ISSN : 0974 - 7451 Volume 5 Issue 6

Environmental Science

An Indian Journal

Trade Science Inc.

Current Research Papers

ESAIJ, 5(6), 2010 [331-335]

Prediction of sodization in coastal irrigated areas

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Received: 4th September, 2010 ; Accepted: 14th September, 2010

ABSTRACT

Sodium (Na+) contamination of irrigation groundwater is a serious worldwide problem. The Mnasra zone which has an agricultural land area that represents 70% of the total area and its agricultural production reach 12% of the national production is threatened by a sodization of underground waters. We know that this water table is the only ground water source available for this region. In this view, this work aims developed a simple mechanistic simulation model for predicting of Future Sodisation in Ground Water located at Mnasra zone. According to this study, we predict a sodization of an important area of 5093 Ha, between the years 2007 and 2021. These results will have a negative impact at medium term and at long term on the agricultural production of this region. © 2010 Trade Science Inc. - INDIA

KEYWORDS

Mechanistic;
Predicting;
Irrigation water;
Sodium;
Morocco.

INTRODUCTION

The contamination of the physical and chemical quality of groundwaters has caused a special attention at the international scale. Studies have been carried out in the past by[1-5]. This problem is mainly due to the over-use of fertilizers and pesticides. The phenomenon of sea water invasion that can spread over kilometers inside lands is a serious risk for coastal zones that are dependant to groundwaters for their supply in fresh water. Under certain conditions, salted water spread inside lands and contaminate groundwaters from the water table that is located close to the sea. Thus, the invasion of fresh waters by salted waters will cause a degradation of soils and a salinization due to irrigation trough these waters. The Gharb region, situated at the north-west of Morocco which has a sandy soil is confronted to nitrogen pollution. Studies have been carried out in this region[6-10] have confirmed an alteration of the physical and chemical quality due to agricultural activities. Thanks to assets due to water quality (plenty of ground water resources) and to soils (soils have less than 6% of clay and more than 82% of sand[11]), the coastal zone of M'nasra has known an increase of the area of irrigated zones that used to reach 5,766 ha in 1998 to 39,686 ha in 2005. Today, the irrigated zone is facing to an important diversification of vegetable crops (pepper, potato, tomato, aubergine, watermelon, cabbage, carrot, turnip…) and exotic crops (banana, strawberry, avocado…). This crop diversity is unfortunately associated with an over-use of fertilizers and pesticides that cause a nitric pollution of M'nasra's water table[12].

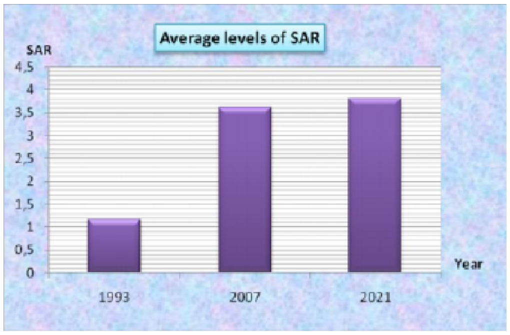

Figure 1 : The average levels of SAR of the waters coming from the 59 wells of M'nasra in 1993, 2007 and in 2021

It is important to notice that the water table of M'nasra is also confronted to other kinds of pollution due to sea water intrusion and to crop intensification, especially the sodization of ground waters.

According to Peterson[13], the main problem with a big quantity of sodium is its effect on soil permeability and on water infiltration. Sodium also directly contributes to water's total salinity and can be toxic for sensitive crops such as carrots, beans, strawberries, raspberries, onions etc.[14,15]. The sodization of ground waters of irrigated areas has generated a particular attention at the international scale and in different region of the world like in China[16], in Pakistan[17], in Niger and in Mali[18], in Uzbekistan[19]. In this way, this work has the objective of firstly, evaluating the sodization of the water of M'nasra's water table used for irrigation, secondly, the study of spatial and temporal evolution of this water table. To do so, 59 wells have been observed between 1993 and 2007, and finally, predicting of Future Sodisation in Ground Water located at Mnasra zone.

Several numerical models of water transport and agrochemicals have been developed to predict the fate of solutes in agricultural soils[20,21]. The method chosen to predict the variation in groundwater Sodium pollution of the water table M'nasra is the same as the population based on an increase (or decrease) geometry (geometric series). With this mathematical model, we calculated future concentrations of Sodium in 2021.

MATERIAL AND METHOD

Data and samples collection

A study was performed in the water region of M'nasra, on water quality. An agricultural land and water quality survey was performed and water samples from various wells were collected and analysed in laboratory. 59 samples of groundwaters were collected on two periods of companions: 1993 and 2007.

TABLE 1 : Average levels of concentration of nitrate levels Max, Min, and deviation types calculated for the 159 wells in 1993, 2003 and 2013

Parameter	SAR		
Year	1993	2007	2021
Max Value	7,04	29,46	10,90
Min Value	0,07	0,76	0,89
Standard deviation	1,11	5,09	2,40
Mean	1,15	3,61	3,81
WHO standard	59	59	59

Measurement methodology

Also, The method chosen to predict the variation in groundwater sodisation of the water table M'nasra is the geometric series. With this mathematical model, we calculated future concentrations of Sodium in 2021:

We have assumed that : q= constante

We knew the concentrations of nitrate measured at 59 wells during periods of companions in 1993 and 2007. With this model, we can calculate the constant q at the end of 14 yeers , as an example:

From the following equation:

$$\mathbf{U_N = q^n \times U_o} \quad \textbf{(1)}$$

We: U_N = SAR in 2007

n = Number of years between the two concentrations (n = N- 0 = 14)

U_0 = SAR in 1993

We calculate **q = ?**

From eq. (1):

[SAR in 2007]= q^{14}×[SAR in 1993]

And then: **q^{14}= [SAR in 2007] / [SAR in 1993]**

And then:

$$\mathbf{q = 10^{1/14\times \log([\text{SAR in 2007}]/[\text{SAR in 1993}])}} \quad \textbf{(2)}$$

With this mathematical model, we calculated future SAR in 2021 for 59 simples:

[Concentrations of nitrates in 2021] = (2)×[Concentrations of nitrates in 2007]

Measure of SAR

SAR (sodium, calcium, and magnesium are stated

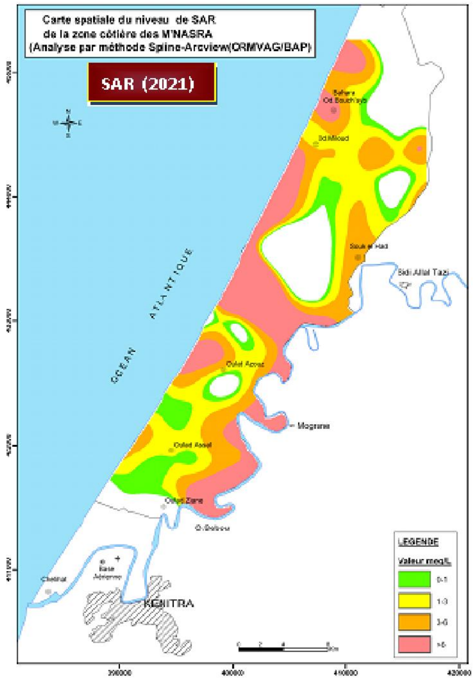

Figure 2 : Maps of the SAR in Mnasra zone (Morocco) in 2021, analysis through spline arcview method

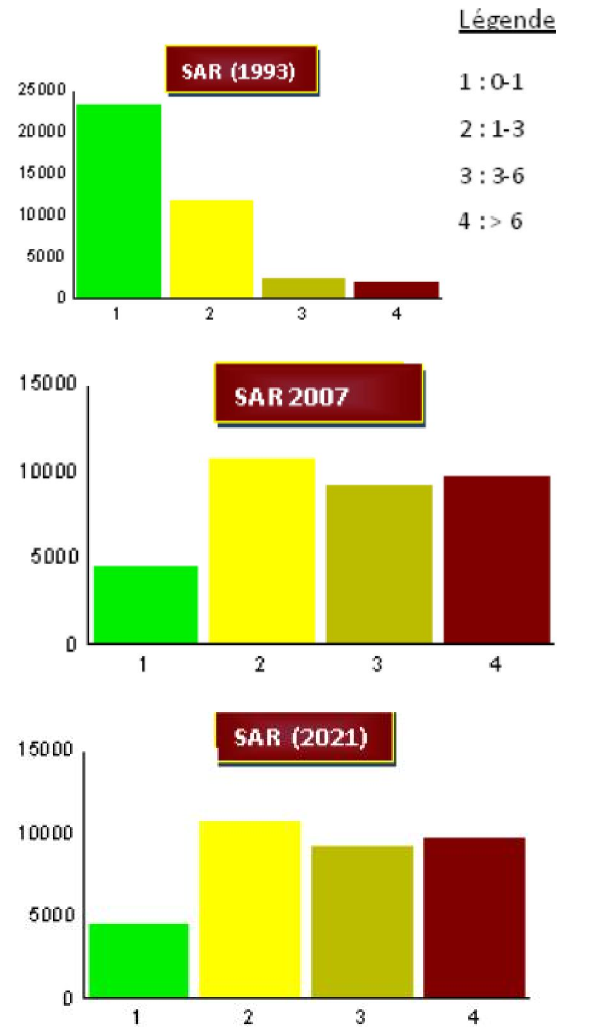

Figure 3 : Spatial repartition of the four classes of the SAR in 1993, 2007 and 2021

in meq/L) is calculated according to the following equation[13]:

$$SAR = \frac{Na^{+}}{\sqrt{\frac{(Ca^{2+} + mg^{2+})}{2}}}$$

The dosage of sodium (Na^{+}) is realized by flame photometry. Calcium ions (Ca^{2+}) and magnesium (Mg^{2+}) are dosed by volumetric method[22].

RESULTS AND DISCUSSIONS

Statistical analysis

The main results show that the overall average SAR calculated in 2021 is 3, 81. We compared the SAR calculated in 2021 with the results measured in 1993 and 2007.

TABLE 1 shows the average levels of SAR, levels Max, Min, and deviation types calculated for the 59 wells in 1993, 2007 and 2021.

We found the results spread over TABLE.1 as histograms presented in figure 1.

In doing the comparison of the overall average of SAR calculated, we can clearly observe that this average will continue to increase as well during the companion 2021. And, in order to see the significance of this increase, we called for a study of variance.

The results of the analysis of variance of the 59 wells and each zone A and B are displayed in the TABLE 2.

The statistical analysis confirm that the zone at the North of the line Y= 430 000 m (38°30′) is the zone which is the most affected by sodization. Indeed, it corresponds to the largest area of the sandy zone, where dunes and interior plateaus have a low relief, from 5 to 20 m high. As a consequence, the water table is very close to the surface (3 to 10 m), this explain the current intensive exploitation and the overuse of fertilizers that are often composed of salts. Thus, the Southern zone, has known a significant increase of sodization. This is mainly due to sea water intrusion in this zone[9].

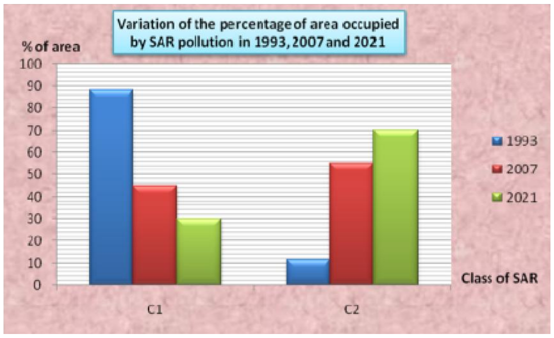

Figure 4 : Variation of the percentage of the area covered by the water table having a SAR inferior and superior to 3 in function of time

Spatial analysis

According to our analytical results, we have us the Geographical Information System (GIS) Arcvie and its spatial extension analyst, to create maps of the calculated of SAR in 2021 (Figure 2).

We compared the latter with the thematic maps of SAR measured during periods of companions: 1993 and 2007 level of 59 wells.

The rough analysis of the above cards, confirmed the sodisation more pronounced in the North of M'nasra. And, in order to predict which area will be occupied by each class of the SAR, and in order to better illustrate the spatial results presented in the fig.2, we have plotted them in a bar chart represented in the figure 3:

We can see clearly that the areas occupied by the class C1 continue to decrease during the companion 2021. Moreover, the areas occupied by the classes C2, C3 and C4 will continue to increase during the same periods companion. And to better express this variation of sodium, We have expressed of the latter in percentages.

We have summarized the results in TABLE 3.

We have presented the data of the TABLE 3 in a bar chart in the figure 4:

(1) The area covered by the water table having a SAR inferior to 3

The area covered by the water table having a SAR inferior to 3 has lost in importance i.e. loss of 5093 Ha between 2007 and 2021.

Therefore, this frequency is around 88,32%, 44,78%, and 29,87% respectively during the measurement periods in 1993, 2007 and 2021.

TABLE 2 : Results of the analysis of variance of the SAR for 59 wells and each zone A and B between 1993, 2007 and 2021

Statistical analysis of wells from	Between 1993 and 2021	Between 1993 and 2007	Between 2007 and 2021
Globale (59puits)	HS	HS	S
Zone A	HS	HS	S
Zone B	S	S	S

S : Significant difference; HS : Highly significant difference

TABLE 3 : Percentage of area occupied by SAR pollution of each class of wells on the total land mapped in 1993, 2007 and 2021

Year	area occupied by class of SAR / total land mapped *100	
	Class 1 (0-3)	Class 2 (>3)
1993	88,32 %	11,68%
2007	44,78 %	55,22%
2021	29,87 %	70,13%

(2) The area covered by the water table having a SAR superior to 3

The area covered by the water table having a SAR inferior to 3 has spread in importance area between 2007 and 2021.

Therefore, this frequency is around 11,68%, 55,22%, and 70,13% respectively during the measurement periods in 1993, 2007 and 2021.

The comparison of the spatial results allows us to confirm a decrease of 15 % in the area in which the table water has a SAR inferior to 3 ppm between 1993 and 2021.

And consequently, we predict an area of 5093 Ha hectares where the water will be polluted by the sodium in 2021.

CONCLUSION

This study concerns the first Attempts for Predicting of Future Sodium Concentrations in Ground Water in 2021 of 59 wells spread over an area of 38 000 Ha. And on the other hand to study the spatial and temporal evolution of the SAR by a statistical analysis following the campaign periods of 1993 and 2007. The analysis of the results has shown the evolution of the general average of the concentration in sodium between the years 1993, 2007 and 2021 which is respectively 1.15, 3.61 and 3.81 i.e. an increase of 2,66. The obtained values in 2008 and 2021 are definitely superior to

Moroccan standards (3). According to this study, we predict an area of 5093 Ha where the water will be polluted by the sodium in 2021.

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