that the risk of salinity is proportional with the piezometric level of water table depth. The obtained values are too high and exceeds the authorized standards of water salinity, for instance the degree of water table salinity vary from: 2.4 g.l-1 and reaches 150 g.l-1 in some regions of Ouargla Basin.

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Keywords: water table; water rising; Salinization; Ouargla; Algeria

1. Introduction

The problems of salted soil and irrigation with salt waters are not specific to a particular region of the world. They are known in Europe (Russia, Hungary) as well as in arid area. However this issue is particularly widespread in arid and semi-arid zones and it has been studied especially in these regions. It is estimated that a third of the 12 million hectares of irrigated land in the world is affected by the problems of salinity [1].

In arid and semi-arid regions, the irrigation of salty soils requires an input of water above the cultures need. This surplus volume laundry salts and repels in depth [2].

The climatic conditions hyper-arid areas of the desert (precipitation <100 mm/year) make that irrigation is essential for agricultural development. But the evacuation of the salt waters (2-8 g.l-1) (of origin underground) after use in an endoreic system has resulted the water table rising, salinization and the hydromorphic soils, putting at risk the quality of the soil and the environment [6].

In 1996, the irrigated area in the world represents 275 million hectares, or a little less than a sixth of the cultivated land. It must be said that, under an arid climate, irrigation appears indispensable [15].

* Corresponding author. Tel.: +213-664-141-500; fax: +213-29-279-828.
E-mail address: *reciouibrahim@yahoo.fr*

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The irrigation usually causes the water rising in the soil until the congestion of the cultures root zone. The saline nature of water table, particularly in the arid and semi-arid regions of the world, causes the accumulation of salts in the root zone [10].

The consequence is obvious: each time that it uses a little salty water to irrigate, there must be at the same time ensure the associated drainage, it means that the installation of large ditches to evacuate waters in excess, and even organizing the pumping to extract the water from the soil before it goes back up in surface [7].

In Africa, nearly 40 Mha are affected by the salinization, nearly 2% of the total surface area [13]. In effect, the degree of water table salinity varies from: 6 to 7 g per liter in the Ouadi R'hir; 2.5 to 6 g per liter in the Saoura; 1.2 to 2.5 g per liter in the water of the Albian aquifer, in the Sahara; in the South Tunisian it reaches 4.7 g in Ksar Khilane, 6.2 g to Zarzis and 3 g to 4.5 g in Gabès [14, 21, 22].

The research works in Algeria show that the water rising occupy a large areas of the northern Sahara and the soil presents an accumulation of limestone and gypseous tablecloths, [3, 23, 24, 25].

The basin of Ouargla has experienced during these last years a problem of water table rising. This latter is due to the multiplication of water points, to the poor drainage of agricultural water, drainage remains little effective due to the absence of outfall [4]. The water table rising has resulted the degradation of soils and plants of the Saharan Ecosystems [17].

The rising and the salinity of water table in Ouargla, as elsewhere in the majority of the eastern regions of the low-Sahara basin, have been the subject of a good number of previous works to explain the origin, causes and the evolution of this dual phenomenon during the recent history and try to rectify [5].

The previous works show that there is a risk of soils salinization with the loaded irrigation water and the water table rising [8]. The salinity of water exceeds in majority the threshold of standard limit which is estimated to: 3 dS /m [16] the soils are considered Saline as soon as the electrical conductivity exceeds 4 ds.m-1 in (25 C°).

The salt accumulation measured in the soil is sufficient to cause a fall of outputs in palm grove. It must fold down the level of the water by a drainage and correct the dose for irrigation to leaching salts [18].

Our research work aims to study the spatial variation of the salinity and the water table rising in Ouargla Basin.

2. Materials and methods

2.1. Study Area

Our study area is located in the city of Ouargla, one of the main Oasis of Algerian Sahara. It is located in the south-east of Algeria at a distance of 750 km from the capital. It occupies an area of 163 238 km^2, it is limited:

- In the north-east by the wilaya of 'El Oued
- In the north-west by the wilaya of Djelfa
- In the south-east by the wilaya of' Illizi
- And in the west by the wilaya of Ghardaïa

Its geographical coordinates are: the longitudes 5°15' and 5°25' Is and latitudes 31°55' and 32°00' Northern [9].

The City of Ouargla is located in a depression (Basin) which includes the agglomerations of Ouargla, N'Goussa, Rouissat, Ain El Beida and Sidi Khouiled. This depression or bowl extends between the Coordinates (UTM, Clarke1880): X = 710 000; Y = 3 530 000 and X = 730 000; Y = 3 600 000. It presents a total area of the Order of 95 000 ha which spread over a length of' approximately 55 km south-west oriented / north-east [09]. It has a favorable topography upon the water stagnation [20].

The Basin of Ouargla is limited by:

- Sebkhet Safioune in the North;
- Ergs Touil and Arifdji in the East;
- The dunes of Sedrata in the South;
- The eastern slope of the backbone of the M'Zab in the West.

2.2. Climate data

Ouargla is located in a Saharan zone, its desert climate characterized by an aridity which is expressed by the irregularity and the scarcity of precipitation, permanent drought, thermal amplitudes very important and a regime of winds which is reflected by current hot and dry. We have exploited the climate data from the meteorological station of Ouargla, the period between 2004 and 2014 to characterize the climate of the region (table 01).

Table 1. Climate data of Ouargla between 2004 and 2014 [11].

months	T min (°C)	T max (°C)	T med (°C)	H (%)	V (km/h)	Insolation (h)	P (mm)	E (mm)
January	5,11	18.77	11.94	61.07	55.60	244.77	9.10	90.70
February	6.83	21.08	13.96	51.21	60.73	241.84	0.64	129.15
March	10.99	25.81	18.40	45.67	60.95	259.09	4.30	204.51
April	16.26	30.38	22.82	39.34	72.29	280.90	2.11	254.53
May	19.75	34.89	27.32	33.90	66.13	301.03	1.47	327.61
June	24.81	40.28	32.54	29.50	57.45	253.20	0.74	399.75
July	28.21	43.71	35.96	25.79	64.53	327.18	0.32	464.44
August	27.54	42.84	35.19	28.84	56.11	330.68	1.70	419.87
September	23.51	37.75	30.63	37.90	55.78	269.05	3.56	299.57
October	17.61	32.18	24.89	44.42	48.73	265.28	5.72	230.60
November	10.46	24.16	17.31	54.85	47.64	249.68	6.56	124.89
December	6.02	19.23	12.62	60.54	45.02	223.28	4.18	88.80
Average	16.34	30.92	23.63	42.75	57.58	270.50	3.37	252.87
						Cumulative	43.76	3287.29

The ombrothermic diagram of GAUSSEN (1953) was used (Fig. 1) to characterize the climate of Ouargla. The principle of this diagram of Gaussen is to place in X axis the months, In Y axis the temperatures (left) and precipitation (right) with the scale P (mm) = 2T (°C).

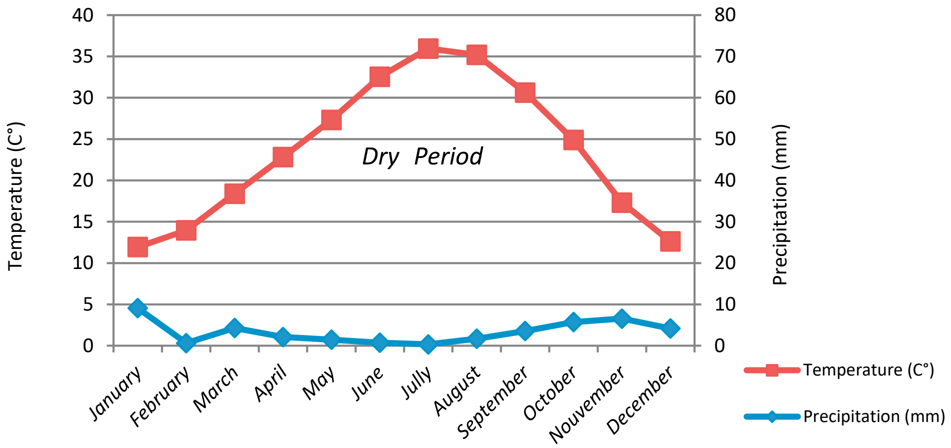

Fig. 1. Ombrothermic diagram of GAUSSEN (Ouargla 2004-2014).

The ombrothermic diagram of GAUSSEN shows that the length of the dry period at Ouargla is spread throughout the year. The Basin of Ouargla is characterized by a hydrological regime where the evaporation is (84 million m^3/year) exceeds 95 % of inflows to the Basin (88 million m^3/year). The water rising in the linked mainly to the endoreism of the bowl has been accentuated in recent years as a result of the increase in the water needs of the different sectors [12].

2.3. Methodological Approach

Our methodological approach is to measure the depth levels of the water table and the salinity of these waters from the piezometers of ANRH (National Resources Hydraulic Agency), about 32 functional piezometers**,** (Fig. 2) they are implanted at the Basin of Ouargla, our objective also is to see the spatial repartition of water table rising and its salinity which affects to the soil and causes a big degradation to their characters (Fig. 3).

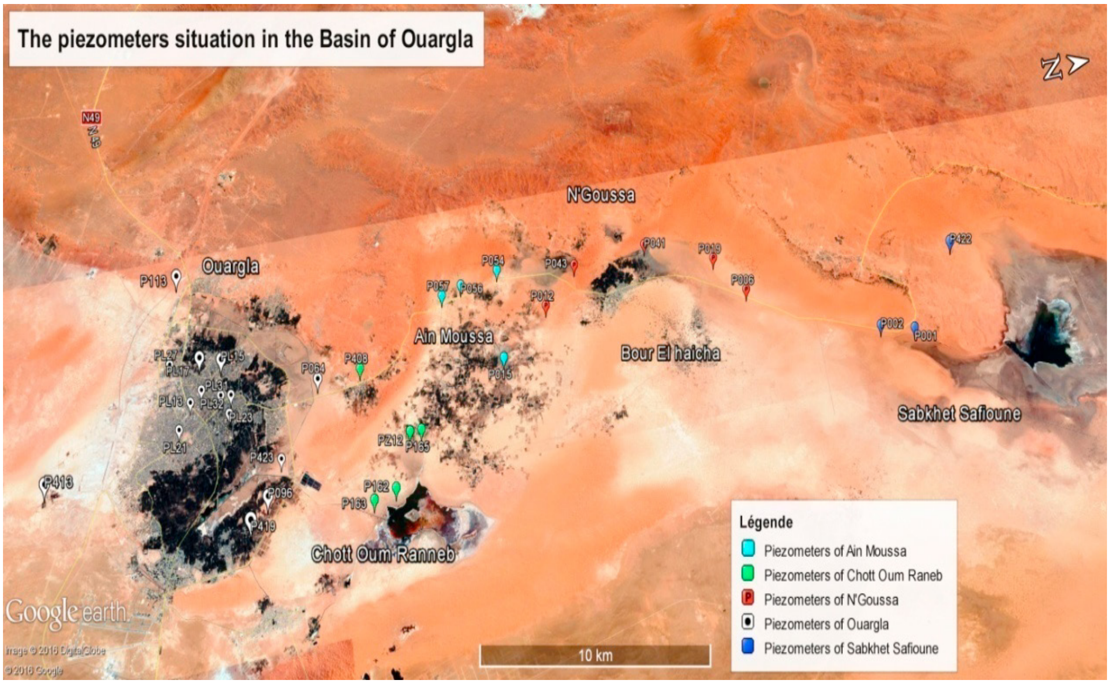

Fig. 2. Satellite view of Study site (Photo Google Earth modified).

Fig. 3. (a) Water table rising; (b) Salinity of soil in Ouargla Basin (Photos from authors 08/03/2015).

The physical parameters (pH, temperature and electrical conductivity) were determined in situ, with a multi-portable parameter. The depth of the water table has been measured with an electric sound probe.

2.3.1. Determination of pH

The pH is measured directly by using an electrode of combined pH. It consists in soaking the electrode in digging it sample, to let stabilize one moment, then to note the pH [26].
The pH meter used in our study is: WTW pH 315i.

2.3.2. Measurement of conductivity

For the determination of conductivity, it's used a multi-element conductivity meter. It is given after rinsing the electrode several times; initially with distilled water then while plunging it in a container containing of water to examine; to make the measurement by taking care that the electrode is completely immersed. The result of conductivity is given directly in µS/cm. The result of the salinity and the dissolved salt rate (TDS) are given respectively in ‰ and mg/l [26].

The conductivity meter type used in our study is: HACH CO150.

2.3.3. Water Table Depth Determination

We used an electric probe to determine the piezometric level of the water table.

3. Results and discussion

The following table represents the obtained results (depth level of the water table, the electrical conductivity, the hydrogen potential and the temperature knowing that the measurement of the samples are taken during the period of February and March 2015.

Table. 2. Data of studied parameters.

Piezometers	X	Y	Depth (m)	pH	T°(in situ)	EC in situ (ms/cm)	CE ms/cm in 25 C°	Salinity (g/l)
P001	722321	3572465	1.64	6.6	19.5	137.1	154,65	117,85
P002	721962	3570826	2.19	6.8	19.2	88.3	100,31	76,44
P006	719365	3564579	2,15	7,68	19,4	20,1	22,73	17,32
P012	718556	3554396	1,7	7,58	18,8	117,2	134,43	102,44
P015	720535	3552018	1,95	8,06	18,27	18,27	21,19	16,15
P019	717663	3563267	1,86	7,46	19	67,4	76,90	58,60
P041	716487	3559870	1,12	7,62	18,3	38,8	45,01	34,30
P043	716904	3556108	1,63	7,52	19,2	134,2	152,45	116,17
P054	716536	3552141	3,67	7,88	22,2	4,88	5,18	3,52
P056	716966	3550240	4,57	7,55	22,8	6,49	6,80	4,62
P057	717297	3549250	4,39	7,58	24,1	6,7	6,83	4,64
P064	720162	3542942	1,58	7,2	17,02	169	202,12	154,73
P096	724673	3540572	1,32	7,54	15,8	108,6	133,69	102,34
P113	714520	3535893	4,34	7,24	21,9	79,5	84,99	65,06
P162	725073	3546440	1,59	7.2	18,7	166,6	191,42	146,54
P163	725372	3545418	1,82	6,52	18,7	165,4	190,04	145,48
PZ12	722931	3547234	1,37	7,08	16,1	62,03	75,80	58,03
P165	722932	3547773	1,34	7,62	16,7	103,3	124,48	95,29
P408(puits)	719930	3544999	4,49	7,52	16,09	6,21	7,59	5,16
P413(puits)	722632	3530332	1,27	7,56	15,6	11,47	14,54	11,08
P419 bis	725549	3539801	0,93	7,51	15,6	14,8	18,77	14,30
P422	718819	3575646	6,55	7,87	19,6	3,15	3,55	2,41
P423	723122	3541188	2,31	7.23	19,4	157.8	178,47	136,00
PL10	719690	3537362	2,52	6,97	22	5,24	5,59	3,80
PL13	720144	3536857	1,36	7,25	21,9	5,77	6,17	4,19
PL15	718688	3538269	5,56	7,12	21,1	3,97	4,32	2,94
PL17	718455	3537215	1,75	7	19,4	11,52	13,03	9,93
PL21	721212	3536381	2,09	7,31	21,9	10,97	11,73	8,94
PL23	720894	3538726	2,51	5,95	21,6	9,86	10,61	7,21
PL27	718351	3535781	5,43	6,75	23,9	57,5	58,88	44,87
PL31	720058	3538295	2,19	7,39	23	4,61	4,81	3,27
PL32	720114	3538785	2,59	6,73	23,8	8,86	9,09	6,18

To determine the mineralization corresponds to the totality of the dissolved salts contained in the water we have use the following mathematical relation [19] :

Mineralization (g/l) = Conductivity fx (*) (µs/cm) in 20 C°; (1)
With: f = 0.850432 if (*) between 833 and 10000 (µs/cm)
f = 0.758544 if (*) greater than 10 000 (µs/cm).
With (*) x 1.116 for 25 C°. (2)

3.1. Precedent Piezometry of the water table

Piezometric data collected from water table shows a variation in level from 2 m until the outcropping in the center of the basin of Ouargla where the water levels have risen about 50 cm between 1959 and 1996 [27,28].

The piezometric Cards established about the basin, by the *ENAGEO, BG* and the *ANRH* (campaign 94 and the recent campaigns 2003, 2004, 2009, and 2011) clearly show that there are two distinct zones separated by a line of sharing the waters at the level of the Hassi Miloud and Bour El Haîcha, which is reflected by two flows, the a toward the north (toward Sebkhet Safione) and the other toward the West (Sebkhet Bamendil). The water is present everywhere in the scale of the region. Its thickness varies from 1 to 8m and is based on a level sealed waterproof, which occupies the entire bottom of the valley of Ouargla. Its capillary fringe arisen often on the soil surface in form of Chotts. It is relatively deep in the points of high topography (Ergs), and less deep in the areas close to the irrigated palm groves.

3.2. Current Piezometry of the water table

In order to better know the evolution of this water rising, how and in what sense made this evolution, we have made a Companion of measurement on all functional piezometers of the Basin of Ouargla. We have used the Surfer software. Version: (9.11.947 – August 25 2010) to establish piezometric cards (Fig. 4).

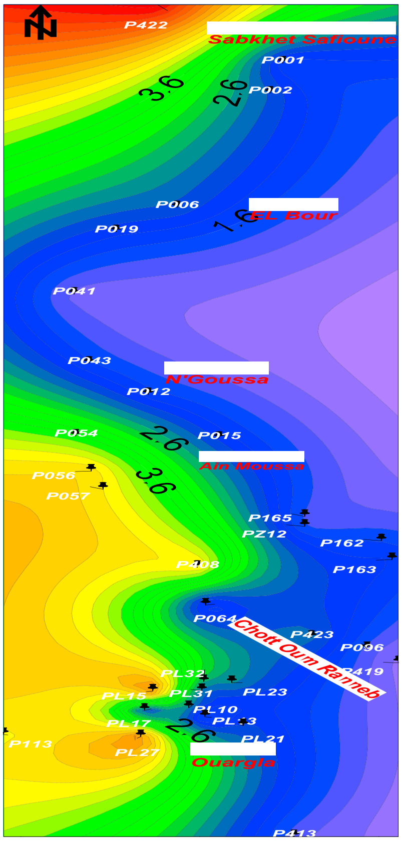

Fig. 4. Piezometric level of the water table (February 2015).

The areas in which the water table is the most profound are located to northwest of Ouargla basin, southwest of' Oum Raneb, in the region of Bour El Haïcha, in the hills of Onk Djemel and in the slopes to the northwest of

N'Goussa. These areas where the water is deep don't correspond to the depressions of the piezometric level, but at the highest topography points (in the natural conditions). The areas in which the water table is less profound are located in the vicinity of irrigated palm groves (Ouargla and N'Goussa) or area of water rejection (in the vicinity of Chott Oum Raneb). The areas where the water is less profound are located in points of bottom topography. They form an alignment since the perimeter of Ouargla up to Sebkhet Safioune. The point where the water is located closest to the surface of water table is located in Sebkhet Safioune. In the agglomeration of Ouargla, the average depth of the water table is about 2 m. In the north palm grove, the depth of water table is less than 1 m, while in the abandoned palm groves, or in the outskirts of it, we found water to less than 0.5 m of the surface of the ground. At the level of the Chott and Sebkhet Bamendil, the water is between 0.5 and 1 m.

3.3. The salinity of the water table

In order to know the spacial distribution of this salinity, we are measured the electric conductivity of the 32 samples in situ with a conductivity meter HACH CO150.

After the measurement we are used the Surfer software (version 9.11.947) to make the spatialization of water table salinity and show the difference between its values in Ouargla Basin (Fig. 5).

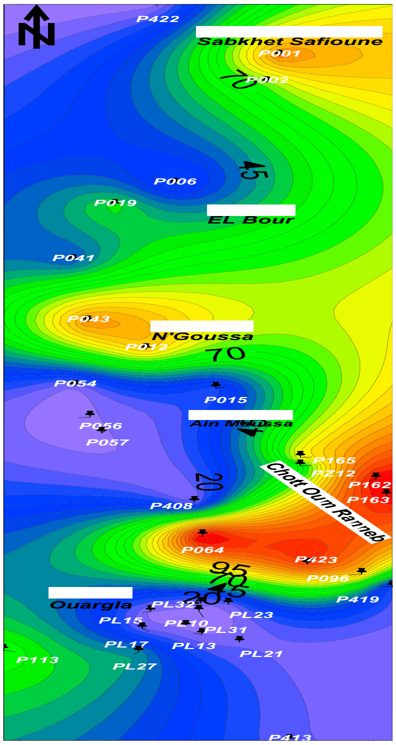

Fig. 5. The water table salinity of the Basin of Ouargla.

The obtained results shows that the salinity of the water table is linked to the lithological nature of aquifer formation (evaporate and carbonates) and the climate of our study area; characterized by precipitation insignificant (<50 mm/year) and high temperatures.

Larger values of the salinity are found in the piezometers, P064, P162 and P163, which are: 154.73, 146.54 and 145.48 g.1^{-}, respectively.

The minimum values are obtained in the piezometers: P422, PL15, PL31, PL054 and PL10 with: 2.41, 2.94, 3.27, 5, 3.52, 3.80 g.l^{-1}.

The rest of obtained results of water table salinity in Ouargla Basin varied between: 4 and 136 g.l^{-1}.

Conclusion

In conclusion we can say that the piezometric depth of the water table of Ouargla Basin undergoes to a drawdown relatively appreciable in comparisons to previous years, but the risk remains always especially in areas of the palm grove where there is an overexploitation of deep aquifer which contribute the refill of the water table. On the other hand and according to obtained results we found that the risk of water salinity has variable values from point to another and this is according to the static level of water table. More than the piezometric level is close to the surface of soil, we found that the salinity increase especially in areas where there are Sebkhas or swamps. Thus it is noticed that there is proportional relationship between the water rising and the water table salinity in Ouargla Basin and the study of the spatial distribution of salinity shows that the lower areas in the Basin have very high mineralization.

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