ISSN 2229-5518

Assessing Inorganic Pollution in Ground Waters within an Agricultural Area of Northeastern Algeria

Labar Sofiane, Djidel Mohamed, Hamilton C. Mei-Ling, Benslimane Farida, Hani Azzedine

Abstract— El-Tarf City, which situated in the north east of Algeria, has mostly focused its economic development on agricultural activities. The principal objective of this study is to assess in a particular context, the impact of inorganic pollution induced by ammonium (NH_4^+), nitrates (NO_3^-), nitrites (NO_2^-), and dissolved oxygen, on the quality of ground waters. The samples studied to that end are those taken in 2012 and 2013 from the groundwaters of the Bounamoussa basin in far north-east Algeria. Results shows that the degree of pollution varies by zone, as well as by month to month with contents often exceeding recommendations made by the World Health Organization (WHO). The protection of water quality and the reduction of the risk contamination are of great importance in the region to a reliable and sustainable water supply.

Index Terms— Coastal aquifer, Agro-hydrobiology, Water quality, Nitrate, Nitrie, Ammonium, Phosphate, El-Tarf region..

1 INTRODUCTION

THE Contaminant increase within aquatic systems measured in recent years, as well as the progressive nature of pollutants and the subsequent chemical transformations leading to toxicity in both the short and long term have made groundwater monitoring and water quality assessment of foremost concern in hydro-ecological research [1]. Nitrates constitute the main parameter of inorganic pollution. These nitrogenous compounds are essentially found in chemical fertilizers, and manures; and constitute the major source of nitrogen to crops.

Farmers have augmented fertilizer use up to 500 kg/ha so as to assure successful crop production. However, if too much fertilizer is used, an excess of nitrates will result. This excess may become a potential contaminant to the ground water system, via nitrate infiltration through amended soils to the groundwater table.

Inorganic contaminants are responsible for the “bad taste” aggravated by chlorination, stimulate the proliferation of microbes, molds and algae resulting in eutrophication [2]; and high level of nitrates have also been linked to detrimental effects in human health [3], [4], [5].

- *Labar Sofiane is currently an associate professor in department of biology, in faculty of natural and life sciences in University of El-Tarf, Algeria , Country, PH-+21338601415. E-mail: labar_sf@yahoo.fr*
- *Djidel Mohamed is currently an associate professor in department of geology in Kasdi Merbah University, Ouargla, Algeria, Country, PH-+21329711902. E-mail: djidelm@yahoo.fr*
- *Hamilton C. Mei-Ling is currently an associate professor in Department of Geological Sciences California State University Bakersfield 9001 Stockdale Highway, Bakersfield, CA 93311-1022 USA,Country, PH-+21329711902. E-mail: c.meilinghamilton@gmail.com*
- Benslimane Farida *is currently* a Phd student in *department of biology, in faculty of natural and life sciences in Badji Mokhtar Annaba University , Algeria , Country, E-mail:* benslimane2405@yahoo.fr
- *Hani Azzedine is currently* a *professor in department of geology, in faculty of earth sciences in Badji Mokhtar Annaba, University , Algeria , Country, PH-+21338876562. E-mail:* haniazzedine@yahoo.fr

Groundwater is one of the most precious natural resources in northeastern Algeria, as it is the principal source of drinking water for the majority of the population.

The groundwater aquifer of Annaba-El-Tarf region is extremely susceptible to surface-derived contamination because of the high permeability of sands and gravels that compose the soil profile of West El-Tarf region [6].

Several studies in El-Tarf region reported various degradations levels of groundwater as one of the major concerns among the public and governmental decision makers [7], [8], [9] but these studies did not include an evaluation of inorganic pollution of groundwater contrary the surface waters.

Groudwater contamination can occur if input of (NO_3^-) into soil exceeds the consumption of plants and denitrification processes [10]. Nitrate (NO_3^-) and nitrite (NO_2^-) are naturally occurring inorganic ions, which are produced in the Nitrogen (N) cycle [11], [12]. Microbial action in soil or water decomposes wastes containing organic nitrogen first into ammonia, which is then oxidized to (NO_2^-) and (NO_3^-) [10]. Because (NO_2^-) is easily oxidized to (NO_3^-), (NO_3^-) is the compound predominantly found in groundwater and surface waters under oxidizing conditions. Contamination with N containing fertilizers, including anhydrous ammonia, as well as animal or human natural organic wastes, can raise the concentration of (NO_3^-) in groundwater [13], as nitrate (NO_3^-) containing compounds within the soil matrix are generally soluble and readily migrate into groundwater systems [14], [15]. The main objectives of this study were: (1) to determine the average levels and distribution of NO_3^-, NO_2^-, NH_4^+, and PO_4^{3-} in the groundwater of the El-Tarf region (Bounamoussa basin), and (2) to assess during all the year the temporal evolution of inorganic pollution parameters.

2 CHARACTERISTICS OF STUDY REGION

The Bounamousa watershed is situated in the extreme northeast of Algeria and adjoins the Mediterranean Sea with the

ISSN 2229-5518

"Kebir Est" river in the East by a unique release: the Mafragh river (fig. 1) [16], [17].

2.1 Climate

The region of study is subjected to a Mediterranean climate characterized by two different seasons: one wet, marked by high rainfall and low temperatures from October to May, and other dry and warm with high temperatures reaching their maximum in August with low rainfall. Prevailing southernly winds blow off of the sea during the winter; and in summer, the hot Sirocco blows in a south-southwesternly direction, carrying with it a drying effect that is strongly felt during a one month period of time [18], [19].

2.2 Geology

The region of study is a part of the geologic whole north-oriental Algerian Tell. This group extends of the region of Constantine on the border between Algeria and Tunisia. In general, the study region includes the following units [16], [17] (Fig. 1) :

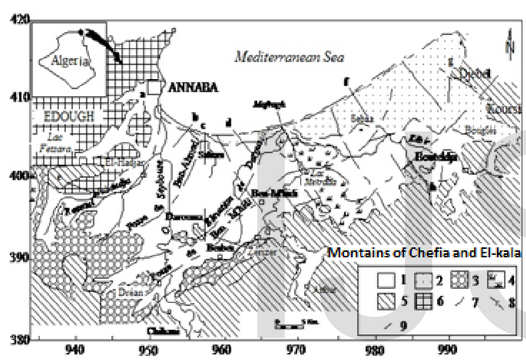

Fig. 1. Geographic and geologic situation of Annaba-ElTarf region [16] (modified).
Legend : 1 : Current and recent alluvium; 2 : Dunes; 3 : Old alluvium; 4 : Swamp or lake; 5 : Numidian sandstone and clay ; 6 : Metamorphic facies ; 7 : Fault ; 8 : Axis pits; 9 : Cutting alignment caption.

- The Triassic formation located in the South of the region of study (Triassic diapirs, vermiculated limestone and pelitic sandstone formation);
- The metamorphic formations situated in the massif of Edough (Annaba city) are dominated by schist, gneiss, marble and amphibolites;
- The sedimentary rocks of Oligocene to lower Burdigalian age are dominated by sandstone, clays and marls;
- The Quaternary formation, composed of sedimentary rocks of marine origin (e.g., alluvial deposits and beach sandstone), and continental origin (e.g., red land sand dunes, fluvial alluvium, and colluviums).

2.3 Hydrology and hydrogeology

Eastern Algeria, with its highly contrasted semi-arid climate, is drained by opposing hydrographic systems trending from North to South: the tributary watersheds of the Mediterranean sea to the north, and a riverine system connected to closed drainage basins to the south. The hydrological data of most stations in the east of Algeria shows the extreme spatial variety of the specific discharges (0.32 - 16.1 L/s/km2 caused by the decisive role of the climate, particularly that of rainfall [19].

The Bounamoussa catchment basin has a surface area of 1158 km2 and an average annual streamflow of 4.45 m3/s. This surface water flow is characterized by a period of high stream discharge from November to April, and a second period of low stream discharge from May to October. Its annual fresh water contribution varies between 36 and 369 hm3 with an average of 140 hm3/year [18].

The hydrogeology of this study region is defined by a deep layer of gravels surmounted by an unconfined layer covering the entire plain. This layer is limited by two separate superficial or surface water tables: one to the South composed of gravel and pebble terraces, and the other to the North of Cordon dune composed of dune sands based on clayey substratum [6], [18].

3 Material and Methods

Water samples were collected from the Bounamoussa catchment basin downstream during the period from June 2012 to May 2013.
Groundwater samples were filtered through 0.45 µm (Sartorius filter); the first few milliliters were used for rinsing and were discarded. The filtrate was transferred to clean polyethylene bottles and stored at 4 °C.
The temperatures (T), electrical conductivity (EC), (pH) were measured in situ using a multi parameter conduct a (pH) meter. Dissolved oxygen and turbidity were also measured at the same time. The concentration of Nitrate (NO_3^-), Nitrite (NO_2^-), Ammonium (NH_4^+) and phosphate (PO_4^{3-}) were measured using the UV spectrophotometric screening method according to standard examination methods of water and wastewater from the American Public Health Association (APHA), American Water Works Association (AWWA), and the Water Environment Federation (WEF), [20].

4 Results and Discussion

4.1 Piezometric level

The groundwater table is characterized by shallow depths which are generally inferior to 5m with a minimum of 0.5 to -3m (fig. 2) [9], [18], [21]. These depths were observed down the gradient of the drainage river and in the coastal zone. The over flow direction of the aquifer is SW-NE [9], [18], [21]. The presence of a shallow depth piezometric level within the coastal area indicates another potential source of pollution: seawater intrusion in the north of the region study [9], [21]. So, the piezometric monitoring (fig. 2) [9] allows to highlight a general decline in levels and the following conclusions:

- The presence of some depressions with less than the sea level ratings and the decline in the general level of the water causes mainly an increase in the fresh and salt-water,

ISSN 2229-5518

- The permanent extension of the curve of zero rating caused by pumping reflects an intrusion of sea water into fresh water through a transition zone,
- The significant decline of groundwater levels especially in times of low water and low seasonal fluctuations in the water leads to a reduction of freshwater flow and penetration of marine waters under the fresh water from the aquifer.

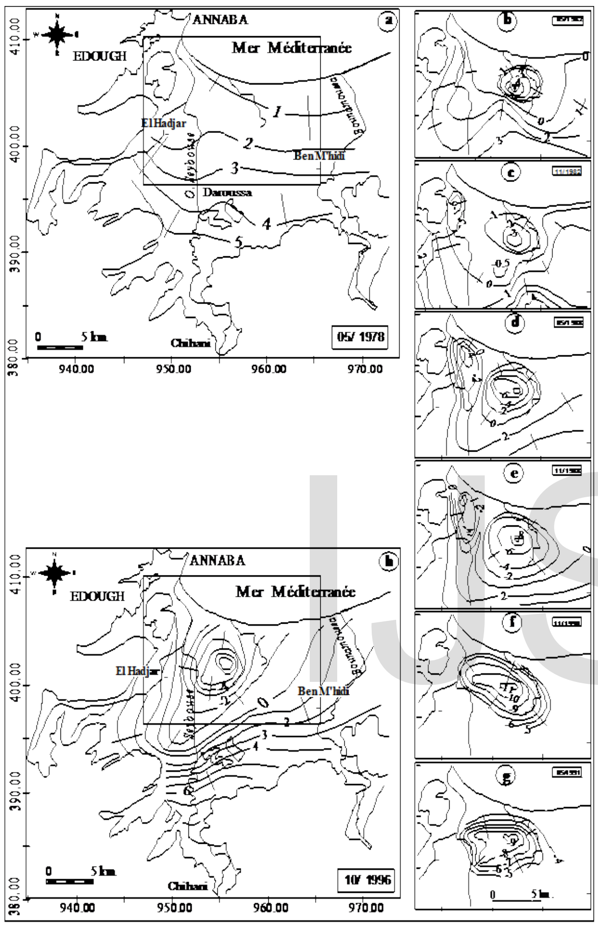

Fig. 2. Evolution of the piezometric level from 1978 to 1996 [9]

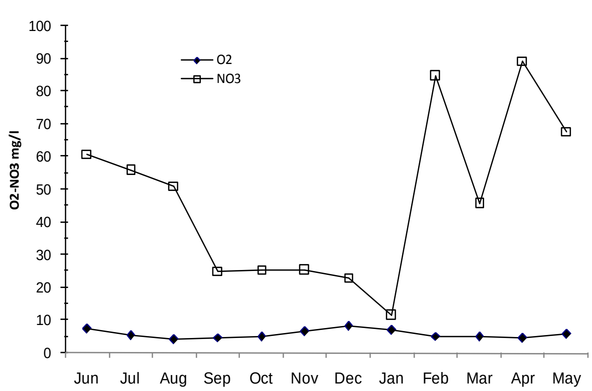

Fig. 3. Evolution of dissolved oxygen and nitrate of ground waters.

4.2 Characterization of pollution

Interpretation of the diagrams representing the various parameters concerning inorganic groundwater pollution gives rise to possible contamination of this particular groundwater system [22].

The evolution (dissolved O2- nitrates) of the surfacial water table in the Bounamoussa basin (fig. 3) shows a decline in nitrate concentration during the period from April to September most likely due to the) lack of precipitation, and an enrichment of the environment in dissolved O2 between September and January which is confirmed by the presence of nitrates.

Fig. 4 (O2-Ammonium) shows an oxidized enough environment marked by small quantities of NH_4^+.

The ammonium of ground waters may originate from the following sources:

- Stream vegetation;
- Animal or Human organic wastes (Man eliminates 15 - 30 g of urea a day);
- Industrial discharges;
- Chemical fertilizers, manures etc.

Its presence is relatively similar to the others Nitrogenous compounds identified in the water: Nitrites and nitrates.

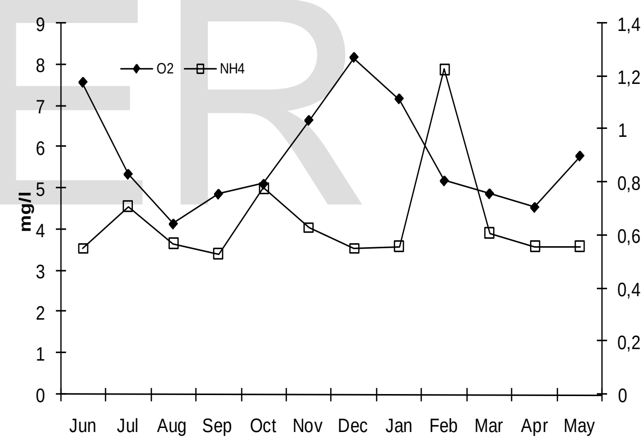

Fig. 4. Evolution of dissolved oxygen and ammonium of ground waters

The figure below (fig.5) illustrates high concentrations in ammonium, nitrate and nitrite ions in groundwater, as opposed to an evident decrease in dissolved oxygen content during the dry period between June and November, where lack of precipitation is common. It follows that nitrates decrease to be transformed nitrites (NO_2^-) and to be finally reduced to NH4+. We therefore bear witness to the natural microbial respiration process of denitrification, which most likely led to the consumption of dissolved O2 in the groundwater [23]. Nitrites result from the incomplete oxidation of ammonia in water. Therefore, either the nitrification process is not driven to completion, or nitrite production is a direct result of nitrate reduction during the denitrification process. Water which contains nitrites is to be considered as suspect because a deterioration of the biological quality is often associated with it.

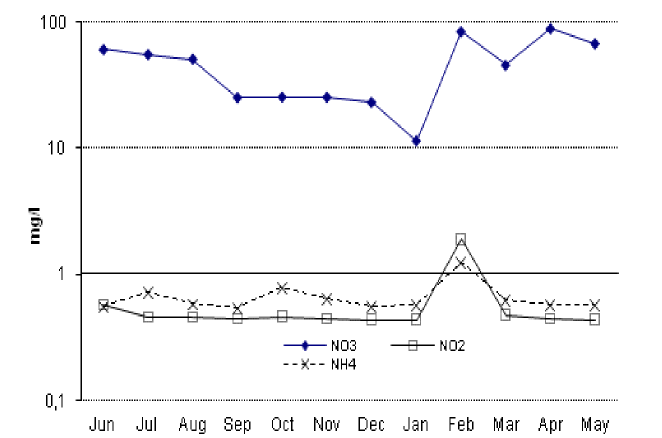

Fig. 5 Evolution of nitrite, nitrate and ammonium of ground waters.

All this is confirmed by the agreement or correspondence between the evolution of the pluvio-thermal diagram and dissolved oxygen (Fig. 6) during the dry and wet periods previously discussed.

The evolution of the concentrations in ammonium, nitrates and nitrites of the ground water in the down of Bounamoussa basin (Fig. 5) shows between January and April an increase of NO_3^-, NO_2^-, and NH_4^+ provoked by the contribution of fertilizer. The presence of organic matters is due to the washing.

Indeed, the migration of nitrates is increases rapidly on cultivable surfaces left naked exposed during winter. Communal and, in some instances, industrial discharges of chemical fertilizers and explosives may also contribute to nitrate enrichment of the superficial groundwater table.

The pluvio-thermal and dissolved oxygen diagram (Fig. 6) are in agreement. We note an increase of dissolved O2 during the dry period (from May to November) and a decrease between November and May (wet period).

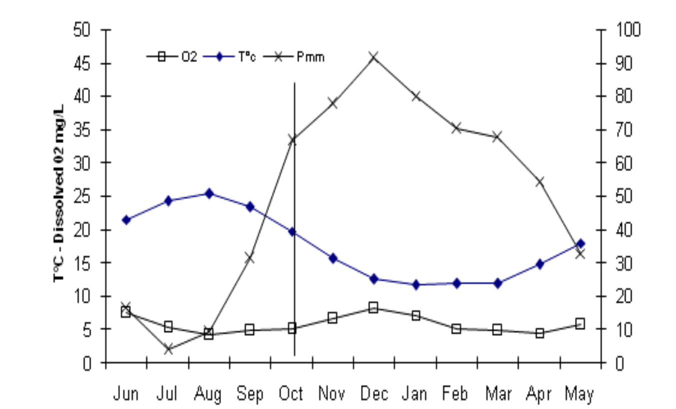

Fig. 6 Graphical representation of climate diagram and dissolved oxygen.

5 Conclusion

The pollution represents a severe problem for the environment because of discharges in the rivers of Kébir East and Bounamoussa [23] due to the excessive use of fertilizers in agriculture.

The degree of pollution varies by zone, as well as by month to month with contents often exceeding recommendations made by the World Health Organization (WHO) [24]. We can note a significant agreement between pluvio-thermal variations and dissolved oxygen in groundwater.

In this region of study, even if groundwater concentration of inorganic contaminants (especially NO_3^-) does not exceed accepted standard limits, the situation still poses serious risk. The current state of groundwater pollution is the reflection of nitrated substances infiltrated a few years before - the importance of the transfer time dependent on the depth of the groundwater and on the structure of the rock [25].

In spite of efforts made to raise awareness to nitrate groundwater pollution, nitrate fertilizer use has not decreased, but has increased due to surface tilling practices linked to increased crop production and progressive agricultural development.

Finally we recommend:

– Several studies should be conducted mainly on the health risk assessment and water toxicology.

– An integrated monitoring program should be conducted. The municipal wells should be sampled 2–4 times a year for the analysis of anions, cations, heavy metals and pesticides. The data of the groundwater quality should be centralized in a data bank or a water archive.

– The objective of the Algerian water institutions should be how to safeguard the water resources system from pollution. The protection of water quality and the reduction of the risk contamination are of great importance to a reliable and sustainable water supply [26].

Acknowledgment

We are grateful to the staff of the direction of environment of El-Tarf department. The ground and field works have conducted in collaboration with them.

References

[1] C. G. Enfield and SR. Yates, Organic chemical transport to groundwater. Pesticides in the soil environment: processes, impacts and modeling. Book n° 2. Madison (Wisconsin): Soil Science Society of America.1990.

[2] C. M. Cooper, "Biological effects of agriculturally derived surface water pollutants on aquatic systems", A review. *J Environ Qual* ; vol.22, pp. 402-408, 1993.

[3] C. S. Brunning-Fann and J. B. Kaneene, "The Effects of Nitrates, Nitrites, and N-nitroso Compounds on Human Health", A Review. *Vet. Hum. Toxicol. Journal*, vol. 35 no 6, pp. 521 – 538, 1993

[4] A. H. Mavhi, J. Nouri, J. J. Babaei, and R. Nabizadeh, " Agricultural

Activities Impact on Groundwater Nitrate Pollution", *Int. J. Environ. Sci. Tech.*, vol. 2 no 1, pp. 41 – 47, 2005.

[5] J. A. Camargo and A. Alonso, " Ecological and Toxicological Effects of Inorganic Nitrogen Pollution in Aquatic Ecosystems", *Environ. Int.*, vol. 32, no 6, pp. 831 – 849, 2006.

[6] N. Kherici and D. Messadi., "Importance des ressources en eaux souterraines des massifs dunaires méditerranéens du Maghreb", *Géologie méditerranéenne* vol. XIX, no 2 : pp 69-76, 1992.

[7] N. Kherici "Vulnérabilité à la pollution chimique des eaux souterraines d'un système de nappes superposées en milieu industriel et agricole Nord Est Algérien", Doctorate thesis, Dept. Of geology, university of. Annaba, Algeria, 1993.

[8] F. Derradji, "Identification quantitative et qualitative des ressources en eau dans la région d'Annaba – El Tarf (Nord-Est de l'Algérie) ", Doctorate Thesis, Dept. Of geology, university of Annaba, Algeria, 2004.

[9] A. Hani, "Analyse méthodologique de la structure et des processus anthropiques : Application aux ressources en eau d'un bassin côtier mediterraneen", Doctorate Thesis, dept. Of geology, Badji Mokhtar Annaba university, Algeria 214p, 2003.

[10] M. McClain, J. Richey and T. Pimentel T, "Groundwater nitrogen dynamics at the terrestrial-lotic interface of a small catchment in the Central Amazon Basin", *Biogeochemistry* no 27, pp. 113–27, 1994.

[11] L. Chery and C. Mouvet, "Principaux processus physico-chimiques et biologiques intervenant dans l'infiltration des produits polluants et leur transfert vers les eaux souterraines", *La houille blanche,* No 718 pp. 82-88, 2000.

[12] B. Shomar, K. Osenbrück and A. Yahya. (2008). "Elevated nitrate levels in the groundwater of the Gaza Strip:Distribution and sources", *Sci Total Environ journal*, 2008, doi:10.1016/j.scitotenv. 2008.02.054, 1-11, Elsevier Science.

[13] P. Thorburn, J. Biggs, K., Weier and B. Keating, "Nitrate in groundwaters of intensive agricultural areas in coastal Northeastern Australia", *Agric Ecosyst Environ*, no94, pp. 49–58, 2003.

[14] M. Rzan , M. Sherwood and A. Fanning, "Leaching of nitrate-N from cropped and fallow soil-a lysimeter study with ambient and imposed rainfall", *Ir Geogr,no* 34 pp. 34–49, 2001.

[15] F. Wakida and D. Lerner, "Nitrate leaching from construction sites to groundwater in Nottingham, UK, urban area", *Water Sci Technol* no 45, pp. 243–8, 2002.

[16] Strojexport, " Prospection géophysique de la plaine de Annaba", Réinterprétation. A.N.R.H., unpublished report, Annaba, Algeria, 30 p, 1975.

[17] J. M. Villa, "La chaine Alpine d'Algérie Orientale et des confins Algéro-Tuunisiens", Doctorate Thesis, University of Piérre et Marie Curie Paris VI, 665p, 1980.

[18] S. Labar, "Contribution à l'identification des aires inondables et qualité physico-chimiques des eaux stagnantes temporaires dans la vallée de la Mafragh « Extrême Nord Est Algérien", Magister thesis, Dept. Of geology, Badji Mokhtar Annaba University, 155p, 2004.

[19] A. Mebarki, " Apport des cours d'eau et cartographie du bilan hydrologique : cas des bassins de l'Algérie orientale", *Sécheresse journal*, vol. 21, no 4, pp. 301-308, 2010. Doi : 10.1684/sec.2010.0265.

[20] APHA, AWWA, WEF, "Standard Methods for Examination of Water and Wastewater", 19th edition APHA, AWWA, WEF, Publishing Washington, DC, 1995.

[21] S. Labar, A. Hani, A. Younsi and L. Djabri, "Impact des unités industrielles sur les eaux superficielles", *Proc. 2nd edition of the international congress on water, waste & the environment the union of the Mediterranean countries*, 2009.

[22] J. Mayet, "La pratique de l'eau. Traitements aux points d'utilisation". Paris : *Le Moniteur*, 1994.

[23] F. Derradji, H. Bousnoubra, N. Kherici, M. Romeo and R. Caruba, "Impact de la pollution organique sur la qualité des eaux superficielles dans le Nord-Est algérien", *Sécheresse* vol. 18, no 1, pp. 23-27, 2007.

[24] WHO, (2006). "Guidelines for Drinking Water Quality", Recommendations 1sAddendum, Geneva, Switzerland, *3rd ed*., vol. 1, 515p, 2006.

[25] F. Derradji, N. Khérici, M. Roméo and R. Caruba, "Aptitude des eaux de la vallée de la Seybouse à l'irrigation (Nord-Est algérien) ", *Sécheresse,* no 15 pp. 353-360, 2004.

[26] B. Shomar, " Groundwater of the Gaza Strip: is it drinkable? ", *Environ. Geol.*, no 50 pp. 743–751, 2006.