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Effect of recharge, irrigation and soil nature on the variation of nitrate in the groundwater of Wadi Nil (Jijel – North-East Algeria)

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This paper presents the effect of recharge, irrigation and soil nature on the variation of nitrate in the groundwater of Wadi Nil (Jijel – North-East Algeria) where the intensive use of fertilizers and the recycling of irrigation water have resulted in an alarming increase in nitrate concentrations. In this plain, the groundwater is increasingly polluted by excessive use of fertilizers in agriculture. Indeed, in several areas cultured with irrigated vegetable crops, water contains nitrate levels which exceed the allowed standards for human consumption. The present study consists of a spatio-temporal monitoring of nitrate in groundwater in relation to the dilution caused by charging during the rainy season, on the one hand, and to the leaching caused by irrigation water during the dry season, on the other hand. The results obtained show an increase in the contamination of groundwater by nitrates and their seasonal variations under the effects of recharge, irrigation and soil nature.

Key words: Agricultural pollution, nitrates, recharge, irrigation, groundwater, soil nature.

INTRODUCTION

The agricultural pollution is a major cause of the deterioration of groundwater quality (Lasserre et al., 1999). The development of agricultural land and the requirements of good production require an input of fertilizers which often leads to groundwater pollution by nitrates due to their high solubility and their weak affinity for ionic exchanges (Addy et al., 1999; Engel et al., 1996).

Many studies proved that, husbandries are the probable cause of the excessive nitrate levels in the groundwater (El Tabach, 2005). Concentrations raised out of nitrates in drinking water are related to health issues such as the methemoglobinemy for children and the cancer of the stomach for adults (Maticic, 1999; Bohlke, 2002). There exist values of limiting acceptable nitrate concentration in drinking water. WHO to define an

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obligatory limiting value fixed at 50 mg/l (Hallberg and Keeney, 1993).

Natural reactions of atmospheric forms of nitrogen with rainwater result in the formation of nitrate (NO_3) and ammonium (NH_4) ions. Nitrate is a common compound, naturally generated from the nitrogen cycle. However, anthropogenic sources have greatly increased the NO_3 concentration, particularly in groundwater (Chand et al., 2011; Vomocil, 1987). The largest anthropogenic sources are septic tanks, nitrogen-rich fertilizers applied to turf grass, and agricultural processes. Nitrogen fertilizers are extensively applied in agriculture to increase crop production, but excess nitrogen supplies can cause air, soil, and water pollution. Arguably, one of the most widespread and dam aging impacts of agricultural over-application of nitrogen fertilizers is the degradation of groundwater quality and contamination of drinking water supplies, which can pose immediate risks to human health (Rail, 1999). There exist values of limiting acceptable nitrate concentration in drinking water.

Thus, in the plain of the Wadi Nil, where the increase in the contents of nitrates of the groundwater, found in certain zones is related to surpluses of manures brought to the cultures. The evolution of nitrate contents in the agricultural zones display the existence of several parameters (the geologic nature of top to aquifer, the effect of the evaporation, the nature of irrigation waters, the rain and the redox conditions (Elmobarak and Mahgoub, 2014)) which could influence the concentration variation.

To address this question, a monthly sampling of groundwater for chemical analysis was carried out during the year 2012 in five wells distributed in terms of the use of land, the use of fertilizer and the frequency of irrigation.

Presentation of the study area

The studied area is located in the north-east of Algeria. The alluvial aquifer of this area forms part of the coastal plains region of Jijel (Figure 1); it covers an area of 83 km^2 and opens to the north of the Mediterranean Sea. It corresponds to the lower Nil valley and its tributaries which contribute to the groundwater recharge (Boufekane and Saighi, 2010).

The maritime location of this plain gives it a mild and damp climate. Between the winter and summer, the monthly median values of temperatures vary from 11 with 25°C (the average air temperature is 17°C/year), the relative humidity is from 70 to 75% and the evaporation is from 41 to 80 mm. The rainfall is relatively high, reaching 900 mm/year (Boufekane and Saighi, 2013).

The geological substratum of the area consists of gneiss and the schist. However, the parts of swallow, sedimentary formations mainly marly Oligocene age, Miocene and Pliocene cover these metamorphic facies. Finally, the depressions and valleys are filled with quaternary alluvial deposits which are interstation terraces aquifers (Boufekane and Saighi, 2013).

The groundwater recharge is mainly directed by infiltration of rainfall and the low water situation by the various rivers which cross the plain. The aquifer forms part of the socio-economic development of the region by the exploitation of the domestic wells and boreholes (36 million m^3/year).

MATERIALS AND METHODS

The study is based on a monthly piezometric monitoring of groundwater and on nitrates analyses carried out on samples of groundwater taken monthly in five water points for year 2012. The chemical analyses were performed by the colorimetric method. The technical characteristics of the photometric device are: UV visible - precision 0.10 mg/l; Interval of measurement 00-30 mg/l; wavelength 555 Nm and the color yellow amber.

The characteristics of the water points selected for the study (Figure 2) are as follows:

i. Point No 1 (borehole ON18) corresponds to a drilling situated in a field of drinking water abstraction. Neither fertilized nor irrigated, its zone of influence coincides with a perimeter of protection of groundwater.
ii. Point No 2 (borehole ON23) corresponds to a drilling located in an agricultural zone little or no fertilized, irrigated from aquifer little loaded with nitrates.
iii. Point No 3 (well P7) corresponds to a drilling situated in a zone of vegetable gardening and greenhouse regularly fertilized; this zone is irrigated from the aquifer. The roof of the aquifer is permeable.
iv. Point No 4 (borehole ON5) corresponds to a drilling located in an agricultural zone fertilized and irrigated only for the summer period.
v. Point No 5 (well P70) corresponds to a drilling situated in a zone of vegetable gardening and greenhouse regularly fertilized; this zone is irrigated from the aquifer. The roof of the aquifer is impermeable (argillaceous).

RESULTS AND DISCUSSION

Recharge and irrigation effect on the variations of the nitrates in groundwater

The graph (Figure 3) shows that the rainy season takes place in winter between November and March. It is therefore natural that, on the piezometric level, the groundwater is in situation of "high water" between December and May with a maximum in March – April.

In terms of nitrate, water collected in Points 1 and 2, located in zones not fertilized, sometimes with perimeters of protection is characterized by low values (less than 23 mg/l), while those collected in Points 3 and 4, which form part of zones of vegetable gardening, fertilized and regularly irrigated, their nitrate concentrations are higher (57 to 125 mg/L). Aside from Point 2 which is in an area irrigated with waters little loaded with nitrate (1-6 mg/L).

Figure 3 shows that the concentration of nitrates in the aquifer changes inversely with the piezometric level.

Indeed, they pass from low values when the groundwater is in situation of "high water" to high values in situation of

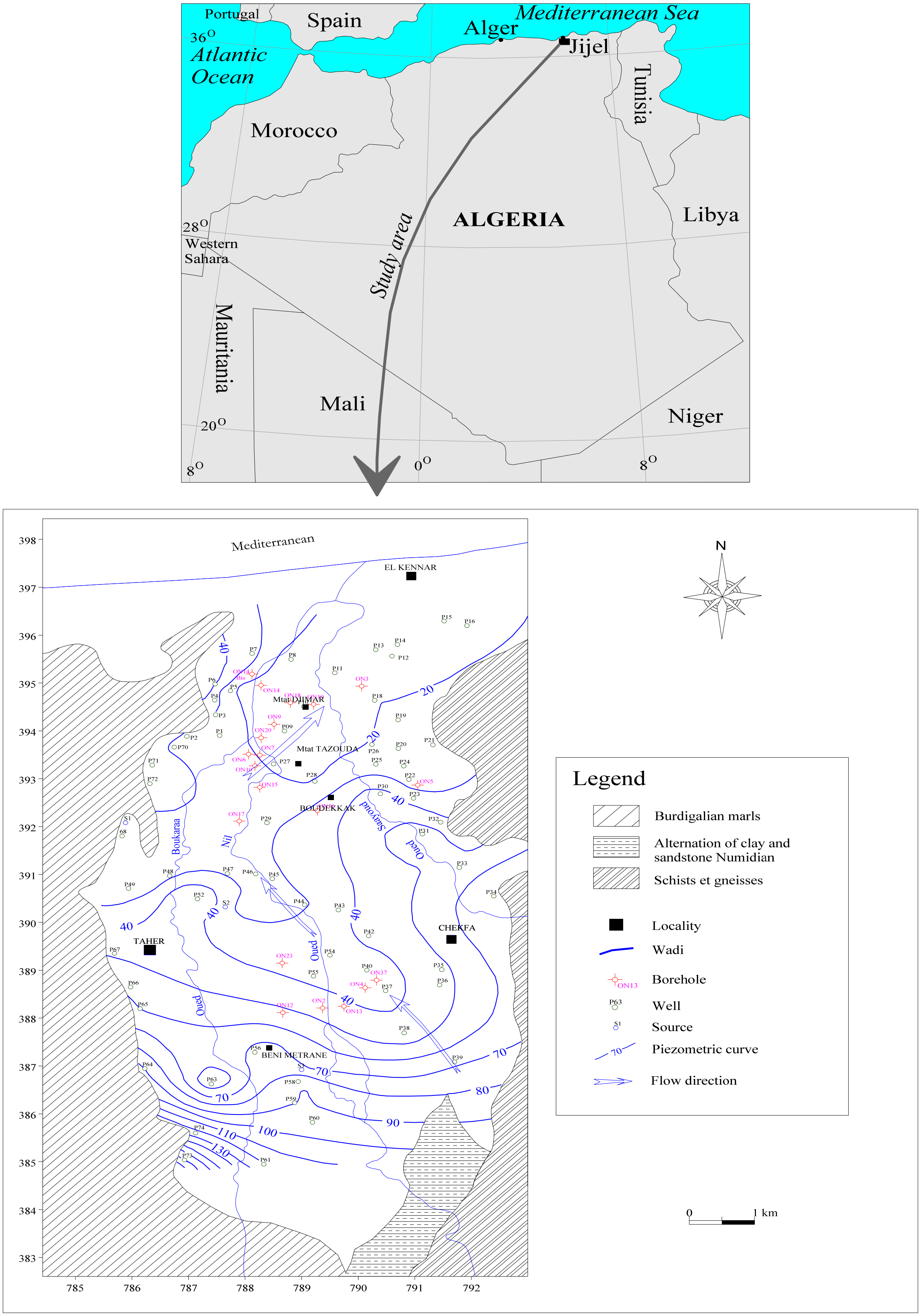

Figure 1. Piezometric map in the plain of Wadi Nil (May 2012).

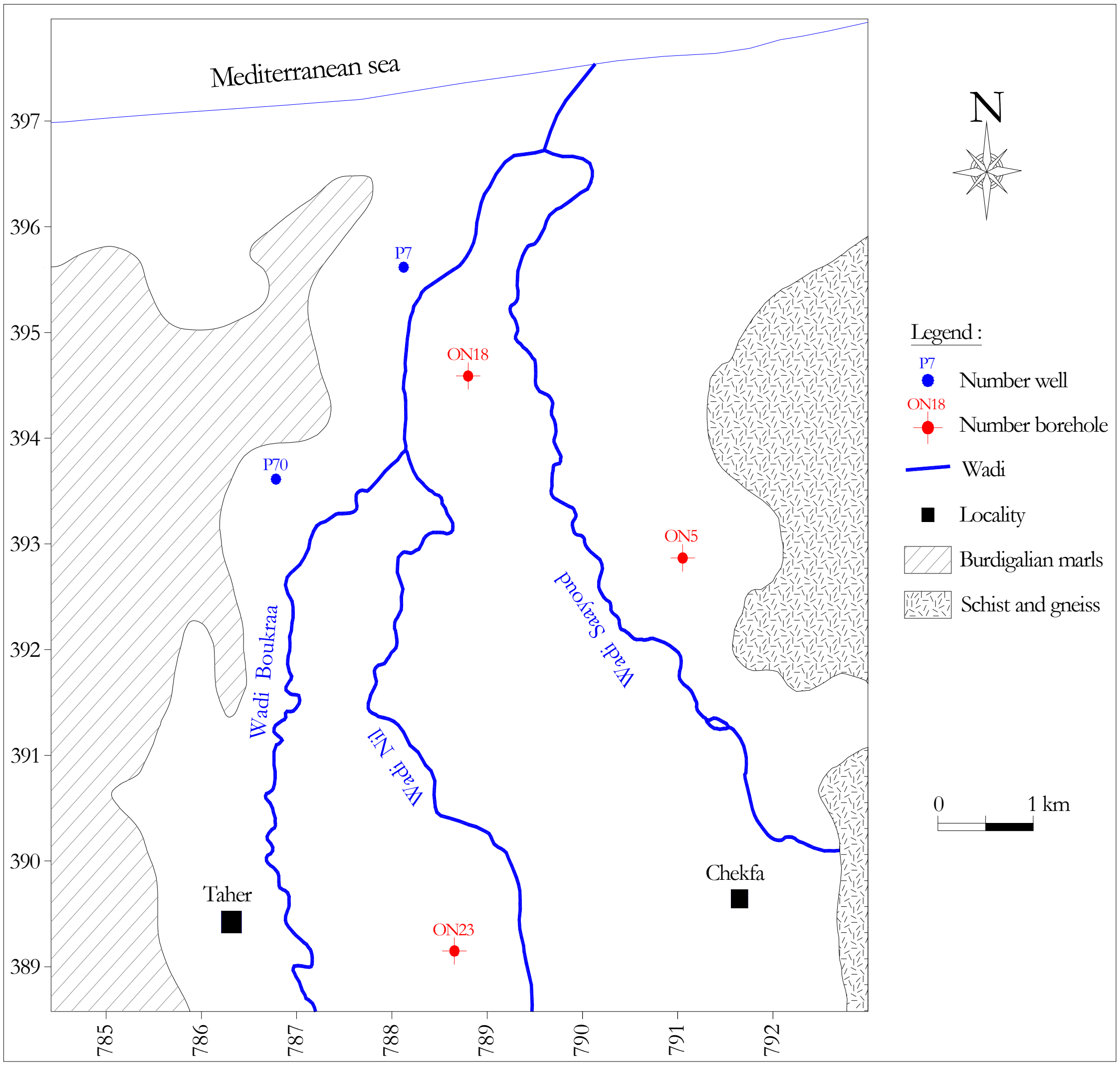

Figure 2. Locations of groundwater monitoring wells.

"low water". This translates the dilution effect caused by recharge during the rainy season. This dilution effect is nevertheless insufficient to bring the nitrate contents to acceptable values, especially in areas where the fertilizer contributions are important as in Point No 3.

More explicitly, each water point has its specificity as follows:

i. The water point No 1 (borehole ON18) which is a drilling located in a field of drinking water abstraction, reflects a natural state without fertilization and irrigation. The nitrate levels in the groundwater (less 23 mg/l) are still below the threshold limit for human consumption in spite of light increase in summer (Figure 3A).

ii. The water point No 2 (borehole ON23) illustrates the characteristic of a zone not fertilized but irrigated with water little loaded with nitrates (1-6 mg/l). In this case, the low nitrate levels which characterize the groundwater are stable all the year (Figure 3B), oscillating around a value of 4 mg/l. They undergo an effect of dilution regularly either by the winter rain or by water of irrigation little mineralized in summer.

iii. The water point No 3 (well P7) corresponds to a zone of intense agricultural practices and greenhouse farming, with permanent contributions of fertilizer and frequent irrigation carried out starting from the well No 3. The leaching of nitrates and their transfer to the groundwater remains all the year with an effect accentuated in summer (Figure 3C). The nitrate levels are constantly with the top of the acceptable threshold: about 80 mg/l in winter in spite of the effect of dilution generated by the rain and nitrate levels higher than 120 mg/l were found in summer due to leaching and transfer of nitrate to groundwater by irrigation water.

iv. The fourth point (borehole ON5) represents an agricultural zone irrigated and fertilized only in summer

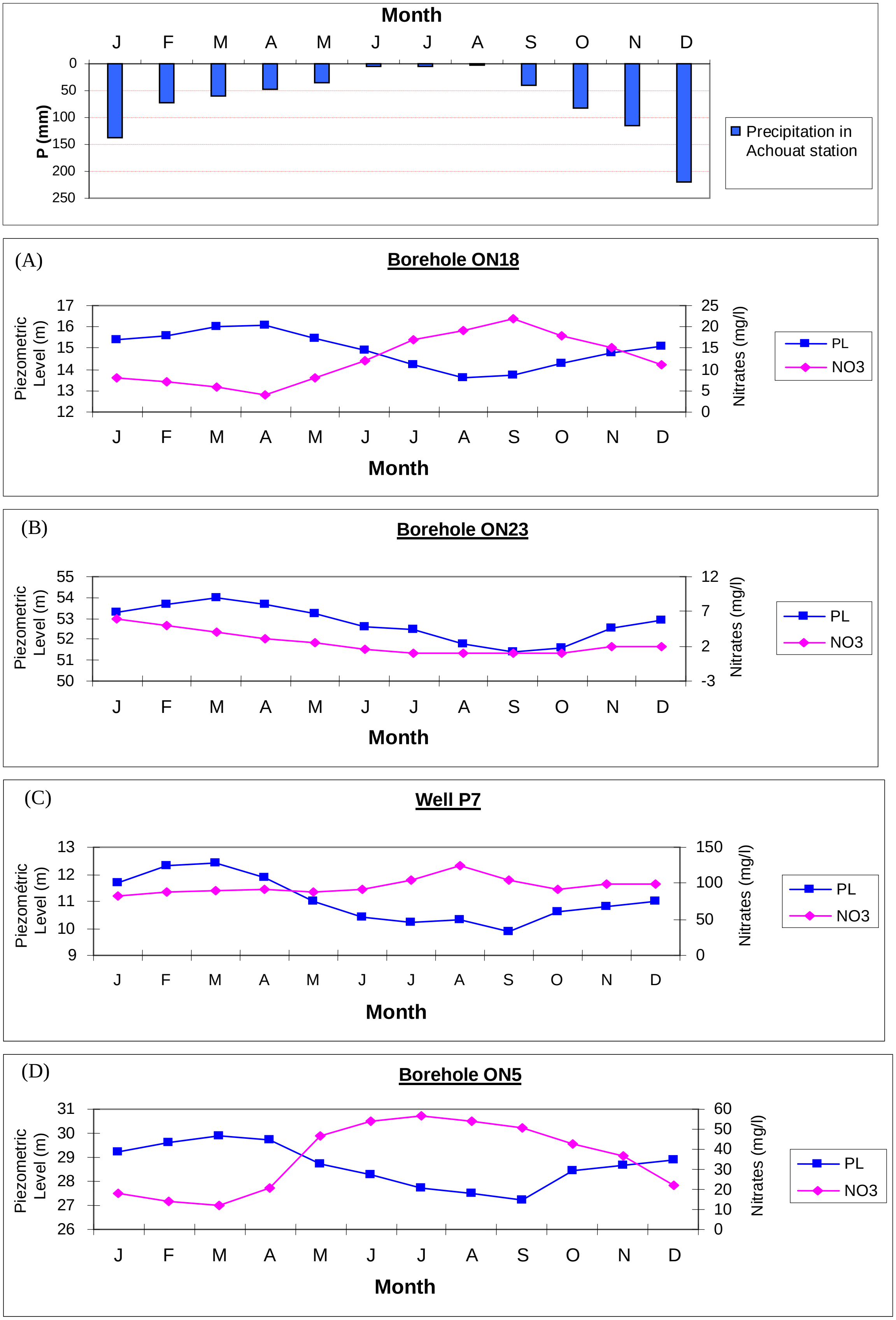

Figure 3. Evolution of nitrate in groundwater with piezometric fluctuations in 2012.

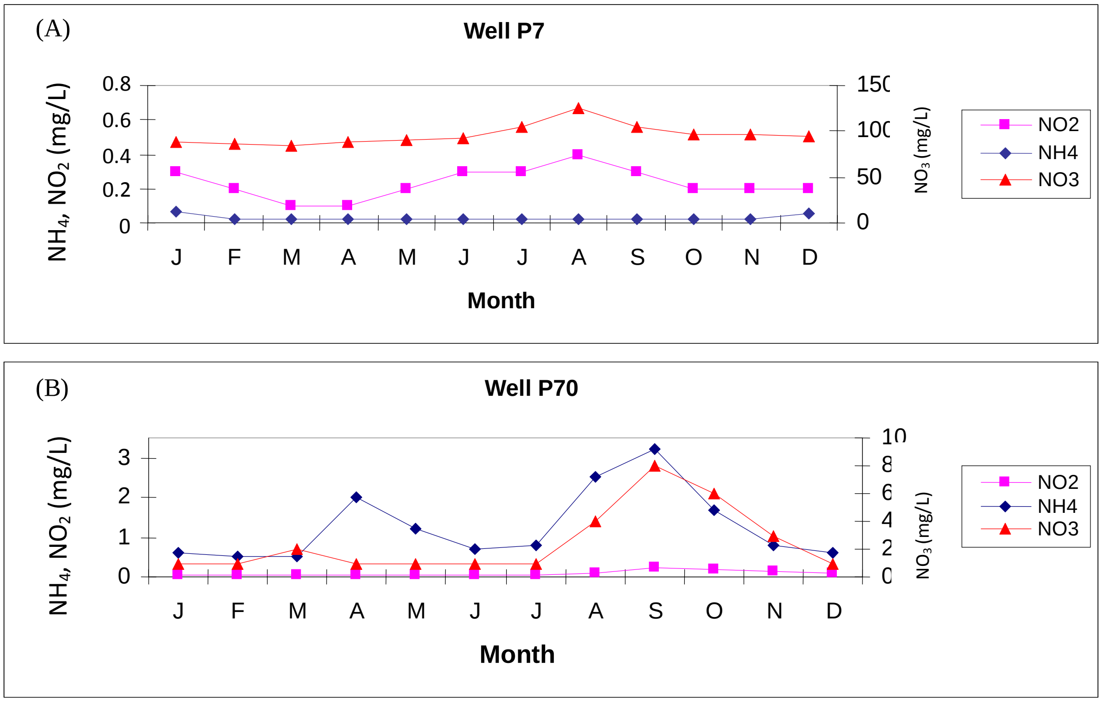

Figure 4. Evolution of the nitrate according to the soil nature.

season. In spite of an intermittency of the fertilizer contributions, the diagram of evolution of the nitrate levels (Figure 3D) is similar to the preceding case but with lower values (maximum 57 mg/L). The dilution effect caused by the winter recharge is however more efficient to lower the nitrate concentrations with 12 mg/L.

In addition, the low nitrate levels recorded on the level of the perimeters protected (as at the water No 1 point), testify to the feature not generalized of the nitric contamination. Drainage waters which join the rivers are still healthy. The main source of nitrate excess in groundwater is of agricultural origin. It is specific, since is highlighted only at plots excessively fertilized and irrigated.

Finally, it should be noted that in addition to its low efficiency, the technique of surface irrigation, not in agreement with the economy of water is largely responsible for the training of nitrate to groundwater. It also helps to maintain the level of water (close enough to the surface), favoring capillary evaporation in summer, increase in hydro-chemical contents and that of nitrates. This is also what is found in 3 out of 4 water points studied.

Soil effect on the variations of the nitrates in groundwater

To study the soil effect on the variations of the nitrates in groundwater, we considered two representative water points: one located in a zone where the roof of the aquifer is permeable (well P7) and the other in the case of an argillaceous roof (P70 well) (Figure 4).

In the well P7, with a permeable roof, the annual evolution of the chemical forms of nitrogen show a weak increase in the nitrates tenors during high water levels (December at March), (Figure 4A). For the period of high water levels; nitrites appear with weak concentrations (0 to 0.41 mg/L) and evolve inversely with the redox potential, due to the effect of the rains which bring back the water more oxygenated towards the aquifer. On the other hand, for the period of low water levels, the reduction in the redox potential under the effect of the bacterial activity will produce an increase in the nitrites. Ammonium often presents rather weak concentrations (0 to 0.071 mg/L), which indicates that the reduction of nitrates stops in the nitrite forms.

In the well P70 with an impermeable roof, the nitrate concentrations remain weak (1 to 8 mg/L), (Figure 4B). The existence of clayey intercalations in the ventilated zone slows down the transit of nitrates towards the aquifer. A peak with 8 mg/L is observed in September during the irrigation period. The ammonium form presents the same evolution and remains with weak concentrations. In period of low water levels, the values of ammonium reach 0.23 mg/L. The nitrites exist in very weak concentrations, considering their transitory character between the forms of nitrate and ammonium (Debieche et al., 2001).

The interpretation of the evolution forms the nitrogen

according to the hydrodynamics of groundwater leads to the following conclusions:

i. The contamination of groundwater of Wadi Nil is linked to inputs of nitrogen fertilizers in excess to the needs for plants,
ii. The water of irrigation and rain play a major role in the transport of nitrate ions from soil to groundwater,
iii. The clayey intercalations which can exist in the roof of the superficial layer protect the aquifer against the filtrations of the flows of nitrogen pollutants to groundwater and favor reducing conditions, allowing nitrate appear in the form of ammonium.

Conclusion

The nitrate pollution of groundwater in the valley of the Wadi Nil is of agricultural origin. The excessive use of fertilizers in the perimeters of vegetable gardening associated with important amounts of irrigation involves in-depth nitrogen excess and constitutes the principal factor in the deterioration of groundwater quality. At certain points of water, nitrate pollution exceeds 50 mg/l. Fortunately, it is confined to those areas where the groundwater is covered with excessively fertilized and irrigated cultures. The low nitrate levels recorded in protected areas and in water Wadi support this conclusion. This finding, although not very alarming, calls however on the fact that the groundwater remains under the threat of a generalized nitrate pollution, if the supply of fertilizers to cultures is not regulated and strictly controlled. It is therefore, without delay, to adopt an action plan aimed at raising awareness among farmers about the dangers of nitrate pollution of groundwater. Well adapted farming practices and rational fertilization have to be implemented to meet the requirements of good returns within the state of the environment.

Conflict of Interest

The author(s) have not declared any conflict of interests.

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