

Groundwater Quality Surroundings Mining Activities Areas in Arlit Region (Tim Mersoï Basin, North Niger)

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Abstract: The study area is a semi-arid area located in the Arlit region. This area contains significant uranium deposits that have been mined by two mining companies since 1968. The objective of this study is to determine the impact of these activities on existing aquifers, in particular Izegouande aquifer. A methodological approach based on hydrochemical methods focusing on the analysis of nitrates and sulfates showed that waters of Izegouande aquifer have high nitrate concentrations ranging from 16 mg/L to 60 mg/L, higher than WHO (World Health Organization) standards drinking water. In addition, these waters show elevated sulfate levels ranging from 16 mg/L to 57 mg/L, therefore acceptable. These high concentrations of nitrates and sulfates are located mainly near wastewater treatment of Arlit city and near industrial zone, which are potential areas for transfer of these elements such as nitrates and sulfates. It is therefore urgent to carry out periodic and regular checks on groundwater in these areas.

Key words: Groundwater quality, mining impacts, nitrates, sulfates, Arlit, Niger.

1. Introduction

In Niger, the mining sector is a significant part of the economy. In Agadez region, this sector is more developed with the presence of several mining companies. The first mining companies exploit uranium mineralization located in Tim Mersoï basin, west bordering of Aïr massif since the early 1960s. The western edge of the Aïr massif is a semi-arid region. Despite the scarcity of surface water, the Arlit zone has considerable potential of groundwater resources and significant uranium deposits [1-4]. This uranium potential has been exploited since the late 1970s by two companies: SOMAÏR (1969) and COMINAK (1976). The latter closed due to the depletion of the uranium reserve in 2020. The uranium resource was accompanied by excessive pumping and negative impacts on groundwater quality in Arlit region [5, 6].

The Tarat aquifer is the main pumped due to these well hydrodynamics characteristics, for water supply

and for industrial activities in the Arlit region. This aquifer has been exploited since 1968 for water supply and industrial operations such as treatment of uranium and dust suppression.

The increase in uranium production in recent years (from 2620 tons in 2010 to 3065 tons in 2012), followed by an ever-increasing population explosion in the city of Arlit and Akokan, has corollary which is an increase of demand for drinking water and also for industrial needs. The formation of Tarat, in addition to being an aquifer, it contains uranium mineralizations.

The Tarat, an aquifer geological formation, also contains mineralization. Thus, some deposits, are below the static level of aquifer hence the need for dewatering of these deposit [6].

This high pressure on this aquifer, first through the supply of drinking water to the population, and then through mining activities, has led to a significant decline in groundwater piezometry since it began operating [7].

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It is in this context that the mining companies turned on the Izegouande aquifer which already ensured for the supply and drinking water of populations [4] with Tarat aquifer. The Izegouande aquifer, due to its shallow depth (40 m) in east of the Arlit flexure, knows a degradation of the quality of its water which is a direct impact of mining activities. Thus, it is therefore urgent to identify the areas impacted by mining activities for better management of these resources in this semi-arid region. It is in this context that the present study aims to locate the areas of the Izegouande aquifer affected by mining activities in Arlit sector.

2. Materials and Methods

2.1 Study Area

Located in northeast part of the country, specifically between longitudes 7°15' and 7°30' East and latitudes 18°30' and 19° North, the town of Arlit is approximately

1200 km northeast of Niamey, capital of Niger, and approximately 250 km northwest of historic town of Agadez. Arlit is located at 4.5 km from Akouta (Fig. 1). The latter was created in 1974 with a creation of COMINAK Company (Akouta Mining Company). The climate is desert, hot semi-arid, characterized by a high temperature with an annual average of 28.7 °C [7, 8]. In a day the temperatures are high with a thermal amplitude up to 30 °C in exposed environments. The area is characterized by a long dry season from October to April and a rainy season from May to September).

Winds associated with high temperatures are responsible for high evaporation. In this region, wind is the main source of transport of eroded materials. The study of the direction of local winds reveals a strong predominance of North-East winds and to a lesser extent South-East and South-West winds. There are also inversions of wind directions between the dry and wet seasons.

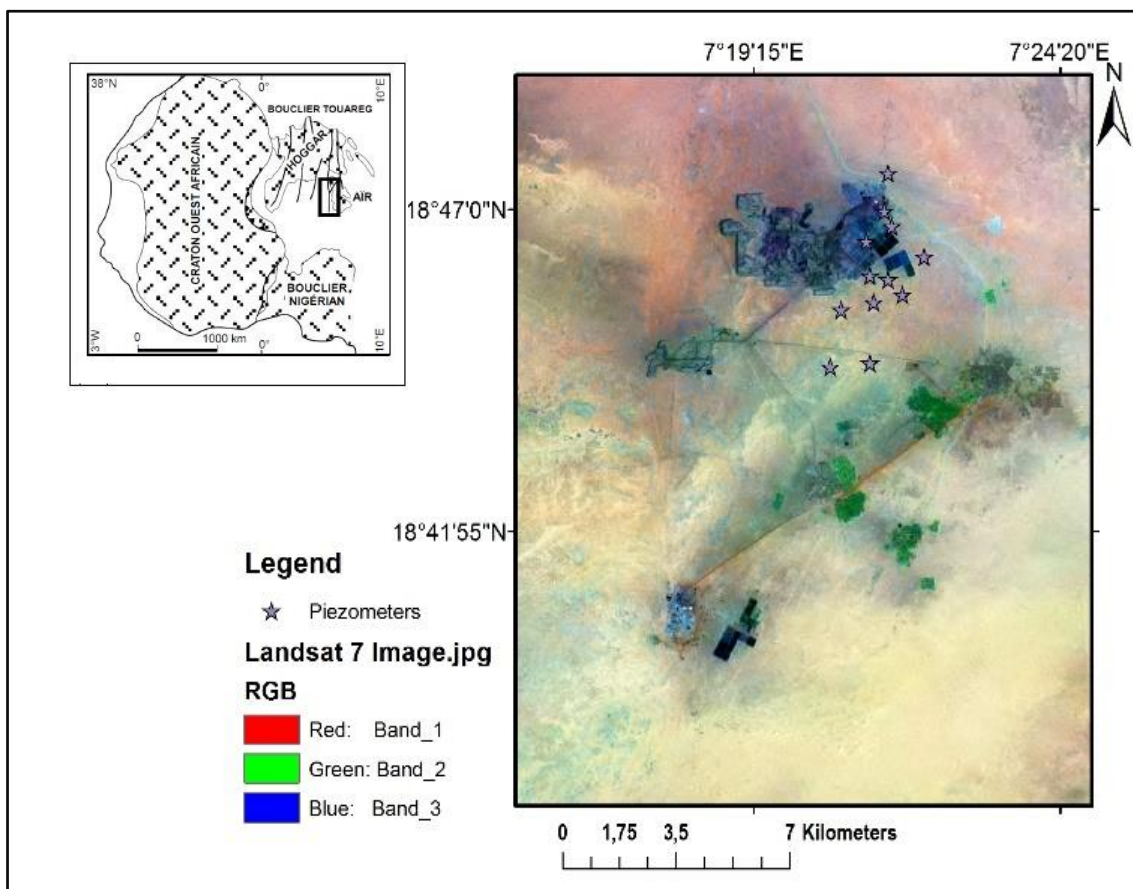


Fig. 1 Location of study area.

2.2 Geological and Hydrogeological Contexts

2.2.1 Geological Context

The Tim Mersoï basin represents a branch towards the north of Iullemeden syncline [9]. It forms a gutter framed by the ridge of In Guezzam to the west and east by Aïr massif [10]. It sinks northwards into the Hoggar massif to Algeria where it takes the name of syncline or Tin Seririne basin [9, 11]. Its western flank has a low slope until the lineament of In Azaoua-Arlit. But by the way of this structure, the basin becomes deeper to the north and west [12-14]. On its eastern edge, the formations present successive stratigraphic bevels that come to south be based directly on the basement of Aïr massif (Fig. 2).

The stratigraphic breakdown (Fig. 3) in Arlit region shows the following series [15]:

The Precambrian: crystallines rocks and Devonocarboniferous, is divided into three series from bottom to top:

- Terada series;
- Tagora series lower;
- Tagora lower series.

Each of these series begins with a sandstone formation, fluvio-glacial at Teragh in Terada, fluvio-estuarian at Guezouman in the lower Tagora (with at the base the radioactive conglomerate of Teleflak) and fluvio-deltaic at Tarat, in the upper Tagora. Each series continues with a marine episode with epicontinental: of Talak shales in Terada, Tchinezogue in lower Tagora and Madaouela in Upper Tagora. These series can end with a fine silty sandstone level: Akokan unit in Terada and Arlit unit in the upper Tagora.

The structuring of Tim Mersoï basin is linked to a division of the base, inherited from the Pan-African Orogenesis. It is characterized by large accidents N-S direction (Arlit lineament) and by a secondary division following a NNE-SSW and ENE-WSW network resulting from the reactivation of basement structures in an upper Panafrican [11, 14, 17].

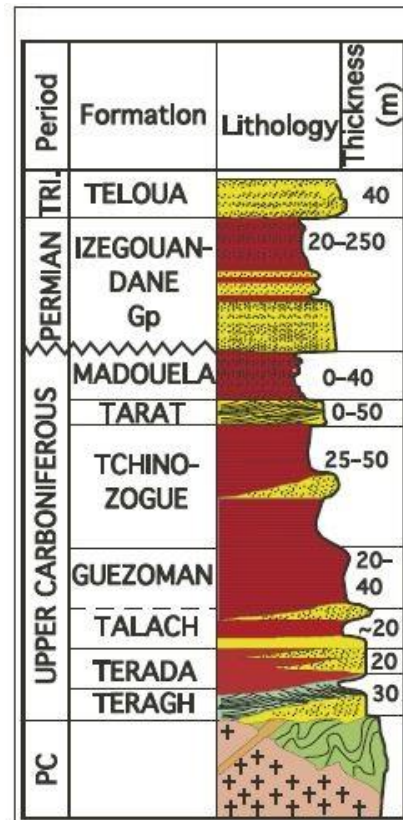


Fig. 2 Generalized geology of northern Tim Mersoï Basin [16].

2.2.2 Hydrogeological Context

At the local level, in Arlit department, hydrogeology (Fig. 3) is well known during the studies conducted as part of mining research. These studies were used to estimate the characteristics of each aquifer [2, 7].

The Guezouman aquifer is formed by the Guezouman formation composed by a clay and sandstone (100 to 200 m deep) [18]. It can thus be considered that the Guezouman aquifer is independent of underlying and overlying aquifers. The Guezouman thick is at 30 to 70 m with an average value of 40 m [2]. Transmissivities are also low, ranging from $1.5 \cdot 10^{-6}$ to $1.8 \cdot 10^{-4}$ m²/s and the storage coefficients are homogeneous values around $4.5 \cdot 10^{-5}$ [19].

The Tarat aquifer is formed by the sandstone series of Tarat formation. This aquifer is characterized by an important thickness variation due to the tectonic structures and the mode of sedimentation. The Tarat aquifer is

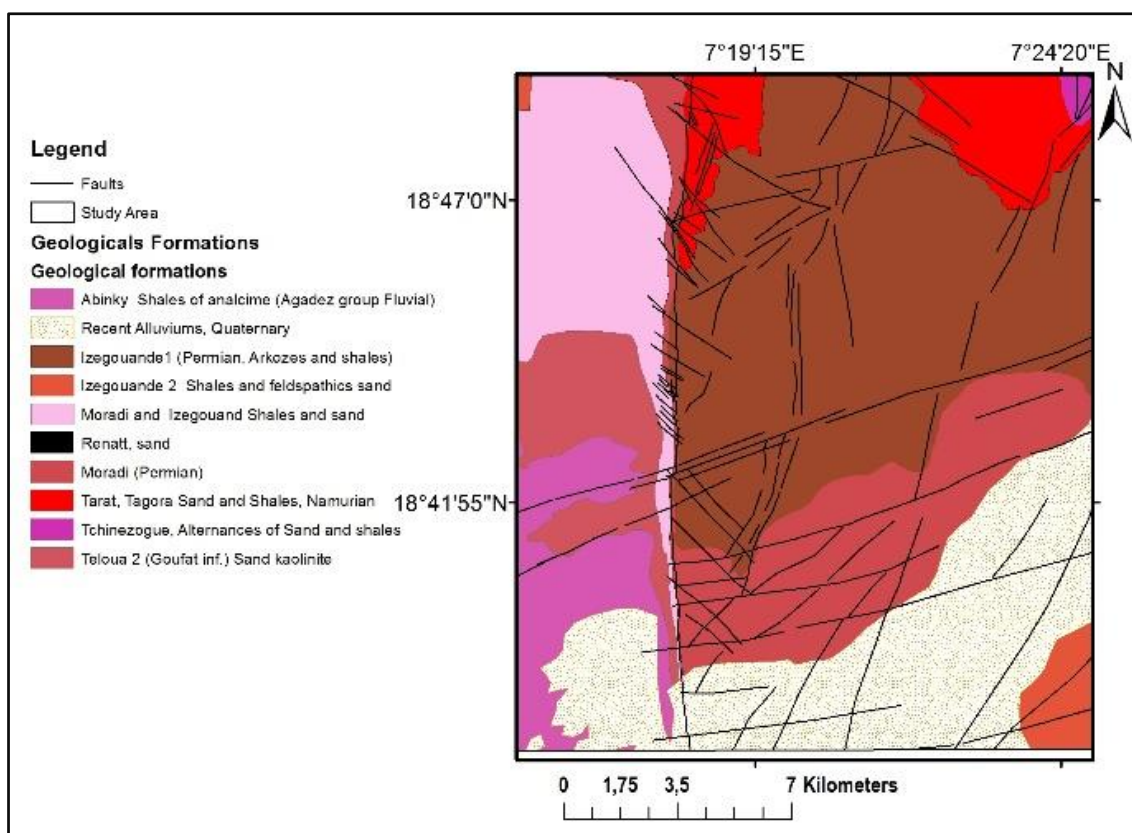


Fig. 3 Geological map of study area.

limited in north and east by its limit of extension and to the west by Arlit fault. The permeabilities are between $7.8 \cdot 10^{-7}$ and $1.2 \cdot 10^{-4}$ m/s and the transmissivities range from $7.4 \cdot 10^{-5}$ to $1.1 \cdot 10^{-3}$ m²/s with storage coefficients being around 10^{-5} [19].

The Izegouande aquifer is constituted by a sandstone and shales of Izegouande formation. However, some tests carried out in the northern Arlit zone showed that the groundwater was rather contained in the lenses of summative modest dimensions of arkosic sandstone, which were especially abundant towards the base of this formation [9]. The permeabilities values are low and range from $1.2 \cdot 10^{-6}$ to $7.5 \cdot 10^{-7}$ m/s and the transmissivities are also low and range from 110^{-4} to $7.8 \cdot 10^{-5}$ m²/s.

2.3 Methods

2.3.1 Sampling

The sampling sites are selected according to the hydrogeological characteristics of the Izegouande

aquifer, so as to sample the aquifer throughout the area. Moreover, given that the Izegouande aquifer is not deep in the study area, it represents the main source of water supply in and it has been subject to much more sampling than the other units. All the piezometers are georeferenced and plotted on geological map (Fig. 4). The network of piezometers to monitor the Izegouande aquifer is in mining sector.

Piezometers captured the Izegouande aquifer are located around the mine located in Arlit city. Twelve (12) piezometers are regularly monitored and were sampled each July except Piezometers 10 and 11 the two piezometers realized in 2011.

2.3.2 Analyses of Samples

In this study, measurements of chemical parameters and sampling were carried out in the piezometer network set up after pumping at least 30 min of pumping to obtain a more representative water of aquifer. The chemical analyses carried out by usual methods mainly concerned two parameters, nitrate and sulfates. The dosage of

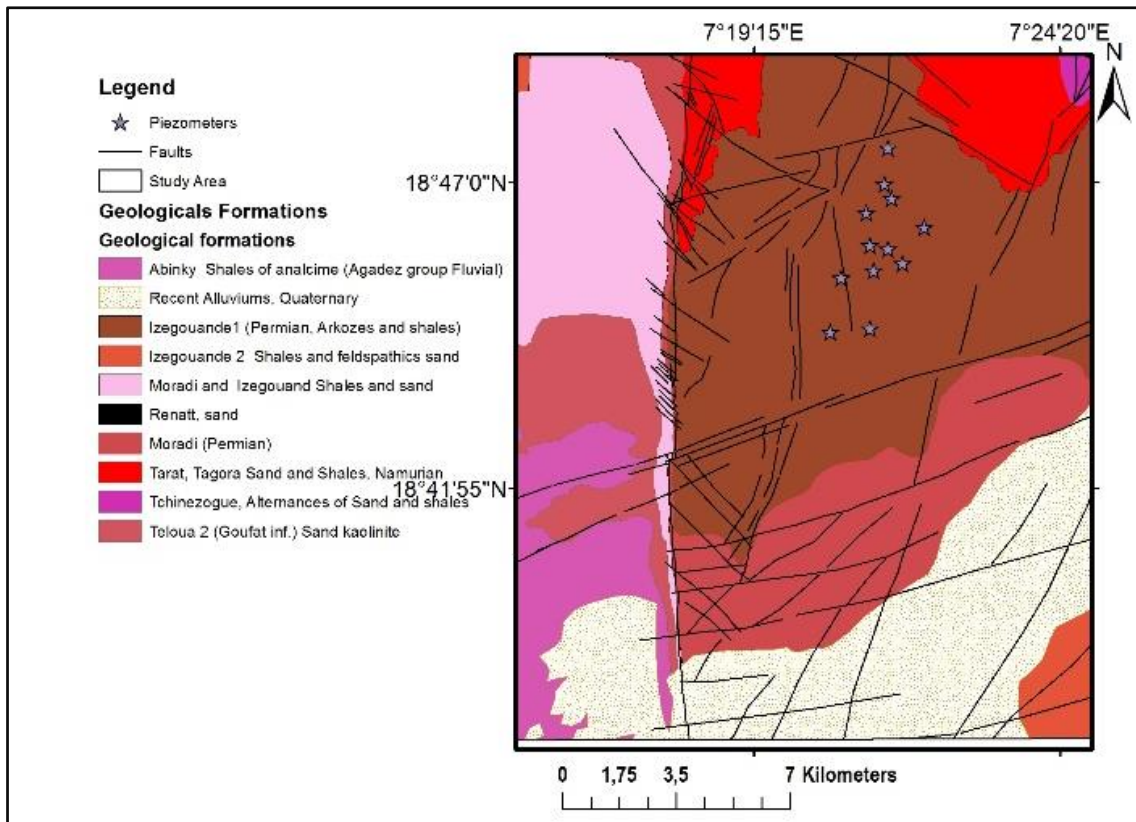


Fig. 4 Sampling piezometer.

these two chemical elements are performed by spectrophotometer for NO_3^- and SO_4^{2-} . The main focus of the chemical data processing is on the elaboration of temporal evolution graphs for certain parameters mainly nitrates and sulfates.

3. Results and Discussion

3.1 Nitrates Concentrations in Groundwater

The Piezometer P1 carried out in 2006 (Fig. 5) shows very high nitrate concentrations exceeding those admitted by the WHO (World Health Organization) [20] (50 mg/L). These levels range from 58 in 2011 to 62 mg/L in 2009. This clearly shows the contamination of the Izegouande water table even before my realization of the piezometer P-1 because the nitrate concentration in 2006, date of the realization of P-1 is 59 mg/L clearly superior to the WHO [20] standards.

The P1 piezometer is located near the city's wastewater treatment. In this area, the water quality of

the Izegouande aquifer has been monitored since its reuse in 2006. Two other piezometers, Am9 and Ar6, installed at 900 m to the northeast and 1,500 m to the northwest of the treatment, give nitrate concentration values since their completion in 2010.

The piezometers P12 and P13 show concentrations higher than those observed in the zone for nitrates (around 600 mg/L in 2012). Among the concentration anomalies, only nitrates (80 mg/L) are still noticeable in the piezometers Am9 and Ar6.

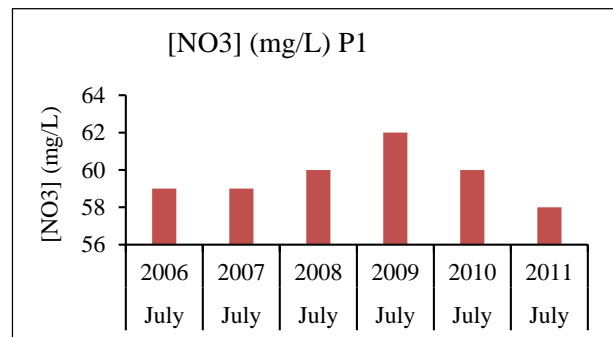


Fig. 5 Nitrate concentration in Piezometer P1.

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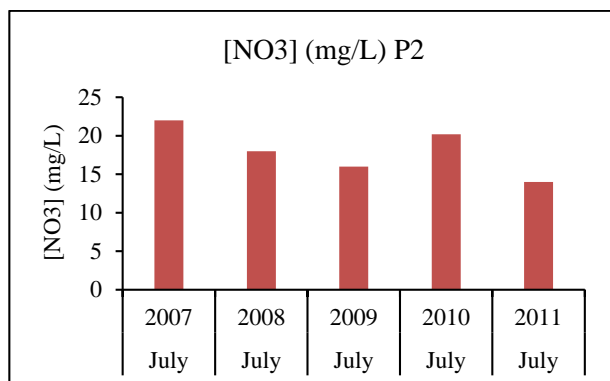


Fig. 6 Nitrate concentration in Piezometer P2.

The piezometers P2 (Fig. 6) show nitrate concentrations of 14 mg/L in 2011 to 22 mg/L in 2007. These high values are observed during the year 2007 in connection with the increase of uranium production. The low levels were observed in 2011, with a decrease of Uranium production by SOMA R.

Wastewater treatment plants are the discharge point for all wastewater in the city of Arlit. They were carried out on the outcrop area of Izegouande formation. Therefore, they constitute potential zones for the infiltration of wastewater into the Izegouande aquifer. The piezometer P2 is located around these purification stations. The piezometric levels measured in the Izegouande groundwater near the treatment plants (piezometers P12 and P13, in order of 395 m) exceed by several meters those measured in the sector (piezometers Ar6 and Az9, in order of 390 m). This shows that there is a recharge of the water table by infiltration of wastewater [21-23].

The piezometers P3 realized in 2006 (Fig. 7) show relatively low values of nitrate contents. These values range from 23 in 2005 to 35 mg/L in 2006, these levels are. From 2006, nitrate concentrations in groundwater decreased. This reduction in nitrate levels could be explained by checks carried out on the piezometers as well as the environmental attenuation measures carried out by environmental monitoring [24, 25]. In the sector of piezometer P3, nitrate concentration does not exceed the WHO [20] standard (50 mg/L) and the Izegouande aquifer is weakly affected by nitrate pollution who only reduces during the years.

3.2 Sulfates Concentrations in Groundwater

The P2 piezometer (Fig. 8) shows relatively high sulfate levels ranging from 16 mg/L in 2011 to 29 mg/L in 2006 and 2010. These values show a decreasing trend from 2006 to 2011 except for 2010, during which an increase in sulfate concentration in water is observed. This could be related to occasional accidental changes [21, 24].

Sulfate levels range from 29 mg/L in 2010 and 2011 to 60 mg/L in 2005 (Fig. 9). This shows that sulfate concentrations decrease over the years. These values are always below the WHO [20] threshold (500 mg/L). However, these concentrations of sulfate are significantly higher than the regional content of sulfate. These high values above the regional hydrochemical bottom could be explained by deverssement of products resulting from the storage of sulfur but also by leaching of heaps and probably by infiltration of the effluents at the level of the basins [22-24].

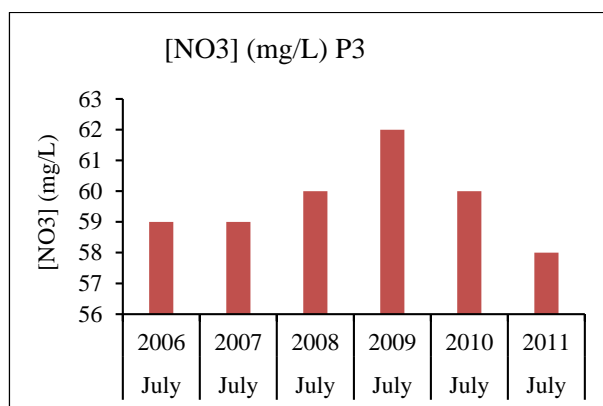


Fig. 7 Nitrate concentration in Piezometer P3.

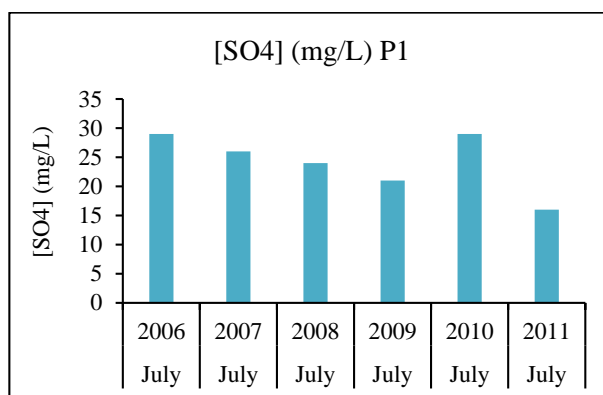


Fig. 8 Sulfate concentration in Piezometer P1.

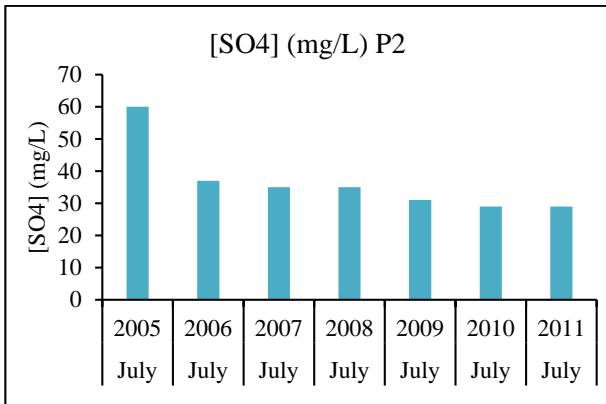


Fig. 9 Sulfate concentration in Piezometer P2.

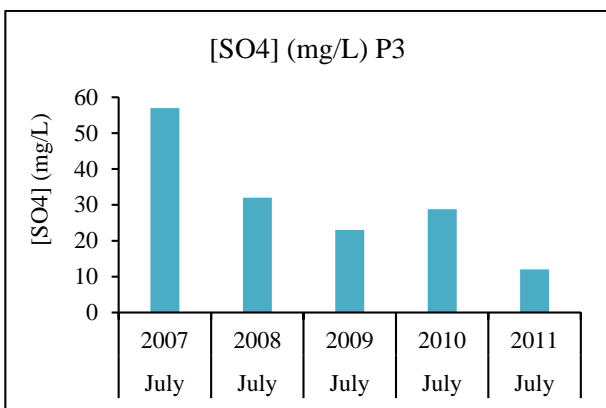


Fig. 10 Sulfate concentration in Piezometer P3.

Regarding the P3 piezometer (Fig. 10) shows significant sulfate concentrations ranging from 12 mg/L in 2011 to 57 mg/L in 2007. This indicates a reduction of the sulfate content (29 mg/L) in the waters of the Izegouande aquifer. This could be explained by mitigation measures. However, in 2010, an increase in sulfate content was observed at the piezometer P3. It should be noted that this peak does not reach the drinking water limit defined by the WHO [20] and dropped during the year 2011 to 12 mg/L.

At the mining sector and Arlit city, the aquifer of Izegouande unconfined. The regional flow in east of Arlit flexure fault is east to west towards sector mining. Locally, higher piezometric levels were observed at mining sector and near of wastewater treatment of Arlit city. These could be piezometric domes created by anthropogenic recharge from the surface [25, 26].

Monitoring of water quality in the mining sector reveals higher concentrations of nitrates and sulfates,

which can locally exceed the values of regional concentration of these elements in water. The highest values were measured downstream of the effluent and tailings ponds. Analyses, carried out on the piezometers located near the purification stations, have shown presence of nitrates at concentrations exceeding the water content of Izegouande aquifer. These overflows of the hydrochemical, although attenuated, are still measurable for nitrates and sulfates on piezometers implanted about 1 km downstream of the purification stations.

4. Conclusions

This study based mainly on the analysis of nitrates and sulfates shows that these elements are present in the groundwater of Izegouande aquifer. These concentrations ranging from 16 to 60 mg/L for nitrates exceeding WHO, 2011 standards accepted of potability and from 16 mg/L to 57 mg/L for sulfates, in line with WHO standards. However, these concentrations must be monitored regularly. In addition, nitrate and sulfate levels are shown to be high surroundings wastewater treatment and industrial sector, showing that these are potential sources of nitrate and sulfate into groundwater. In addition, other sources of transfers of these elements in groundwater are to be investigated.

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