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Physical and chemical analysis of the nitric pollution of M'nasra groundwaters in irrigated areas

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ABSTRACT

The area of M'nasra, which has a water table that represents the only resource, allows the supply of a population of 140 000 inhabitants. It ensures the development of a dynamic irrigation over an area of about 38 000 Ha in which more than 50% of lands are sandy soils that are very permeable. This coastal zone is a place where agriculture is very intensive supported by fertilizers composed of nitrogen and pesticides that are used at a large scale. This work deals with the physical and chemical study of waters from 59 wells and the spatial and temporal evolution of the nitric pollution during the campaign periods of 1993, 2003, 2007 and 2008 for different places of M'nasra's region. The results of the statistical analysis have shown a mutation of the nitric pollution in the region. This reveals that 73.6% of observed wells do not respect the World Health Organization (WHO). Furthermore, the spatial analysis has shown up a nitric pollution spread on an area of 1370 Ha between the years 1993 and 2008.

KEYWORDS

Nitrate;
Underground water table;
Pollution;
Degradation;
M'nasra.

INTRODUCTION

Since a couple of years, the protection and the conservation of natural environments particularly water quality has become an important issue and a main goal in development programs. Indeed, the context of degradation and scarcity touching national water resources is becoming more and more threatening has encouraged our country to consider at the same time as the efforts concerning development and management of water resources, a special interest to water saving essential for irrigation and to the control of all kinds of pollution as well.

The intensive cropping of cultivated lands at the level of irrigated areas has created since a couple of years the apparition of the problem of underground water resources pollution by the nitrate ion.

Nitrates have a particularity that other chemicals have not. In fact, nitrate is a nutritive mineral element for plants and microorganisms. For this reason, nitrate salts such as potassium nitrate (still called saltpeter, with a formula KNO_3), sodium nitrate ($NaNO_3$) calcium nitrate ($Ca(NO_3)_2$), or also ammonium nitrate (NH_4NO_3) are used for the fabrication of nitrogen fer-

tilizers[1]. However, their excessive presence into the soil can contaminate the different water sources and cause problems to human health[2,3] and to the animal[4-6]. Indeed, nitrates are pollutants easily leachable and can reach the water table without being transformed[7].

The problem caused by nitrates has sparked off the maximum interest during these last few years and has become among the current worldwide issues, such as the case of Taiwan[8]; Shangan in China[9]; in the United States[10]; Hong-Kong[11], etc. As for Morocco, it is at the level of great irrigated basins where this kind of problems are feared especially in the Gharb (M'nasra), Tadla, Souss and the coastal zones of El Jadida. In fact, the intensification of agriculture in these regions is followed by an over use of nitrogen fertilizers and manure. It is important to know that these irrigated areas that only cover 12% of the useful agricultural area, consume more than 50% of fertilizers[7].

The nitric pollution of the water table of the coastal zone of the Gharb (M'nasra) has been noticed in 1993 thanks to a study that has been carried out on more than 159 wells and has revealed that about 3/4 of the wells exceed this standard, with levels in certain wells exceeding four times the threshold level[12].

This work aims to study the physical and chemical analysis of 59 wells identified in the coastal zone of M'nasra. On one hand, to study the spatial and temporal variation of the nitric and ammonium pollution following the campaign periods of 1993 and 2008 and in different places of M'nasra's region, and on the other hand to see the spatial dispersion of these 59 wells studied in function of their contamination degree under the form of thematic maps.

EXPERIMENTAL

Material and method

Zone of the study

The area of M'nasra, studied in this work is the coastal shore of Gharb, covering a geographical area of about 48 000 ha. More than 26 100 ha of soils have less than 6% of clay and more than 82% of sand. The half of the area, about 54% is covered by sandy lands with a high permeability[12].

Sampling and measurement methodology

Choice of wells

The choice of the wells has been essentially based on two criteria: crop intensification and the depth of the water table.

Sampling

For the sampling, the water has been taken directly from the irrigation network used for wells which are equipped of pushback pumps. For wells that are not equipped, the samples are taken with a ballasted metallic container. All the samples have been put into flasks made of polyethylene or made of borosilicate glass. The samples are carefully marked and kept at +4°C, until their arrival at the laboratory.

Dosage des nitrates

The nitrates have been measured by molecular absorption spectrometry. After their reduction in nitrite on cadmium, the nitrates are quantitatively reduced in nitrites by cadmium (Cd) covered of a copper layer after a treatment by copper sulfate. The produced nitrites form with 4-amino benzene sulfonamide a diazoic compound, this one coupled with N-(Naphty-1) ethane-1,2-diamine form a pink complex that is likely of being measured with a spectrophotometer at a wavelength of 540nm[13].

Figure 1 : Localization of the 59 studied wells in the zone of M'nasra

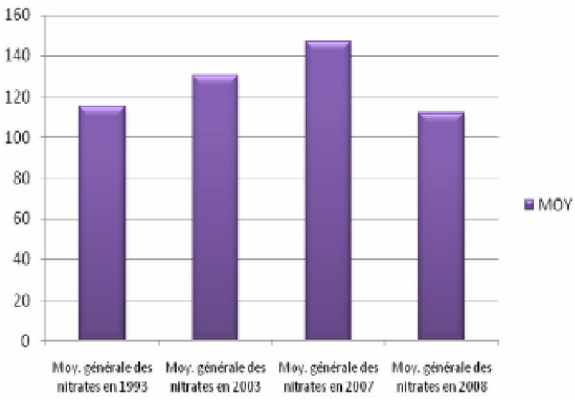

Figure 2 : Variation of the general mean of the nitrate concentration in the 59 wells in function of time

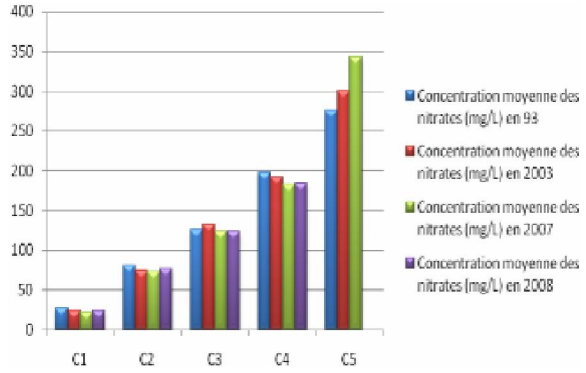

Figure 3 : The average levels of nitrate concentrations of the waters coming from the 59 wells of M'nasra in 1993, 2003, 2007 and in 2008

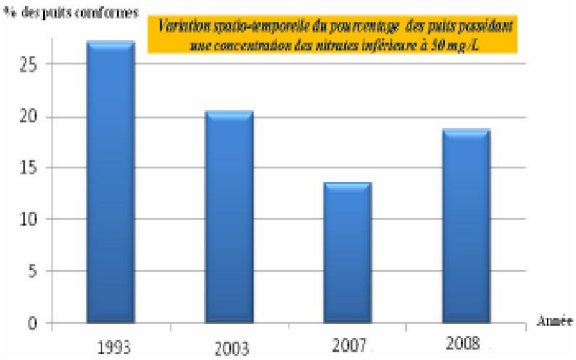

Figure 4 : Variation of the percentage of the wells having a nitrate concentration inferior to 50mg /L in function of time

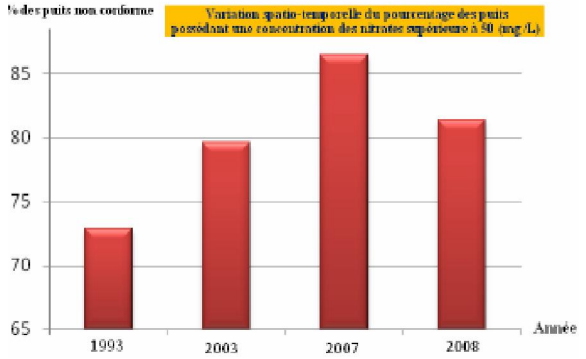

Figure 5 : Variation of the percentage of wells having a nitrate concentration superior to 50mg /L in function of time

RESULTS AND DISCUSSION

Statistical analysis

To do not have a negative impact of human health, the concentration of nitrate in drinkable waters should not exceed 50mg/L[14].

The main results show that the general means of nitrate concentration in 1993, 2003, 2007 and 2008 are respectively of 115.2mg/L, 130.6mg/L, 147.2mg/L, and 112.1mg/L; it represent an increase of 15.4 mg/L between 1993 and 2003, and 32 mg/L between 1993 and 2007, and a decrease of 35.1 mg/L between 2007 and 2008.

The TABLE 1 shows the average levels of the nitrate concentration, the Max and Min levels and the standard deviations calculated at the level of the 59 wells in 1993, 2003, 2007 and 2008.

We have exploited the results presented in the TABLE 1 and we made a bar chart:

By comparing the general mean of the calculated nitrate concentration, we can clearly notice that this mean increases in function of time. The statistical analysis of the nitrate concentration of the 59 wells, and so each zone A and B of the area of M'nasra, in 1993, 2003, 2007 and 2008 is presented in the TABLE 3. Just like we have reported before, the zones A and B are also noted.

Zone A

It is the zone located at the North of the coordinate line Y = 430 000 m, it represents 72% of all the studied wells.

Zone B

It is the zone located at the South of the coordinate line Y = 430 000m, it represents 28% of all the studied wells. This statistical study has shown us two essential things.

The nitric pollution is concentrated mostly in the North part of the coordinate line Y = 430 000m, of the area of M'nasra.

Between 2007 and 2008: the nitric pollution has been aggressive in the South part of the coordinate line

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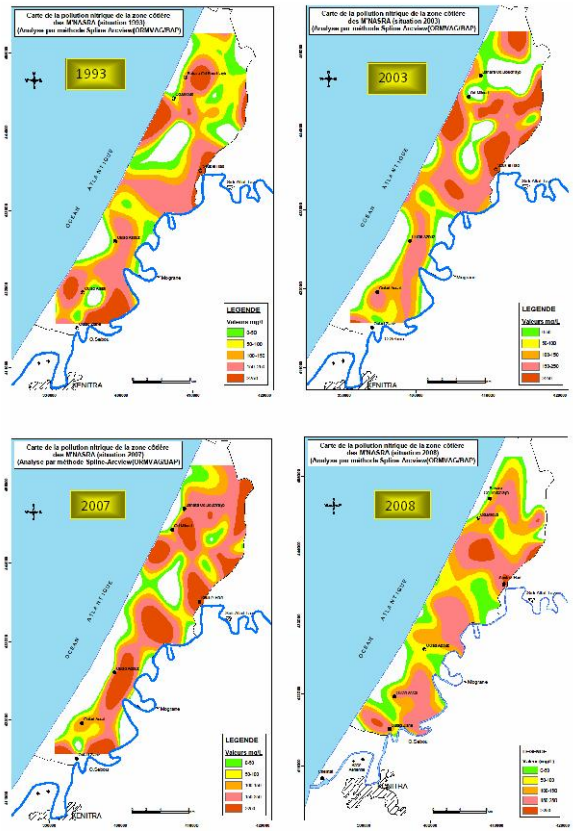

Figure 6 : Map of the nitric pollution of the area of M'nasra, Analysis by the Spline Arcview method Situation : 1993, 2003, 2007 and 2008

Y = 430 000m, of the area of M'nasra.

Isolated analysis

The results concerning the average levels of nitrate concentration for the different studied classes are recorded in the TABLE 2.

We have presented the data of the TABLE 2 in a bar chart in the figure 3.

By looking at the average nitrate content of these wells in function of time, we can conclude that:

Concerning the class 1

The global situation of these wells has slightly improved going from a nitrate average of 28.06mg/L in 1993 to 24.2mg/L, 22.1mg /L, 24.0mg/L respectively in 2003, 2007 and in 2008.

Concerning the classes 2 and 3

The average levels have known non distinctive changes in function of time.

Concerning the class 4

The global situation of these wells has slightly improved going from a nitrate average of 197.3mg/L in 1993 to 191.7mg/L, 182.9mg /L, 184.8mg/L respectively in 2003, 2007 and in 2008.

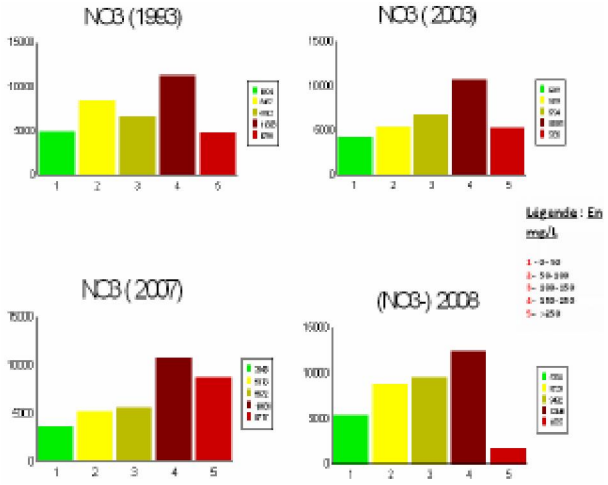

Figure 7 : Spatial repartition of the five classes of nitrate concentrations in 1993, 2003, 2007 and 2008

On the other hand for the class 5, the situation of the wells has been dramatically deteriorated going from a nitrate average of 276.5mg/L in 1993 to 300.6mg/L, 342.7mg /L respectively in 2003, and in 2007. We can notice the disappearance of the class in 2008.

Variation of the % of wells having a nitrate concentration inferior to 50 mg /L of 59 wells in 1993, 2003, 2007 and in 2008 (Figure 3)

The results from the isolated analysis of nitrate concentration that has concerned 59 wells obtained in the year 1993 and in 2008, have revealed that more than ¾ of wells exceed the WHO standard.

The results obtained in 1993 show that the class of wells having a nitrate concentration inferior to 50mg /L, represents 27.12% of the wells.

On the other hand, the same class only represent respectively 20.34%; 13.56%; and 18.64% in 2003, 2007, and in 2008, and consequently, we notice a diminution of the wells having a good quality.

Variation of the % of wells having a nitrate concentration superior to 50 mg/L over 59 wells

The results obtained in 1993 show that the classes of wells having a nitrate concentration superior to 50mg / L, represent 72.88% of wells.

On the other hand, the same classes represent respectively 79.66%; 86.44%; 81.36% in 2003, 2007 and in 2008.

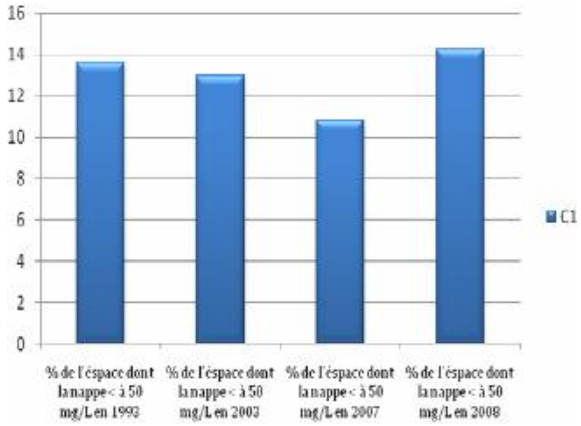

Figure 8 : Variation of the percentage of the area covered by the water table having a nitrate concentration inferior to 50 (mg/L) in function of time

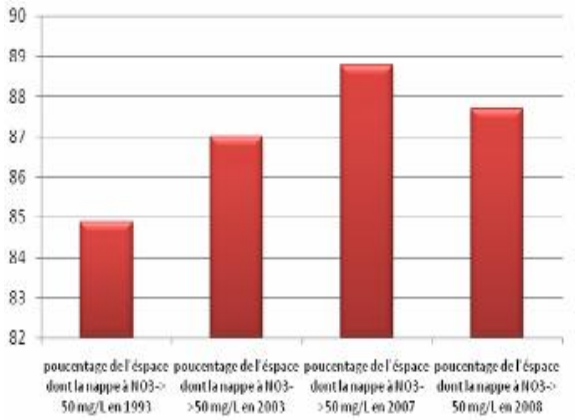

Figure 9 : Variation of the percentage of the area covered by the water table having a nitrate concentration superior to 50 (mg/L) in function of time

TABLE 1 : Average levels, max, min, standard deviation and temperate depth of nitrates at the level of the 59 wells in 1993, 2003, 2007 and in 2008

Parametres	$(NO_3^-)^1$ (mg/L)	$(NO_3^-)^2$ (mg/L)	$(NO_3^-)^3$ (mg/L)	$(NO_3^-)^4$ (mg/L)
Annee	1993	2003	2007	2008
Valeur min	600	800	905	434
Valeur max	29600	36500	42160	400
Ecart type	7770	9149	10314	830
Profondeur moyenne (m)	135	15	12	135
Moyenne	1152	1306	1472	1121
Norme selon L'OMS	50	50	50	50

We have noticed that, an increase of the percentage rate of the wells having a bad quality between 1993 and 2007; and also a slight diminution of this one i.e. 5.08 % between 2007 and 2008. This diminution is necessarily due to the annual rainfall supply (912mm).

Spatial analysis

To study and to compare the spatial repartition of polluted zones of the area of M'nasra, we have elaborated thematic maps of the nitrate concentration in 1993, in 2003, in 2007, and in 2008 at the level of the 59 wells (Figure 5).

In order to better illustrate the spatial results presented in the figure 5, we have plotted them in a bar chart represented in the figure 6.

The area covered by the water table having a nitrate concentration inferior to 50 (mg/L)

The area covered by the water table having a nitrate concentration inferior to 50mg/L in 1993, would represent only 4 904 Ha over 36 007 Ha mapped i.e. 13.62% whereas the same area used to represent respectively in 2003, 2007 and in 2008, 4 219 Ha over 32 467 Ha mapped, 3 645 Ha over 33 683 Ha mapped and 5 370 Ha over 37 706 Ha mapped i.e. loss of 12.99% ; 10.82% and 14.24% over the total area.

TABLE 2 : Variance analysis of the 59 wells and at the level of the North zone and at the South of the line Y = 430 000 m of M'nasra's zone

Analyse statistique des puits de	Analyse de variance des nitrates					
	Entre 1993 et 2003	Entre 1993 et 2007	Entre 1993 et 2008	Entre 2003 et 2007	Entre 2003 et 2008	Entre 2007 et 2008
Zone A	S	S	S	S	S	S
Zone B	NS	NS	NS	NS	NS	S
Zone A + Zone B	NS	NS	NS	NS	NS	S

These results show that the area covered by the water table having a nitrate concentration inferior to 50 mg/L, has lost in importance i.e. loss of 1 259 Ha between 1993 and 2007.

And consequently, we had an area of 1 725 Ha of which the water table of M'nasra has known an improvement between 2007 and 2008.

The area covered by the water table having a nitrate concentration superior to 50 (mg/L)

The area covered by the water table having a nitrate concentration superior to 50 mg/L in 1993, would represent 27 554 Ha over 32 458 Ha mapped, i.e. 84.89 % whereas the same area used to represent respectively in 2003, 2007, and in 2008, 28 239 Ha, 28 813 Ha and 28 458 Ha over 32 458 Ha mapped

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TABLE 3 : The average levels of nitrate concentrations of the waters coming from the 59 wells of M'nasra in 1993, and in 2007

Classe	1993		2003		2007		2008		Qualite selon I'OMS
	Number de puits	Concentration moyenen nitrates (mg/l)	Numbre de puits	Concentration moyene nitrates (mg/l)	Nombre de puits	Concentration moyenen nitrates (mg/l)	Nombre de puits	Concentration moyenen nitrates (mg/l)	Bonne
C1	16	28.06	12	24.4	08	22.1	11	240	
C2	14	81.34	14	748	16	741	17	7696	
C3	12	126.1	13	133	10	124.3	11	1239	
C4	13	197.3	12	191.7	16	1829	20	1848	Mauvaise
C5	04	2765	08	300.6	09	342.7	-	-	
Moyenne generale	59	1152	59	1306	59	1472	59	1121	

i.e. from 87 %, 88.77% and 87.68% of the total area.

These results show that the area covered by the water table that has a nitrate concentration superior to 50 mg/L, has spread i.e. of 904 Ha between 1993 and 2008.

And consequently, we have had an area of 904 Ha where the water table of M'nasra has known pollution by nitrate.

The spatial analysis of the results obtained from the 59 wells has confirmed that we had a total area of 1 370 Ha where the water table of M'nasra has known a pollution by nitrates between 1993 and 2008.

Comparative analysis

The results obtained confirm the variation of the salinization of the water table in isolated areas but at the spatial level as well.

Indeed, this zone is a place where agriculture is very intensive, especially for vegetable crops e.g. peanut, pepper, etc. Thus, the over exploitation of the water table and the over use of fertilizers participate in a direct way to the pollution of the water table. The rate of polluted wells that was 72.88% in 1993 has increased to 81.36% in 2008, i.e. an increase of about 9 points.

In Morocco, it is at the level of great irrigated zones where that kind of problems should be considered especially in the Gharb (M'nasra), Tadla, Souss and the coastal zones of El Jadida. Indeed, the intensification of agriculture in these regions is followed by an over use of nitrogen fertilizers and manure. It is important to know that these irrigated areas that only cover 12% of the useful agricultural area, consume more than 50% of fertilizers[7]. The nitric pollution of the water table of the coastal zone of Gharb (M'nasra) has been stated by the Office Régional de Mise en Valeur Agricole du Gharb[12] since 1993 thanks to a monitoring realized on 20 wells of this zone. The results have revealed that 16 of the 20 wells had a content of more than 50 mg/l which correspond to the threshold level recommended by the WHO and 3 of the 4 wells having a content inferior to this value had a concentration between 40 and 50 mg/l. Some wells have a concentration more than three times higher than the concentration of recommended by the standard. Several international studies have shown that the pollution of underground waters by nitrates is due to the over use of fertilizers and pesticides[15-18] and the bad agricultural practices, especially the over use of nitrogen fertilizers coupled with a non adapted irrigation system are the main causes. This statement has recently been confirmed by the study carried out by the Secrétariat d'Etat Chargé de l'Environnement[19] in the elaboration of a program aiming to minimize and to control the impact of fertilizers and pesticides on the environment of the Sebou basin. This study has revealed that crops such as peanut, pepper and potato can together release more than 1 000 T of nitrogen into the water table of the coastal zone having a minimal global value of 4 MDH that have only been used to contaminate the water table without any positive agronomic aspect[20].

CONCLUSION

This study concerns on one hand the physical and

chemical analysis 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 nitric pollution by a statistical analysis following the campaign periods of 1993, 2003, 2007 and 2008. The obtained results have shown an evolving and spread pollution by nitrates touching the water table. Indeed, 73.6% of prospected and analyzed wells do not match to drinkable water standards according the world health organization (WHO). Furthermore, the spatial analysis has revealed a nitric pollution touching an area of 1 370 Ha between the years 1993 and 2008.

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