Hafiane, F. Z., Tahri, L., Nouayti, N., El Jarmouni, M., Arifi, K., Idrissi Elamrani, A., Fekhaoui, M. (2020): Assessment of spatial and seasonal nitrate variation of groundwater in the irrigated perimeter (Tadla Plain-Morocco). Agriculture and Forestry, 66 (1): 203-214.

DOI: 10.17707/AgricultForest.66.1.19

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ASSESSMENT OF SPATIAL AND SEASONAL NITRATE VARIATION OF GROUNDWATER IN THE IRRIGATED PERIMETER (TADLA PLAIN- MOROCCO)

SUMMARY

The Nitric pollution in the groundwater of the Tadla plain increases the risk of degrading the quality of water resources and creates a risk to human health and the environment. This study aims to establish the state of pollution of the groundwater by nitrates in Béni Aamir and Béni Moussa aquifers, to follow its temporal evolution and to map its spatial distribution using Surfer software. To assess the contamination of well water by nitric pollution, 200 samples were collected in four seasonal campaigns between March 2017 and May 2018, with a rate of 43 samples taken per season. The spatial distribution of nitrates in the groundwater shows that the majority of the catchment points reached by this pollution are located in agricultural areas. Additionally, there was a range of 160.15 mg/L (4.65–164.5 mg/L). The temporal distribution of nitrate in the groundwater of Béni Aamir and Béni Moussa shows an increase in response to the agricultural intensification in this region, and a variation depending on the period of withdrawal. Including the increase in the quality degradation in all wells, from 1% in campaign N°01 to 7.06% in campaign N°02 and to 5.7% in campaign N°03, and to 0% as very bad quality in campaign N°04. The fact that the campaign N°02 has been carried out during the agricultural season, proves the link between the Nitrate pollution and chemical products uses during this period. Therefore, the impact of chemical products uses on the groundwater quality in this region.

Keywords: environnement, groundwater, nitrate, pollution, Tadla Plain.

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Notes: The authors declare that they have no conflicts of interest. Authorship Form signed online.

Received:31/12/2019 *Accepted:09/03/2020*

INTRODUCTION

Groundwaters are the second largest freshwater reservoir on Earth after that of the polar glaciers. Aquifers are therefore exploited for irrigation but above all for the supply of drinking water to the population (Matzeu et al, 2017). This essential resource for life is too often exposed to problems of domestic, industrial or agricultural pollution (Zeddouri et al, 2013). In Morocco, water availability has so far been very limited and is likely to decrease significantly in the long term. As well as, the World Bank's 2018 forecast estimations triggered the alarm bell. Indeed, renewable water resources per capita are likely to be reduced by half, from 750 m3/hab/year in 2000 to 500 m3/hab/year in 2030, thus classifying Morocco as a country in a situation of chronic water stress (El Menouar, 2012). The deterioration of the quality of water resources through the proliferation of different sources of pollution (fertilizers and pesticides, untreated wastewater discharges, uncontrolled solid waste discharges, urbanization, etc.) is as significant a threat as that linked to quantitative imbalance (Nouayti et al, 2015).

Since the 1980s, the Tadla plain has undergone considerable progress in terms of hydro-agricultural development, which is still ongoing in other extension areas. It actively contributes to the increase of national agricultural production (Rico et al, 2000). Nevertheless, the emergence of problems of natural resource degradation, including nitric pollution of groundwater, has incited the managers of the perimeter to implement promising projects aimed mainly at improving the competitiveness of irrigated agriculture in Tadla through rational management and preservation of the quality of its resources (Hafiane et al., 2019; El Hamidi et al, 2018). In this context, an intensification of research on the whole plain is becoming necessary in order to determine the sensitivity of the resource to any form of pollutant introduced from the soil surface, and hence the importance of establishing the state of groundwater pollution by nitrates and of monitoring its temporal evolution. Nitric nitrogen, which is largely derived from human activities, is a major health and environmental problem when it is found in the natural environment, particularly when the resource is destined for the production of drinking water (Zhai et al, 2017).

The diagnosis of the nitric quality of groundwater, conducted on groundwater in the region's agricultural zone, showed that nitrate levels are higher than the water potability standard set at 50 mg/L. This spatial variability of water nitrate levels also indicates diversity in their origin, and given the data on the annual increase in nitrate level in groundwater show that the water situation is likely to become worrisome if appropriate measures are not taken immediately. Thus, our study consists in deepening the current state of knowledge through the identification and analysis of nitric pollution.

MATERIAL AND METHODS

Study zone

The Tadla plain (Fig. 1) is located approximately 200 km southeast of Casablanca in the Beni-Mellal province. It extends over a large portion, estimated at 3,600 km², of the middle basin of Oum-er-Rbia between the High Atlas in the south and the Phosphate plateau in the north (Hafiane et al, 2019).

The plain is intersected for approximately 160 km from east to west by the Oum-er-Rbia wadi, which splits it into two vast hydraulically independent irrigated areas: the Beni Amir and Beni Moussa perimeters on the right and left banks of the Oum-er-Rbia, respectively. The Beni Amir are irrigated from the waters of Oum-er-Rbia (Kasba-Zibania diversion dam), and the Beni Moussa from the waters of the Oued el Abid (Bin el Ouidane dam). The total irrigated area is about 124,000 ha (Taibi et al, 2015).

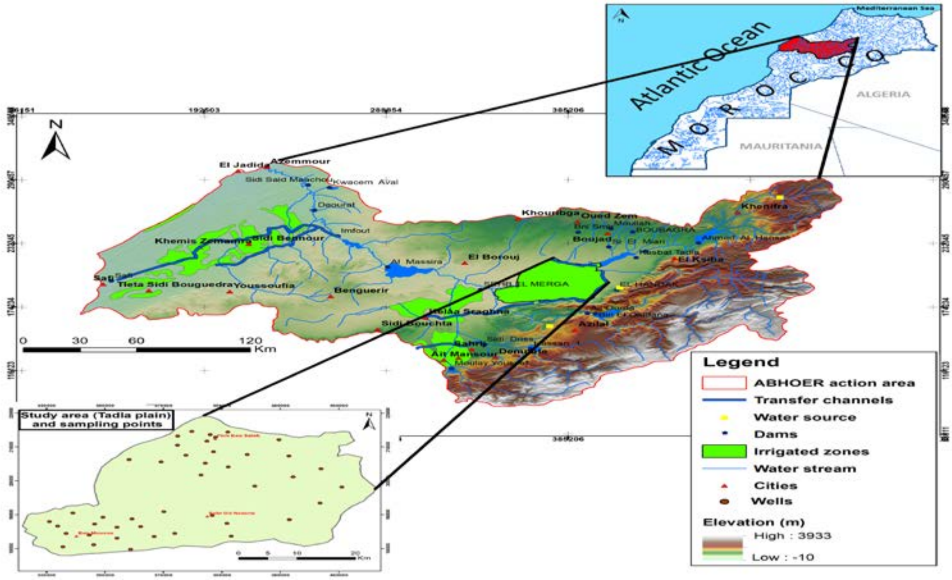

Fig. 1. Geographical location of the study zone in Central Morocco

Sampling and Analysis

Sampling is carried out on both groundwaters (Fig. 2). The sampling points are then determined and located on maps developed using the Geographical Information System (GIS). These points are selected according to the information collected through the survey, the study covers forty-three (43) wells located in areas where the sources of pollution are major, these are intensive pastoral or agricultural fields. The 43 wells chosen are strictly among those where chlorination is not practiced. They have easy access to agricultural fields. Water samples are placed in sterile polyethylene vials rinsed with distilled water and sample water beforehand. These water samples are then transported in a cooler at 4°C and processed in the laboratory within 24h of collection.

On the basis of groundwater analysis campaigns covering both dry and wet periods, water samples were collected in collaboration with the Tadla Regional Office for Agricultural Development (ORMVAT) and the Oum Er Rbia Hydraulic Basin Agency (ABHOER) during the period March 2017 - May 2018, for a total of 43 wells per campaign. The analyses were carried out according to the NM ISO 7890-3 (2012) standard at the "ABHOER" laboratory. The physical parameters were measured in situ, focusing primarily on temperature, electrical conductivity and hydrogen potential. The coordinates of the water points are verified using a GPS.

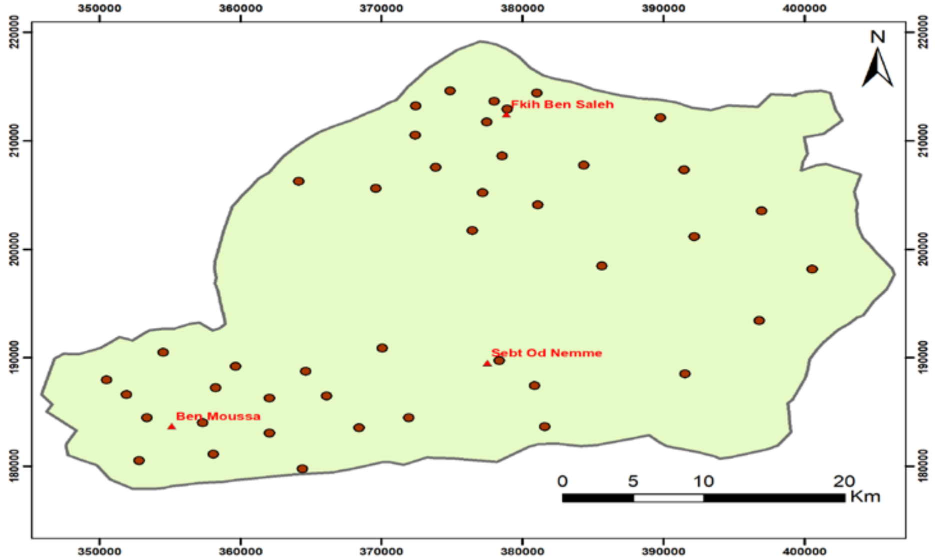

Fig. 2. Wells water in the perimeter of (Beni Moussa & Beni Aamir)

Samples of (1L) one liter are taken in polystyrene vials and deposited in a refrigerated place, then sent to the ABHOER water chemistry laboratory in Beni Mellal within 24h of the sample being collected. A spatio-temporal portrait of each campaign according to the season (dry or wet) was well drawn up to determine the geographical nitric pollution in the area studied by the Surfer software.

RESULTS AND DISCUSSION

The determination of water quality requires the positioning of each element measured on an evaluation grid containing the threshold limits of each parameter, thus permitting the degree of water pollution to be determined. During this study, the evaluation system adopted is the one that subdivides water quality into four levels: Very Good (blue color), Acceptable (green color), Mediocre (yellow color), Poor (red color), Very Poor (purple color). This evaluation grid is applied on the basis of the results of the analyses obtained.

The results obtained concerning the sampling points are part of a study that covers the period between March 2017 and May 2018, which revealed the following observation (Fig. 3).

The groundwaters Beni Aamir and Beni Moussa are more affected by nitric pollution in campaign 02, i.e. all the points showed 41.6% Poor to very Poor quality followed by both campaigns 01 and 03 such that 39.7% Poor to very Poor quality. While the campaign 04 showed excellent to average quality in all points 96.16% with low contamination 5.7% to poor quality in all wells. This period, the groundwater was the most favorable period in terms of quality status compared to others.

There was also an increase in the degradation of groundwater quality in all wells from 1% very poor quality in campaign 01 to 7.06% in campaign 02 and 5.7% in campaign 03 followed by 0% very poor quality in campaign 04 in all wells, this is explained by the decrease in fertilizer use and groundwaters regeneration through the succession of dry and wet periods.

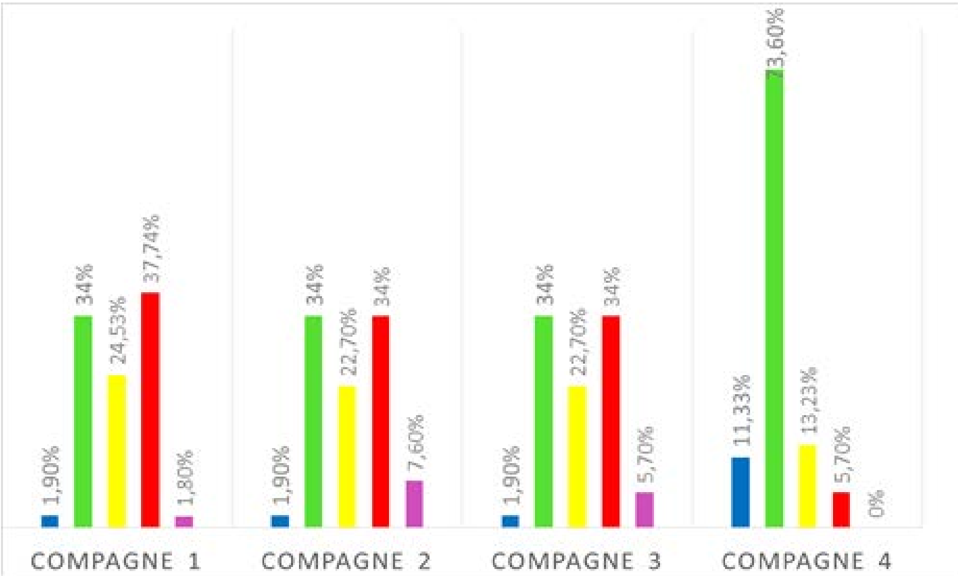

Fig. 3. Statistical analysis of nitrate results for the four campaigns

The interpretation of the map (Fig. 4) through spatial analysis showed that the wells studied have different spatial variations from one well to another, these values vary between 4.65 mg/L to 150 mg/L, upstream an excellent quality was recorded in well 28 (4.65 mg/L), while well 24 showed a very poor quality (146.98 mg/L).The wells (5, 6, 7, 8, 12, 32, 34, 35, 36, 37, 38, 39 and 43) showed values ranging from 5 to 25 mg/L with good quality. The wells (3, 4, 14, 16, 17, 20, 22, 23, 29 and 42) showed values ranging from 25 to 50 mg/L with average quality.

As for the wells (1, 2 ,9 ,10,11,13,15,18,19,21,25,26,27,30,31,33,40 and 41), they showed values ranging from 50 to 100 mg/L with poor qualities. The spatial analysis of the map (Fig. 5) showed that the wells studied have different spatial variations across wells, values range from 4.65 mg/L to 154 mg/L. The upstream part is more affected by contamination (very poor to poor quality) while the downstream part has an excellent to average quality except for two wells (32 and 43) with very poor quality. Whereas the well (4) has an excellent quality. The wells (1, 2, 3, 5, 6, 7, 8, 9, 15, 16, 17, 18, 19 and 37) have shown values ranging from 5 to 25 mg/L with good quality. The wells (11,12 ,14, 22,23, 27,35,36, 41and 42) showed values ranging from 25 to 50 mg/L with average quality.

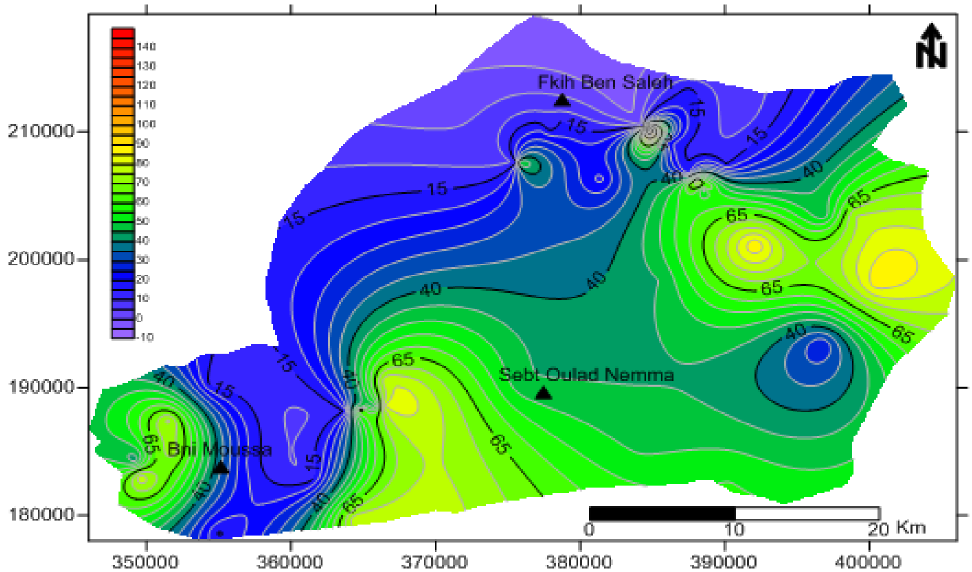

Fig. 4. Map of spatio-temporal variation of nitrates during the campaign 01.

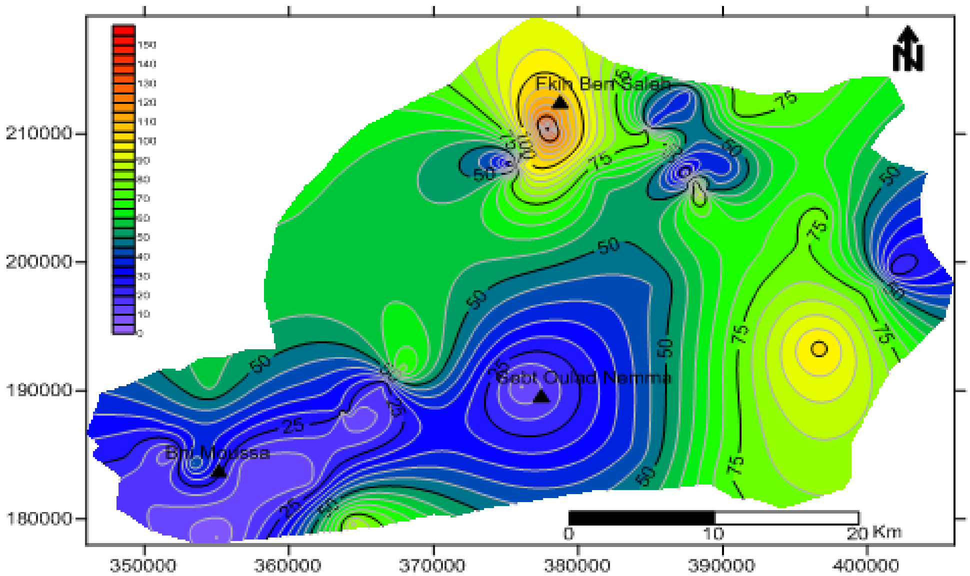

Fig. 5. Map of spatio-temporal variation of nitrates during the campaign 02.

The wells (21, 23, 24, 25, 28, 29, 33, 34, 39, 40 and 43) have reported values ranging from 50 to 100 mg/L with poor quality. Also, the wells (31, 32 and 30) showed values > 100 mg/L with very poor quality. The interpretation of the map (Fig. 6) by spatial analysis has also shown that the wells have different spatial variations from one well to another, the values vary between 5.7 mg/L and 164.5 mg/L, the upstream part is more affected by contamination (very poor to poor quality) with the exception of the four wells (30, 31, 40 and 42) with good quality.

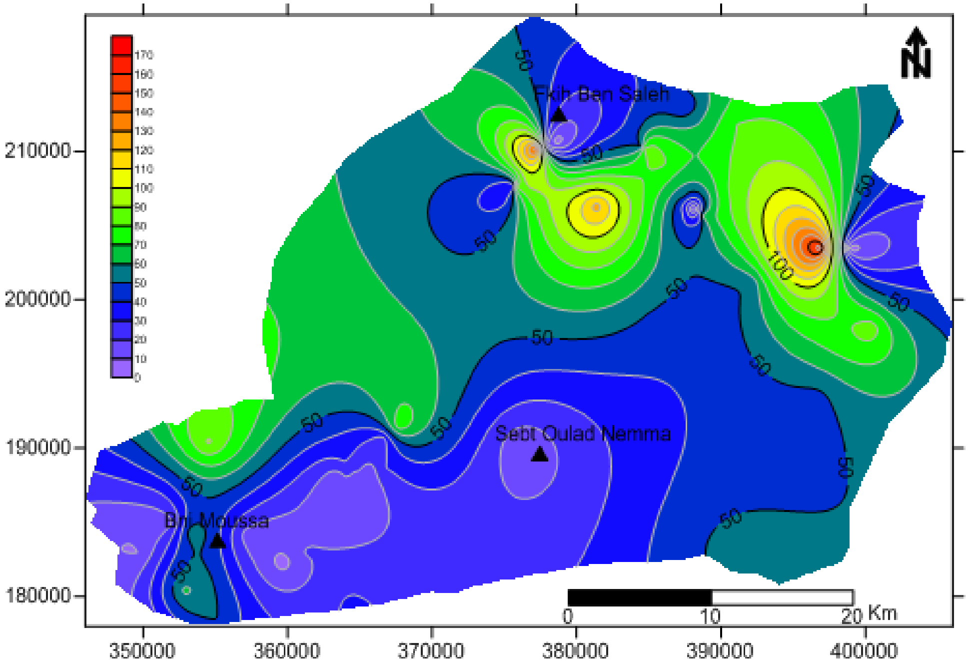

Fig. 6. Map of spatio-temporal variation of nitrates during the campaign 03.

The wells (2, 3, 4, 6, 8, 9, 10, 11, 12, 13, 15, 16, 17, 19 and 20) showed values ranging from 25 to 50 mg/L with average quality especially in the downstream Beni Moussa zone. The wells (21, 23, 24, 25, 26, 28, 29, 33, 34, 35, 38, 39, 41, and 43) have reported values ranging from 50 to 100 mg/L with poor quality. As for the wells (1, 5, 7, 14, 18, 22 and 32), showed values > 100 mg/L with very poor quality.

Interpretations of the map (Fig.7) by spatial analysis showed generally average to good quality with the exception of the three wells (23, 31 and 43) with poor quality. The wells (30 and 35) showed an average quality, and wells (1. 9, 10 and 15) have reported values with very poor quality. Generally, season 04 remains the good period compared to contributions to other periods.

It can be concluded that the four nitrate maps showed a spatio-temporal variation in quality according to the sampling periods, these variations are due to intensive and irrational agricultural activities.

According to all the maps (Fig.4.5.6 & 7) it can be concluded that nitrate levels are very high throughout the southern part of the groundwater, more precisely the southwestern part of Beni Moussa and the northwestern part of Beni Aamir and this is due to the flow direction from the NE to the SW, as demonstrated with (Arauzo et al., 2017; Chidya et al., 2016; Fetouani et al., 2008; Ouedraogo et al.,2016). So according to this spatial diffusion of pollution, it can also be deduced that nitric pollution is more concrete in the agricultural areas that are most affected.

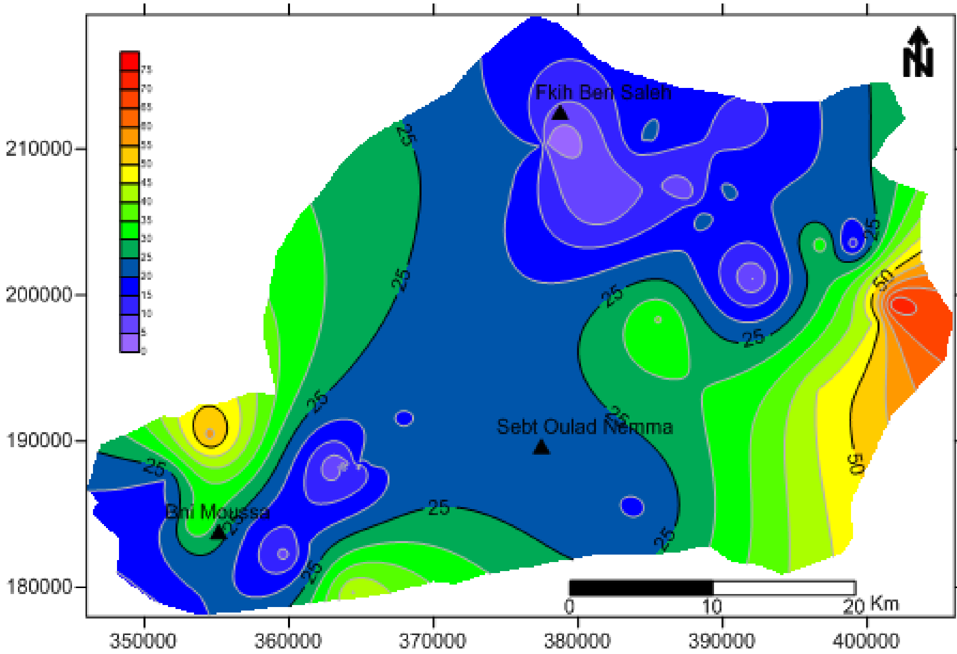

Fig. 7. Map of spatio-temporal variation of nitrates during the campaign 04.

The main sources of industrial pollution are located in the groundwater of Beni Amir and Beni Moussa (sugar factories, canneries, oil mills and dairy plants); have a major impact on the increase in nitrate levels and organic matter. Each map shows a North-South progression of the nitrate pollution front throughout the groundwater. The variation in the spatial and temporal profile of the observed high nitrate levels would be related to the degree of urbanization. Indeed, the South-East and South-West parts are cities, villages (Béni Mellal city and Oulad Moussa Commune) highly urbanized with an industrial session. Agriculture contributes to groundwater pollution because of the often-irrational use of fertilizers and pesticides that farmers add to improve the productivity of the plot.

The quantity of nitrogen leached to the groundwater or runoff reaches the Tadla groundwater by leaching. According to (Barakat et al., 2016; Bentekhici et al., 2018; Lalami et al., 2014; Lagnika et al., 2014; Nouayti et al., 2015), they have come to similar conclusions. The origin of nitrates in groundwater can be multiple. Nitrates are very often the result of agricultural activities (fertilizers, industrial breeding) as demonstrated with (Hamutoko et al., 2016; Moussa et al., 2018). This degradation seems to be mainly due to human activity; this conclusion is similar to (Zhai et al., 2017).

Nitrogen fertilization of the surrounding agricultural areas at the points studied, waste water, lost wells and livestock waste, the results achieved are similar to the conclusions reached by (Barakat et al.,2016; Fetouani et al.,2008; Lagnika et al., 2014; Nouayti et al., 2015; Matzeu et al., 2017; Vrzel et al., 2016), including animal excreta. The high nitrate levels sometimes correspond to the reduction of nitrates to nitrites by reducing aerobic bacteria, the same conclusions of which can be found in a study by (Heriarivony et al., 2016; Lamribah et al., 2013). In addition, in natural water, whether groundwater or surface water, nitrate mineralization (N mineralization) can have several origins. Indeed, in the Tadla plain, work that reports excess nitrate in groundwater is increasingly frequent (Barakat et al., 2016; Chidya et al., 2016; El Bouqdaoui et al., 2009; Stuart et al., 2011).

This spatial variability in nitrate levels can also be due to the nitrogen provided by meteoric waters as demonstrated by (Shen et al.,2019). The high levels of nitrates found in the waters of the Quaternary aquifer are of urban origin due to the infiltration of domestic wastewater into the ground, sewage, septic tanks, latrines and the decomposition of organic matter, according to (Chidya et al., 2016; El Bouqdaoui et al., 2009; Martinelli et al., 2018). Furthermore, nitrate levels above the WHO and NM guidelines have been reported in Moroccan groundwater by (Barakat et al., 2016; Bricha et al., 2007; El Bouqdaoui et al., 2009; Fetouani et al.,2008; Nouayti et al., 2015). It can also be deduced that the spatial variation in nitrate quantity is probably related to the depth and design techniques of the wells. In fact, the contamination of the groundwater is due to the piezometric level, it is noted that these results are similar to the those of (Ahoussi et al., 2013; Barakat et al., 2016; Fetouani et al.,2008; Martinelli et al., 2018) which showed that the groundwaters are the richest in nitrates. These, given their shallow depth, are the most vulnerable.

Finally, let us not underestimate the health risk associated with the consumption of this groundwater by the sedentary population, and precisely by infants. According to (Ameur et al., 2016; Shen et al.,2019; Zhai et al., 2017; Degbey et al., 2011), the same result was also found that young children were the most vulnerable group to exposure to nitric contamination.

CONCLUSIONS

The spatial distribution of nitrates in the waters of the Quaternary aquifer in the irrigated area shows that the majority of the points that capture this aquifer are subject to nitrate pollution. This variation in nitrate levels is related to population growth and rapid urbanization in the area, and also with a view to ensuring agricultural development, agricultural supply in high productivity sectors has significantly improved. This positive momentum has been further boosted by the Green Morocco Plan (GMP), which has led to the expansion of these products and the increased use of fertilizers and pesticides. This highlights the great pressure exerted by human activities on the groundwater of the said aquifer, which contributes to the degradation of its quality. This spatialized approach to nitric contamination allows interested organizations to ensure sustainable management of groundwater resources. It is a decision-making support tool for spatial planning and development by identifying the areas most threatened by nitric pollution.

ACKNOWLEDGEMENTS

Authors are especially grateful to acknowledge the Department of agricultural development (DDA) of Tadla and Department of irrigation and drainage network management (DGRID) of Tadla for his assistance in this study. Authors also would like to acknowledge the staff for their kind help in sampling collection.

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