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Hydrochemical assessment of water quality for irrigation: A case study of the wetland complex of Guerbes-Sanhadja, North-East of Algeria

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Abstract

The wetland complex of Guerbes-Sanhadja (north-eastern Algeria), has experienced in recent years a certain economic expansion, particularly agricultural, about 47% of the useful agricultural area marked by several varieties of crops ranging from market gardening to speculative crops, requiring large quantities of water for irrigation purposes, however the swampy areas are the main sources used for irrigation purposes in this practice. It is therefore necessary for this water to have physicochemical properties adapted to plants, in particular the absence of salinity. This study was done to evaluate the status of the swamps areas quality and its suitability for irrigated agriculture. To achieve this objective, water samples from ten swamps areas water were collected from Guerbes-Sanhadja in February and June of 2016. The water quality of these swamps was estimated from different water quality parameters such as pH and electrical conductivity (*EC*), the chemical parameters like Na^+, K^+, Ca^{2+}, HCO_3^-, SO_4^{2-}, Cl^-, BOD_5, NO_3^-, NO_2^-, NH_4^+ and PO_4^{3-}. Based on the physico-chemical analyses, irrigation quality parameters like sodium absorption ratio (*SAR*), percent sodium (% Na), residual sodium carbonate (*RSC*), permeability index (*PI*), magnesium hazard (*MH*) were calculated. The results showed that the overall concentration of nitrate was very high. About 60 percent of the swampy areas had suitable water quality for chloride, and they had a concentration below the permissible limit for crop irrigation. From the Richards diagram, it is observed that most of the samples from the study area fall in the good to permissible classes for irrigation purpose.

Key words: *Algeria, irrigation, residual sodium carbonate (RSC), sodium absorption ratio (SAR), water quality, wetland complex of Guerbes-Sanhadja*

INTRODUCTION

The supply of irrigation water in the complex is a determining factor in agricultural production. However, the development of irrigated agriculture can pose a threat to the environment because of the resulting multiple soil degradation (salinization, sodisation and alkalinisation).

Most of problems come from the typology of irrigation water, land use characteristics, water resources management, and cropping or irrigation systems. Good management practices reduce the environmental risks of agriculture. These farming practices take into account current knowledge of soil and water conservation without sacrificing productivity [HADJ-SAID 2007].

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The agricultural region of Guerbes-Sanhadja is used for the cultivation of several crop varieties, requiring large quantities of irrigation water [BOUSSEHABA 2010]. The agriculture is characterized by a wide variety of industrial crops (4370 ha), vegetables (3280 ha), grain (1750 ha) and forage (360 ha) [HEDJAL *et al*. 2016].

In complex of Guerbes-Sanhadja wetlands, waters of swamps are considered as the main water source used for irrigation purpose [BOUDINAR 2009], these waters can affect the physicochemical properties of soils; the most important from the point of view of plant growth is soil salinity.

Excessive amounts of dissolved ions in irrigation water affect plants and agricultural soil, both physically and chemically, reducing productivity [DAIFALLAH 2009]. The physical effects of these ions are to lower the osmotic pressure in the structural cells of the plant, thus preventing water from reaching the branches and leaves. The chemical effects disrupt plant metabolism [KAKA *et al.* 2011]. Water quality problems in irrigation include the salinity, chlorite, alkalinity indices of sodicity [DAIFALLAH 2009].

Geochemistry and adequacy of water of wetlands Guerbes-Sanhadja for irrigation purposes have not been studied in detail. Since the Sanhadja wetlands are used for irrigation, current studies seek to discern the hydrochemistry of this water and classify the water to assess its suitability for irrigation.

STUDY AREA

The Guerbes-Sanhadja wetlands complex covers the eastern coastal area of the Skikda Wilaya. This complex is located downstream of the Wadi El-Kebir West basin, thusco vering most of the surface of the wetlands is about 230 km^2 of the basin Wadi El-Kebir West. It is limited by the massive Edough in the North-East, by the massive Filfila in the North-West, by the Mediterranean Sea to the North, by the massive Boumaiza in the Southeast and by Djebel Safia in the South-West (Fig.1).

According to KHAMMAR [1980], HADJ-SAID [2007] and HEDJAL [2015] the region consists of, two superimposed aquifers (shallow and deep). The shallow groundwater aquifers are represented by a sandy formation overcoming a deep groundwater contained in the alluvial deposits separated by a semi-permeable layer in some areas of which whole system is based on a substratum consisting of Numidian formations characterised by an alternation of clays and marl (Fig. 2).

Concerning the topography, the study area is characterized by the different (plains, hills, mountains). The altitude an average of 10 m, in the centre of the region and cumulates at 561 m in the North-West, 48.5% of the land has a slope less than or equal to 3% and the rest at 12.5% [BOUSSEHABA 2010; HEDJAL *et al.* 2016; METLLAOUI 2010].

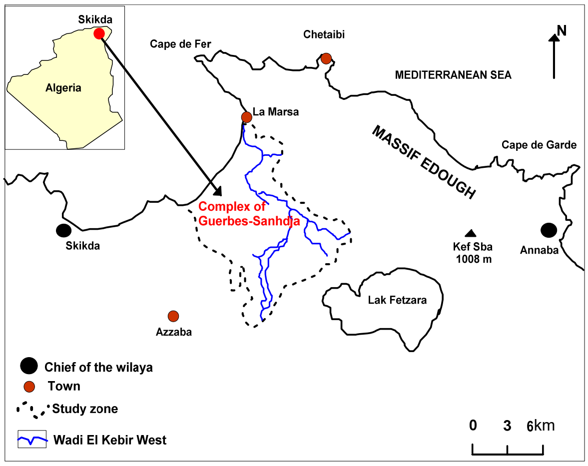

Fig. 1. Situation map of the study area; source: TOUBAL *et al*. [2014], modified by HEDJAL *et al.* [2017]

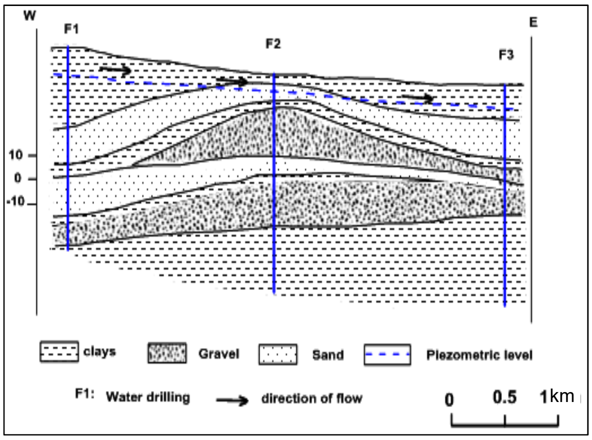

Fig. 2. Hydrogeological cross-section through the study area; source: own study

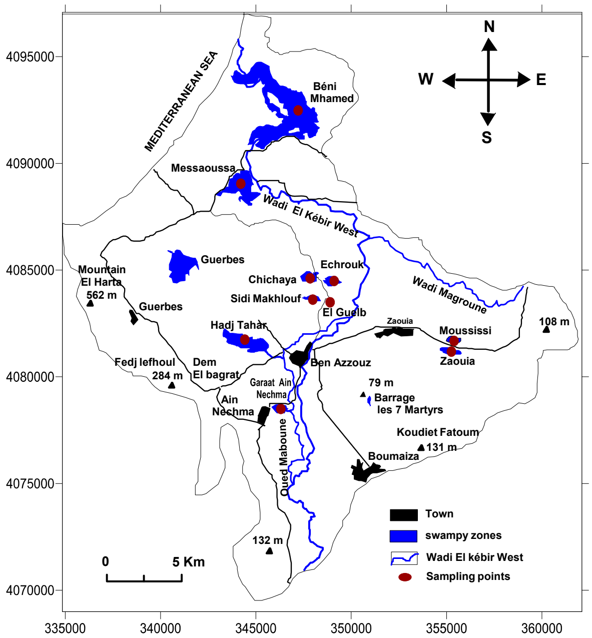

Fig. 3. Map inventory of water points in the region; source: own elaboration

The complex of Guerbes-Sanhadja wetlands with its Mediterranean climate receives high annual average rainfall of 725 mm. It is subject to an annual average temperature of about 18°C and an average potential evapotranspiration of 450 mm [HEDJAL 2015].

MATERIALS AND METHODS

The work consists of evaluating the water quality of wetlands used for irrigation of a 10 water points that represent Guerbes-Sanhadja region. The samples of water taken have been from a low water period in June 2016 and a high period in February 2016.

The coordinates of the various water points were taken using a Global Positioning System (GPS) type Garmin wap (62 stc 79946) (Fig. 3).

The water samples taken were kept in polyethylene bottles previously washed with distilled water and then rinsed with the water to be analysed and transported to the laboratory the same day for analysis.

The water samples have been analysed at the Central ADE Laboratory of the city Skikda for the following parameters:
– physical parameters (pH, electrical conductivity);
– cations (Ca^{2+}, Mg^{2+}, K^+, Na^+ and NH_4^+);
– anions (HCO_3^-, SO_4^{2-}, Cl^- and CO_3^-);
– pollution indicators (BOD_5, NO_3^-, NO_2^-, PO_4^{3-}).

The geochemical characterization focused on the measurement, in situ, the physical parameters of the water using a multi parameter meter of the Consort type C 65. These parameters concerned potential of hydrogen (pH) and electrical conductivity (*EC*).

The nutrients (nitrates, nitrite, ammonia and phosphates) were determined by spectrophotometry using a HACH-ODYSSEY Tayland spectrophotometer, BOD_5 was measured by incubation of the water sample in the presence of a solution of phosphate and allylthiourea in darkness at 20°C.

Concerning the major elements, the chloride contents were determined by the Mohr method under neutral conditions using a standard solution of silver nitrate in the presence of potassium chromate [RODIER 1982]. Bicarbonate, calcium and magnesium have been affected by titrimetry (colorimetric method). Sodium and potassium are determined by atomic absorption spectrophotometer.

The aptitude of water for irrigation can be judged not only from the total salt concentration but also by from the type of salt and the ions which constitute it [AYERS, WESTCOT 1985; ROUABHIA, DJABRI 2010]. It is therefore imperative to study the parameters that define the characteristics of water destined for irrigation. Among these parameters: sodium adsorption (*SAR*), sodium percentage (% Na), residual sodium carbonates (*RSC*), magnesium hazard (*MH*) and the permeability index (*PI*).

To understand the evidence of evolution of the global organic pollution of the waters, the organic pollution index (*OPI*) [BENRABAH *et al*. 2006] was calculated. The *OPI* was developed by spreading the values of pollutants (BOD_5, ammonium, nitrites and phosphates) into five classes (Tab. 1). Following these analyses, we determined the class of analysed pollutants, which were then used to calculate the average of the number of classes (*OPI*) of four properties according to the grid evaluation (Tab. 2).

Table 1. Interval of organic pollution indices classes

Class	BOD_5 mg $O_2 \cdot dm^{-3}$	NH_4^+ mg $N \cdot dm^{-3}$	NO_2^- μg $N \cdot dm^{-3}$	PO_4^{3-} μg $P \cdot dm^{-3}$
5	<2	<0.1	<5	<15
4	2–5	0.1–0.9	6–10	16–75
3	5.1–10	1–2.4	11–50	76–250
2	10.1–15	2.5–6	51–150	251–900
1	>15	>6	>150	>900

Source: BENRABAH *et al*. [2006].

Table 2. Grid evaluation of organic pollution types

Organic pollution level	Limit of class
None	5.0–4.6
Weak	4.5–4.0
Moderate	3.9–3.0
Strong	2.9–2.0
Very strong	1.9–1.0

Source: BENRABAH *et al*. [2006].

The parameters evaluated to determine the quality for irrigation are shown in the table below (Tab. 3). The adequacy of the samples was analysed on the basis of results obtained and the indices evaluated; compare the values obtained with the classification as suggested by different authors.

RESULTS AND DISCUSSION

Table 3 presents the statistical parameters of the different factors intervened in water quality for irrigation.

Potential of hydrogen (pH) influences the form and availability of nutrients in irrigation water. The pH value in this case should be between 6.5 and 8.4 [AYERS, WESTCOT 1985]. With these values, the solubility of most microelements is optimal.

Figure 4 shows that the pH is slightly alkaline during the low water period, returning to the neutrality during high water period which can be caused by biological activity. In general, these waters are in the recommended standard for irrigation, with a pH between 6.5 and 8.4. With the exception of the swamp Chychaya which exceeds the norm with a value of about 8.55 during low water period.

The electrical conductivity. The concentration of total salt content in irrigation waters, estimated in terms of *EC* [ALSHEIKH 2015; RODIER 2009]. It is the most important parameter in determining the suitability of water for irrigation use [GUASMI *et al*. 2013]. In order to have an idea about the electrical conductivity variation through the swampy areas, a plot of spatial evolution has been drawn in (Fig. 5).

Table 3. Minimum, maximum, means and standard deviations (*SD*) of calculated parameters in low-water period (June 2016) and a high water period (February 2016)

Month	Statistics	pH	*EC* µS·cm^{-1}	NO_3^- mg·dm^{-3}	Cl^-	*SAR*	*RSC*	Na	*PI*	*MH*	*OPI*
					meq·dm^{-3}			%			
February	max	7.71	2 243.00	33.00	23.00	1.41	1.10	42.94	73.33	94.49	1.75
	min	6.73	223.00	11.00	0.40	0.12	–49.39	2.49	6.39	33.33	4.75
	mean	7.21	673.90	21.82	4.50	0.57	–21.84	11.46	19.36	80.21	3.58
	SD	0.31	589.81	7.24	6.78	0.37	12.66	11.37	19.33	17.78	0.79
June	max	8.55	4 590.00	23.10	28.00	0.78	–1.68	24.21	53.36	91.81	3.75
	min	6.99	279.00	8.30	1.20	0.33	–49.39	7.68	11.49	35.00	2.50
	mean	7.86	972.10	15.39	5.27	0.59	–18.53	12.48	20.93	80.97	3.05
	SD	0.56	1 300.63	4.30	8.59	0.15	12.34	4.96	11.90	16.68	0.40

Explanations: *EC* = electrical conductivity, *SAR* = sodium absorption ratio, *RSC* = residual sodium carbonate, *PI* = permeability index, *MH* = magnesium hazard, *OPI* = organic pollution index.
Source: own study.

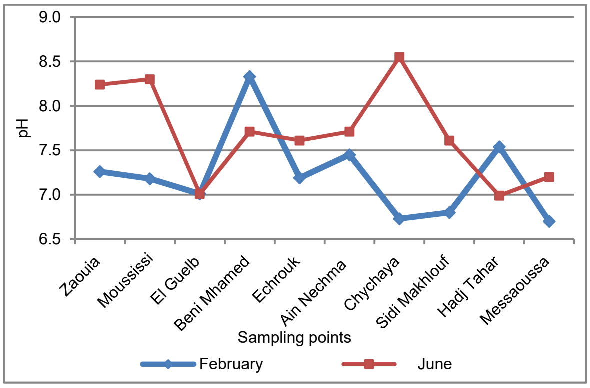

Fig. 4. pH variation of the water in the swampy area of Guerbes-Sanhadja; source: own study

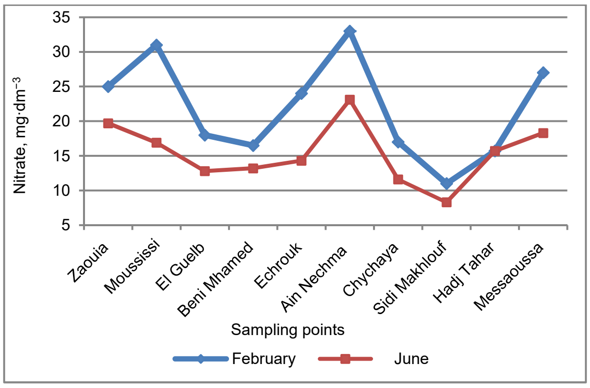

Fig. 7. Spatial evolutions of nitrates in the study area; source: own study

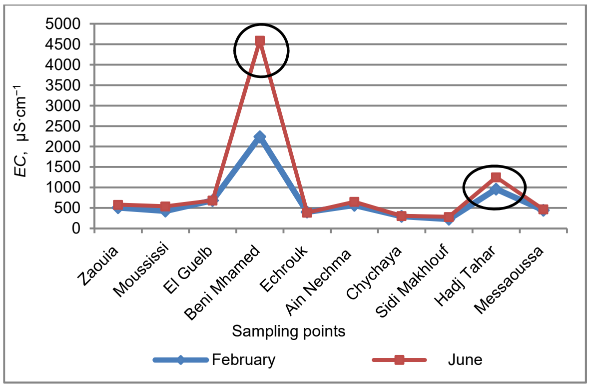

Fig. 5. Variation of the electrical conductivity (*EC*) in the study area; source: own study

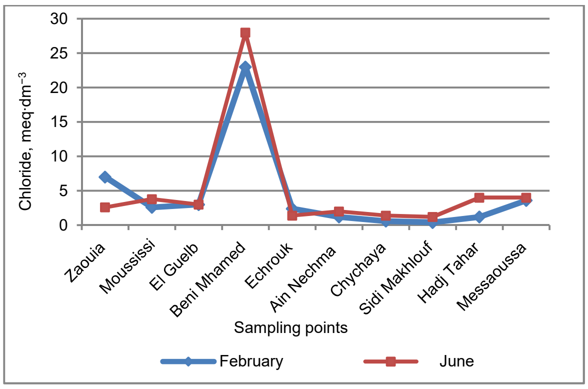

Fig. 6.Variation of the chloride in the study area; source: own study

The values of electrical conductivity ranging between 223 and 2243 µS·cm^{-1} and from 279 to 4590 µS·cm^{-1} during the high and low-water periods, respectively (Fig. 5). These differences are due to rainy contributions which dilute the concentrations.

Chlorides. The origin of this element is mainly related to the dissolution of salt-bearing minerals [ATTOUI *et al.* 2016]. To highlight the water quality of swampy areas, the following classification [BOUAROUDJ, KADEM 2014; GUASMI *et al.* 2013] was used:
$Cl^- < 4$ meq·dm^{-3} non toxicity,
$4 < Cl^- < 10$ meq·dm^{-3} moderate toxicity,
$Cl^- > 10$ meq·dm^{-3} severe toxicity.

The Figure 6 shows that during high and low-water periods the waters of points are from moderate to severe toxicity and therefore are not suitable for irrigation at Zaouia, Hadj Tahar, Messaoussa and Beni Mhamed.

The most common toxicity of chloride in irrigation water of these swamps is due to that chloride is not adsorbed or held back by soils; therefore it moves with the soil-water, which is taken up by the crops, moves and accumulates in the leaves.

Nitrates are present in highly soluble forms [GUASMI *et al.* 2013]. Their presence is associated with intensive use of chemical fertilizers [BENRABAH *et al.* 2016]. In this form, nitrogen is a nutrient salt used by most plants [BENRABAH 2013].

Sensitive crops may be affected by nitrogen concentrations above 5 mg·dm^{-3}. Most other crops are

relatively unaffected until nitrogen exceeds 30 mg·dm^{-3} [AYERS, WESTOT 1985]. To evaluate the toxicity of waters of swampy areas, we used the following classification [BOUAROUDJ, KADEM 2014]:
$NO_3^- < 5$ mg·dm^{-3} non toxicity,
$5 < NO_3^- < 30$ mg·dm^{-3} moderate toxicity,
$NO_3^- > 30$ mg·dm^{-3} severe toxicity.

The Figure 7 shows the values of nitrates ranging between 11 and 33 mg·dm^{-3} and from 8.30 to 23.10 mg·dm^{-3} during the high and low-water periods, respectively. This progressive increase in the concentration of this element and most remarkable at the level of Guerbes-Sanhadja plain essentially due to several factors (leaching from agricultural land, the use of fertilizers, leakage of wastewater collection networks) [DAIFALLAH 2009; HEDJAL 2015].

We can conclude that nitrate levels recorded in the swampy areas waters are from moderate to severe toxicity and therefore are not suitable for irrigation.

Organic pollution index. The map clearly shows than during high water period that pollution varies depending on the localities from none to very strong (see Fig. 8a). High values are localized at the waste discharges (sewage, septic tanks) at Ain Nechma, Chychaya and Echrouk sampling sites. For the other stations, it is due to the contribution of agricultural activities (use of fertilizers and pesticides) and leaching of the agricultural lands. During low-water period (Fig. 8b), the waters of the swamp areas reveal relatively low to moderate pollution due to the dilution by an additional flow of the Wadi El-Kebir West and its tributaries.

Overall, high concentrations of nutrients (nitrite, ammonia and phosphates) are generally indication of the organic pollution associated with eutrophication condition. Moreover, domestic effluents particularly which contain detergents, fertilizer runoff, and wastewater are the main reasons of high organic pollution levels in surface water such as wetlands areas of Guerbes-Sanhadja [HEDJAL 2015].

The high concentration of organic pollution index makes the water unsuitable for irrigation uses.

Residual sodium carbonate (*RSC*). The quantity of bicarbonate and carbonate in excess of alkaline earths (Ca^{2+}+ Mg^{2+}) also influences the suitability of water for irrigation purposes.

When the sum of carbonates and bicarbonates is in excess of calcium and magnesium, the carbonates and bicarbonates are precipitated to the equivalent quantity of Ca and Mg; the excess of carbonates and bicarbonates will then react with Na to appear as *RSC* [GOUAIDIA *et al.* 2013; RICHARDS (ed.) 1954]. This approach is based on the equation [EATON 1950]:

$$RSC = (CO_3^- + HCO_3^-) - (Ca^{2+} + Mg^{+2}) \text{ meq·dm}^{-3} \quad (1)$$

A high value of *RSC* in water leads to an increase in the adsorption of sodium in soil [EATON 1950]. If *RSC* exceeds 2.5 meq·dm^{-3}, the water is generally unsuitable for irrigation. If the value of *RSC* is between 1.25 and 2.5 meq·dm^{-3}, the water is marginally suitable, while a value less than 1.25 meq·dm^{-3} dictates safe water quality [GUASMI *et al.* 2013].

The Figure 9 shows values below 1.25 meq·dm^{-3} are observed for all swamp areas waters and for both companions' samples. On the basis of the *RSC*, waters are safe to irrigation use.

Permeability index (*PI*). The soil permeability is affected by long-term use of irrigation water. The sodium, calcium, magnesium and bicarbonate contents of the soil influence the permeability through changing soil physical and chemical properties.

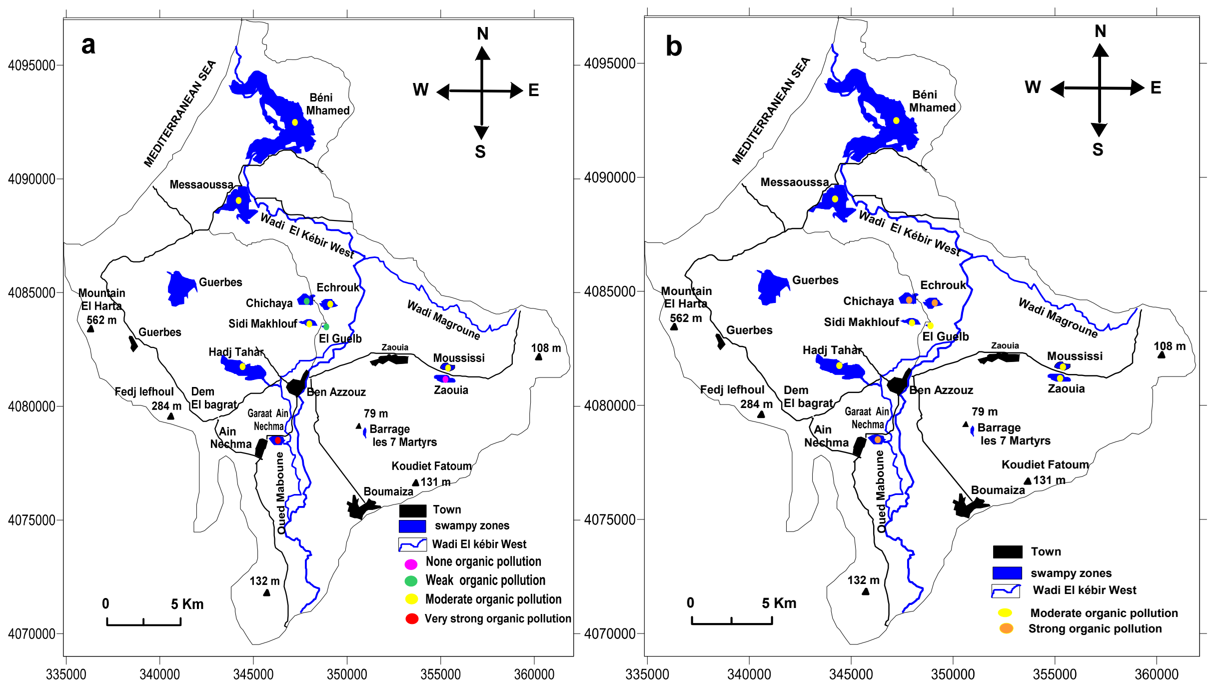

Fig. 8. Organic pollution index (*OPI*) map of Guerbes-Sanhadja swamp waters: a) in February 2016; b) in June 2016; source: own study

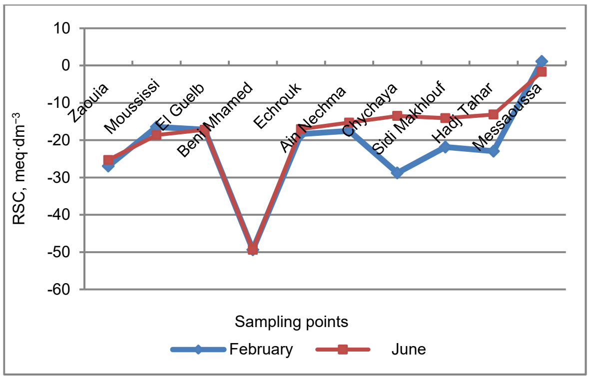

Fig. 9. Spatial variation of *RSC* values of swamp areas of Guerbes-Sanhadja; source: own study

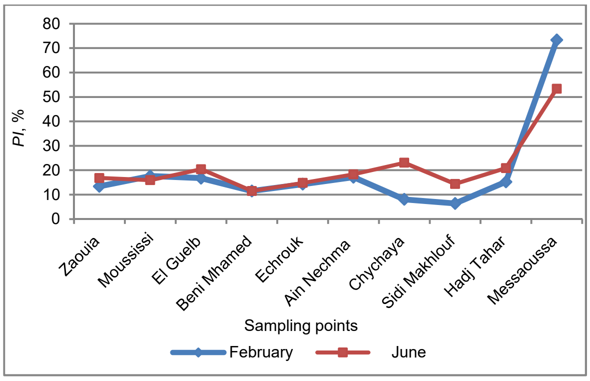

Fig. 10. Spatial variation of permeability index (*PI*) values of swamp areas of Guerbes-Sanhadja; source: own study

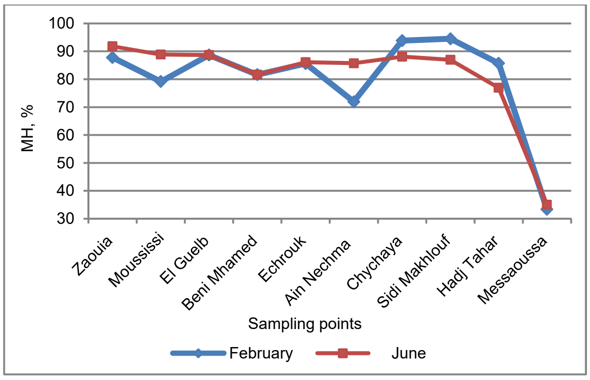

Fig. 11. Spatial variation of magnesium hazard (*MH*) values; source: own study

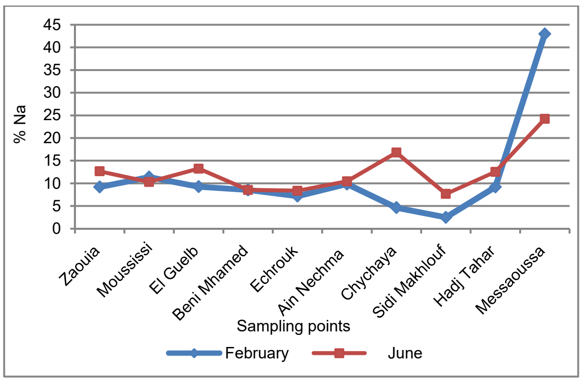

Fig. 12. Spatial variation of % Na values; source: own study

DONEEN [1964], classified irrigation waters based on the permeability index (*PI)* where:

$$PI = \frac{\mathrm{Na} + \sqrt{\mathrm{HCO_3}}}{\mathrm{Ca + Mg + Na}} \, 100\% \qquad (2)$$

The *PI* values >75% indicate excellent quality of water for irrigation. If the *PI* values are between 25 and 75%, they indicate good quality of water for irrigation. However, if the *PI* values are less than 25%, they reflect unsuitable nature of water for irrigation [HADJI *et al*. 2013; VENKATESWARANA *et al*. 2015].

According to the Figure 10, 90% of the surface water samples collected during the study period record *PI* < 25%, indicating the bad quality of the water for irrigation purpose.

Magnesium hazard (*MH*) present in water would adversely affect the soil quality rendering it unfit for cultivation. Magnesium ion concentration plays an important role in soils productivity, so that it is used to determine whether the water is suitable for irrigation or not. If magnesium hazard was less than 50, then the water was safe and suitable for irrigation. While *MH* value >50% makes it unsuitable [LLOYD, HEATHCOAT 1985]. This ratio proposed by [SZABOLCS, DARAB 1964] is as below:

$$MH = \frac{\mathrm{Mg^{2+}}}{\mathrm{Ca^{2+} + Mg^{2+}}} \, 100\% \qquad (3)$$

In the Guerbes-Sanhadja area, the magnesium hazard (*MH*) values were reported to be in the range of 33.33 to 94.81% (Fig. 11). Whose 90% of swamps areas of Guerbes-Sanhadja showed magnesium index value more than 50%, making waters unsuitable for irrigation purpose. High concentration of magnesium is attributed to dolomite and dolomitic limestones in the Guerbes-Sanhadja wetland [HEDJAL 2015].

Percent sodium (% Na) in water is a parameter computed to evaluate the suitability for irrigation [WILCOX 1948]. The percentage of Na can be calculated by the following relation:

$$Na = \frac{\mathrm{Na^{+}}}{\mathrm{Mg^{2+} + Ca^{2+} + K^{+} + Na^{+}}} \, 100\% \qquad (4)$$

According the classification of swamps areas samples with respect to percent sodium (Fig. 12, Tab. 4) varied from 2.49 to 42.94% during high water period and from 7.68 to 24.21% during low water period. Therefore, according to percent sodium, waters are, generally, suitable for irrigation practices during the two sampling periods.

Sodicity index. Sodium absorption ratio (*SAR*) is considered as a better measure of sodium (alkali) hazard in irrigation water as it is directly related to the adsorption of sodium on soil and is a valuable criterion for determining the suitability of the water for irrigation. Excessive sodium contents relative to the calcium and magnesium reduce the soil permeability and thus inhibit the supply of water needed for the crops [TODD 1980]. The *SAR* is used to predict the sodium hazard of high carbonate waters especially if they contain no residual alkali. The excess sodium or lim-

Table 4. Sodium percent water class acc. to WILCOX [1948] in study sites

Na %	Water class	Study site	
		February	June
<20	excellent	Zaouia, Moussissi, El Guelb, Ain Nechma, Sidi Makhlouf, Chychaya, Echrouk, Hadj Tahar, Béni Mhamed	Zaouia, Moussissi, El Guelb, Ain Nechma, Sidi Makhlouf, Chychaya, Echrouk, Hadj Tahar, Béni Mhamed
20–40	good		Messaoussa
40–60	permissible	Messaoussa	
60–80	doubtful		
>80	unsuitable		

Source: own study.

ited calcium and magnesium are evaluated by *SAR*, which is computed as:

$$SAR = \frac{Na^{+}}{\sqrt{\frac{Ca^{2+} + Mg^{2+}}{2}}} \quad (5)$$

Where: *SAR*, Na^{+}, Ca^{2+} and Mg^{2+} are in meq·dm^{-3}.

According to AYERS and WESTCOT [1985], the *SAR* value of all the samples are found to be less than 3 meq·dm^{-3} (Tab. 3, Fig. 13) and are classified as excellent for irrigation for the two sampling periods.

Hazard salinity. The salinity may cause adverse effects to plants due to sodium and chlorides. The sodium then exerts a deleterious effect on vegetation indirectly by degrading the physical properties of soil. Under this action, the soils become compact and asphyxiating for plants [TODD 1980]. When the concentration of Na^{+} ions in the soluble state in the soil is high, these ions frequently replace the Ca^{2+} cations in the absorbent complex.

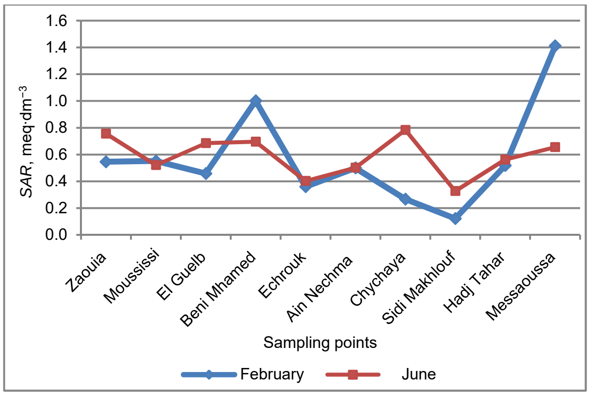

Fig. 13. Sodicity index (*SAR*) for the swamp areas of Guerbes-Sanhadja; source: own study

The risk is determined from the adsorbed sodium values (sodium adsorption ratio *SAR*), for a given electrical conductivity.

According to the Figure 14, data from the study area are plotted on *SAR* versus *EC* diagram (Richards's classification [RICHARDS 1954]) in order to categorize the suitability of swamps areas waters for irrigation activities.

During the entire period of observation, it appears in this graphical (Fig. 14) presentation that the quasi-totality (80%) of water samples of Guerbes-Sanhadja to the C2S1 class (water can be used without special measures to irrigate moderately salt-tolerant crops on soils with good permeability). For the other stations fall in C3S1and C4S1 classes each with its own characteristics which are illustrated in the Table 5.

For both sampling periods, the waters of swamps areas generally retain the same qualities for irrigation. The majority of the samples (80%) belong to the C2S1

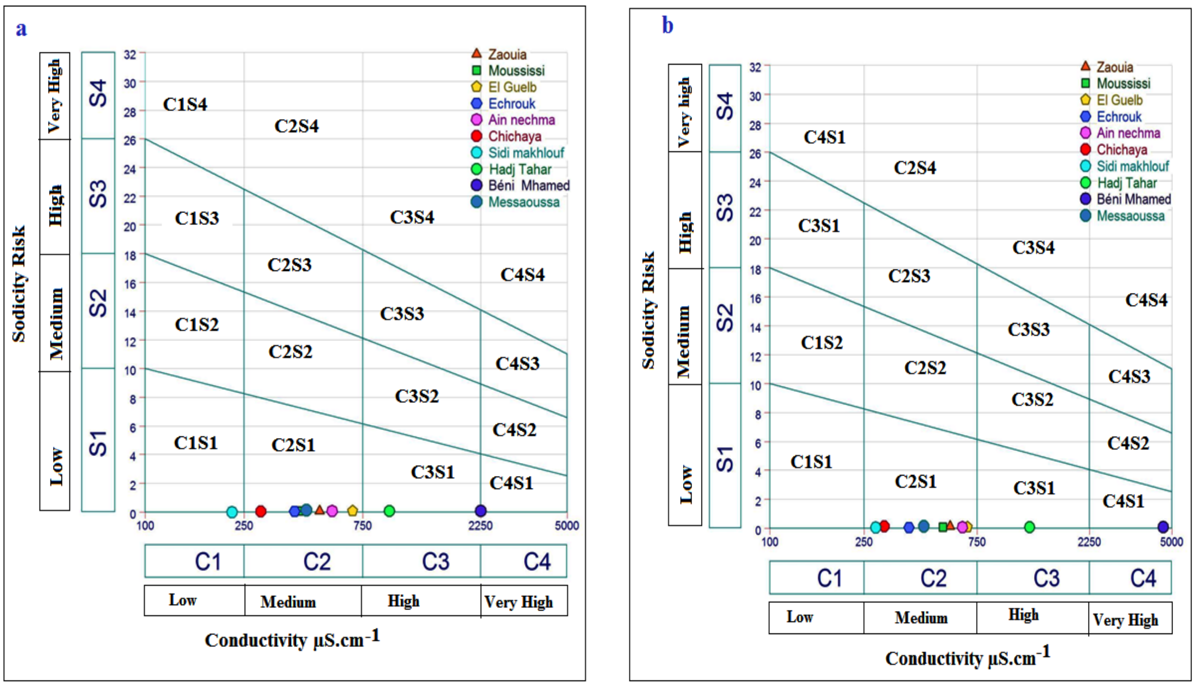

Fig. 14. Water quality with respect to *SAR* and *EC*: a) in February 2016; b) in June 2016; source: own study

Table 5. Water quality classification for irrigation purpose in study sites

Degree	Quality	Class	Values		Study site		Possibilities of utilization
			SAR meq·dm^{-3}	*EC* µS·cm^{-1}	February	June	
1	very good	C1S1	0–10	100–250	Sidi Makhlouf		safe to use water for irrigating most crops
2	good	C2S1	10–18	250–750	Zaouia, Moussissi, Messaoussa, El Guelb, Ain Nechma, Chychaya, Echrouk	Zaouia, Moussissi, Messaoussa, El Guelb, Echrouk, Ain Nechma, Sidi Makhlouf, Chychaya	in general, water can be used without special measures to irrigate moderately salt-tolerant crops on soils with good permeability
3	moderate	C3S1	18–26	750–2250	Hadj Tahar Béni Mhamed	Hadj Tahar	generally, water suitable for irrigation of salt-tolerant crops on drained soils; changes in salinity, however, must be controlled
4	harmful	C4S1	>26	2250–5000		Béni Mhamed	water unsuitable for irrigation but may be used under certain conditions: high soil permeability, good leaching plants, highly tolerant to salt

Source: own study.

class (medium salinity and low sodium content class); however, water that belongs to this class is also useful for almost all plants provided that moderate amount of leaching takes place or for plants with reasonable salinity tolerance without large practices for salinity control, except the water of Beni Mhamed wetland that falls in the mediocre class during low water period is of a sodicity more important than that of the previous class during high water period. Also, water of this swamp cannot be used for irrigation of soils with restricted drainage. Even with adequate drainage, special management for salinity control is required and crops with good salt tolerance should be selected. Such areas need special attention as far as irrigation is concerned.

CONCLUSIONS

The study has allowed to determinate physico-chemical characteristics of waters of complex of wetlands of Guerbes-Sanhadja for irrigation and to evaluate their suitability by Richards's diagram and different parameters.

The investigation indicates, on the basis of the organic pollution index (*OPI*), that pollution varies depending on the localities from moderate to very strong. High rate of *OPI* is across all sampling sites during the two periods, and hence water cannot be used for irrigation practices.

The analyses of all the parameters characterizing the salinity during the whole period has been used to assess the quality of these waters by conventional methods. This assessment revealed that the waters are medium to high salinity, particularly North of the complex of Guerbes-Sanhadja. Nevertheless, it remains low for other sites. Hence the possibility of their use for irrigation.

According to the value of *SAR* that remains low, swamp waters have a low risk of alkalization, this assumption is confirmed by the *RSC*, whose value is less than 1.25 meq·dm^{-3}, and could be used in irrigation on any type of soil.

The Richards classification shows that, overall, the use of these waters for irrigation in this wetland during both periods is suitable for irrigation of the various crops. Taking into account the concentration of mineral salts, especially during periods of low water at some places where the water becomes harmful and unsuitable for irrigation but can be used under certain conditions (high soil permeability, good leaching and plants tolerant to salts).

In terms of perspective, field monitoring in parallel with an experimental study in the laboratory to monitor and predict the geochemical and physical evolution of soils irrigated by different types of water proves to be necessary.

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Hydrochemiczna ocena jakości wody do nawodnień: Przykład kompleksu środowisk podmokłych Guerbes-Sanhadja, północnowschodnia Algieria

STRESZCZENIE

Kompleks środowisk podmokłych Guerbes-Sanhadja (północnowschodnia Algieria) był w ostatnich latach terenem ekspansji gospodarczej, głównie rolniczej. Około 47% użytków rolnych wykorzystano do uprawy kilku rodzajów roślin od ogrodnictwa po uprawy polowe wymagające dużej ilości wody. Obszary bagienne są głównym źródłem tej wody. Dlatego ważne jest, aby jakość wody do nawodnień była odpowiednia dla roślin, zwłaszcza żeby nie była zasolona. Przedstawione badania wykonano w celu oceny stanu wód na obszarach bagiennych i ich przydatności do nawodnień. Próbki wody pobrano z dziesięciu stanowisk z Guerbes-Sanhadja w lutym i czerwcu 2016 roku. Analizowano pH, przewodnictwo elektrolityczne oraz stężenie Na^+, K^+, Ca^{2+}, HCO_3^-, SO_4^{2-}, Cl^-, BOD_5, NO_3^-, NO_2^-, NH_4^+ i PO_4^{3-}. Na podstawie wyników analiz obliczono parametry jakości wody, takie jak współczynnik adsorpcji sodu (*SAR*), procent sodu (%Na), rezydualny węglan sodu (*RSC*), wskaźnik przepuszczalności (*PI*) i ryzyko magnezowe (*MH*). Wyniki świadczą o bardzo dużym stężeniu azotanów. Na ok. 60% obszarów bagiennych wody mają odpowiednie stężenie chlorków, mniejsze niż limity dopuszczalne dla wód do nawadniania. Z diagramu Richardsa wynika, że większość próbek z badanego obszaru mieści się w dobrej lub dopuszczalnej klasie jakości wody do irygacji.

Słowa kluczowe: *Algieria, jakość wody, kompleks środowisk podmokłych Guerbes-Sanhadja, nawadnianie, rezydualny węglan sodu (RSC), współczynnik adsorpcji sodu (SAR)*